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RESEARCH IN PROGRESS

DOCTORAL CONSORTIUM

DEVELOPING A TAXONOMY FOR REVENUE MODELS OF PLATFORM BUSINESS MODELS

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Platform business models like Uber Ride or Airbnb Lodging enable innovative business models by operating digital platforms to connect providers and consumers of products and services in two-sided markets. A particular challenge with platform business models is designing an appropriate revenue model to capture value. This paper presents a taxonomy that classifies the different dimensions and characteristics of revenue models for platform business models. A proven taxonomy development method is used that includes a review of current literature related to platform business models. The taxonomy provides a comprehensive classification of platform revenue models and is applied to a real-life case. The results of this paper include a UML class model and a final taxonomy with 14 dimensions and 64 characteristics. The paper contributes to the design process of novel platform business models and expands the understanding of how digital platforms can generate revenues.

Keywords:
platform business models, revenue model, digital platform, taxonomy, dimensions

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1 Introduction

The significance of digital platforms continues to grow, and companies such as Uber Ride, Airbnb Lodging, Spotify Music, and eBay Marketplace have established innovative platform business models. Regardless of the industry, every company must make strategic decisions about their business model to stay competitive (Parker et al., 2016). The emergence of platform business models raises the question of what competitive advantages a company can achieve with its own business model and underscores the need for design knowledge to innovate novel (platform) business models. The motivation of this paper is based on a research preview from Bartels & Gordijn (2022) and addresses the design of systematic revenue models for platform business models. We provide a taxonomy that classifies relevant dimensions and characteristics of revenue models for platform business models. The research question for this paper is as follows: *Which dimensions and characteristics can be used to describe revenue models of platform business models?*

To answer this research question, we used a taxonomy development process following Nickerson et al. (2013) and extracted relevant dimensions and characteristics from a literature review. We also present a use case of the *Smarte.Land.Regionen* (SLR) platform, a digital solution-brokering platform for German counties, where the proposed taxonomy was applied to design a possible revenue model. In follow-up research, the taxonomy will be developed into a design tool to help practitioners create platform business models more systematically. This paper is structured as follows. In section 2, we introduce key terms and relevant related work. Section 3 presents the research design of the taxonomy development process and section 4 shows the taxonomy we created. Section 5 presents the use case to which the taxonomy was applied. Finally, section 6 presents our discussion, limitations, and an outlook on future work.

2 Theoretical Background

In our understanding, a *platform business model* is characterized by four aspects adapted from the definitions of Koch & Krohmer et al. (2022), Gordijn & Wieringa (2021), and Täuscher & Laudien (2017): (1) A platform business model describes the concept of how economic value is created, distributed, and consumed in a network of parties, called a digital ecosystem. (2) It creates value through a digital platform, operated by a platform operator (i.e., asset broker), which connects at least two market sides – asset providers and asset consumers. (3) It brokers assets such as products or services via its digital platform. (4) A digital platform can serve as the hub of a digital ecosystem consisting of companies working collaboratively and competitively to meet customer needs (Moore, 1996). The *revenue model* is part of the value capture dimension of a business model and clarifies which monetization mechanisms are used to generate revenues. Accordingly, the revenue model of a platform business model, as we understand it, explains how revenue can be generated by enabling brokering services via a digital platform connecting asset providers and asset consumers. A *taxonomy* is defined as a structure above the technical terms of a subject area (Freichel et al., 2021a). In this paper, a taxonomy is considered a form of classification of relevant dimensions and characteristics for revenue models of platform business models.

Van de Ven et al. (2021) presented a taxonomy for *business models of data marketplaces* with 17 business model dimensions and 59 business model characteristics. Springer & Petrik (2021) showed a taxonomy for *platform pricing of digital platforms* in the context of the Industrial Internet of Things (IIoT) with 13 impact factors and 38 characteristics. Staub et al. (2021) elaborated a taxonomy for *digital platforms* with 16 design dimensions and 44 characteristics. A similar taxonomy for digital platforms was elaborated by Freichel et al. (2021a) with 16 dimensions and 40 characteristics. Täuscher & Laudien (2018) presented a taxonomy for *marketplace business models* with 14 business model attributes and 43 specifications. They applied their taxonomy to a sample of 100 digital marketplaces and showed that there are recurring revenue models, meaning that about 74% of all platform business models studied use a commission model as the key revenue stream. This finding prompted us to investigate platform revenue models to gain a deeper understanding of crucial business model variations. Compared to existing taxonomies that conceptualize digital platforms and their business models holistically (see van de Ven et al. (2021), Freichel et al. (2021a), or Staub et al. (2021)), our work focuses on the dimensions and characteristics of revenue models for platform business models and aims to contribute to a better understanding of how digital platforms can generate revenues.

3 Research Design: Taxonomy Development Process

The development process of our taxonomy for revenue models of platform business models follows the guidance of Nickerson et al. (2013) as a well-structured methodology for researchers who intend to develop taxonomies step by step. The literature review, development process, and data presented in this paper are fully documented and can be found here: Bartels et al. (2023).

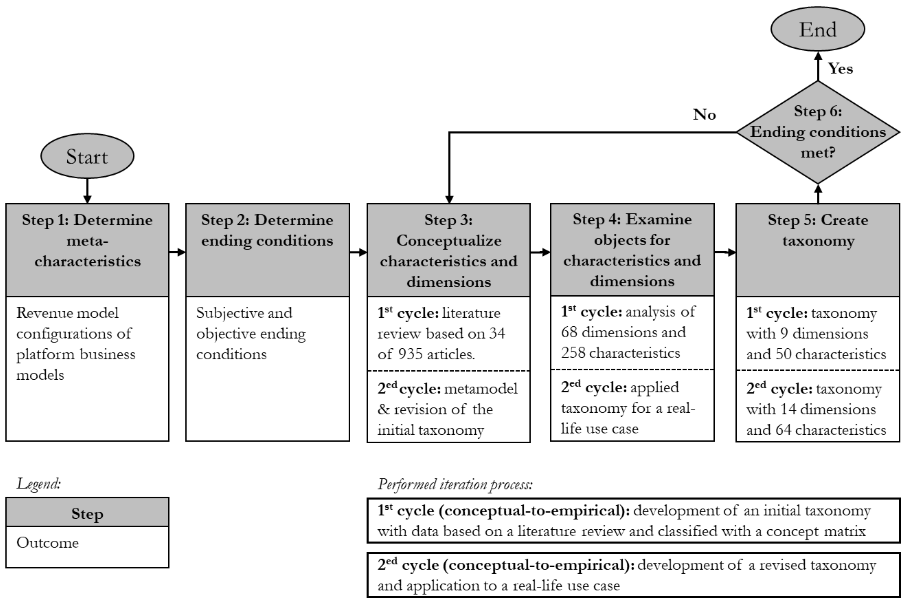

Figure 1: Taxonomy development process adapted from Nickerson et al. (2013)

As shown in Figure 1, the purpose and object of the taxonomy is defined in *Step 1*. In *Step 2*, the ending conditions are set, i.e., the criteria that the taxonomy must meet in order to be accepted. For the development of the taxonomy, *Step 3*, *Step 4,* and *Step 5* are repeated in two *conceptual-to-empirical* iteration cycles. After applying the taxonomy to a real-life case, all ending conditions in *Step 6* are met.

3.1 Determination of meta-characteristics and ending conditions

The purpose of our taxonomy follows the research preview of Bartels & Gordijn (2022), and revenue models of platform business models such as the revenue models of eBay Marketplace, Airbnb Lodging, or Uber Ride form our *object of interest*. The configuration aspects of these revenue models (e.g., $0.35 insertion fee per listing on eBay) are determined as the relevant *meta-characteristics* of our taxonomy. Following Nickerson et al. (2013), we consider *objective and subjective ending conditions* that must be met for the taxonomy to be accepted: (1) The taxonomy must comprise the *main dimensions and characteristics* of a revenue model for platform business models, and (2) *no new* dimensions or characteristics should be added in the last iteration. Subjectively, the taxonomy must be (3) *meaningful without being unwieldy or overwhelming* and (4) *extensible* in order to add new dimensions or characteristics. Finally, (5) each dimension and characteristic must provide useful explanations about the object (*explanatory*).

3.2 First cycle: Literature research and classification

To get a data basis for the creation of the taxonomy, we conducted a literature review on revenue models of platform business models. The databases of Scopus, Web of Science, IEEE Xplore, ACM Digital Library, Google Scholar, and Dimensions were searched using the following string: *(ecosystem OR platform) AND (business model OR value capture OR revenue model OR profit model)*. This resulted in a total of 930 papers. The screening process of titles, abstracts, and full text was guided by the definition of inclusion and exclusion criteria. Of the total of 930 papers, 29 papers were included based on the following inclusion criterion: *The paper focuses on relevant dimensions or characteristics of revenue models for platform business models* (IC). In addition, five more papers were added to the included results, as we consider them relevant: Derave et al. (2022), Freichel et al. (2021a), Springer & Petrik (2021), Van de Ven et al. (2021), and Weking et al. (2020). A total of 34 papers were thus used for developing the taxonomy. The remaining 901 papers were excluded based on the following exclusion criteria: 204 papers were *duplicates* of another paper (EC1), 30 papers were *not in English* (EC2), six papers were *less than three pages* (EC3), 13 papers were *not research papers* (EC4), 41 papers were *not accessible* even after contacting the authors (EC5), and 607 papers *did not meet the inclusion criteria* (EC6). The full-text review of the 34 included papers resulted in a total of 68 dimensions and 258 characteristics for revenue models of platform business models. The review process of the literature search with each criterion is documented here: Bartels et al. (2023). To synthesize the data, a classification was created as a *concept matrix* according to Webster and Watson (2002). First, all dimensions were sorted alphabetically by title, studied based on the descriptions, and coded using our own classifications. Of the 68 dimensions examined from the literature, nine dimensions could not be classified – the remaining 59 dimensions were grouped into nine self-coded dimensions. Figure 2 gives an overview of the selected revenue model dimensions derived from the literature. The concept matrix summarizes the comprehensive classifications for revenue models of platform business models on the left side (A) while showing relevant dimensions for revenue models on the right side (B). Figure 2 shows that nine dimensions could be extracted based on 27 papers. Here, "revenue model", "revenue stream", "revenue source", and "pricing model" are frequently used as relevant dimensions.

(A) Meta-descriptions of the analyzed papers						(B) Own derived and classified revenue model dimensions							
N°	Authors	Provides a **classifictaion** (e.g. taxonomy)?	Number of business model-related **dimensions**	Number of value capture-related **dimensions**	Number of value capture-related **characteristics**	**Revenue model**	**Revenue stream**	**Revenue source**	**Payment frequency**	**Pricing model**	**Price mechanism**	**Price discovery**	**Price discrimination**
1	Curtis et al. (2020)	Yes	16	5	28		x	x			x		x
2	Derave et al. (2022)	Yes	12	5	24		x	x	x			x	x
3	El Sawy & Pereira (2013)	Yes	19	4	0	x				x			
4	Enders et al. (2008)	No				x							
5	Freichel et al. (2021a)	Yes	7	3	0		x	x					
6	Freichel et al. (2021b)	Yes	16	2	4	x	x	x			x		
7	Ghezzi (2010)	No											
8	Giessmann et al. (2014)	Yes	5	1	5		x						
9	Helfat & Raubitschek (2018)	No											
10	Hoyer et al. (2009)	No											
11	Hyrynsalmi et al. (2012)	No				x							
12	Immonen et al. (2014)	No								x			
13	Janssen & Zuiderwijk (2014)	No				x							
14	Kim (2016)	No						x					
15	Kohler (2015)	No					x						
16	Kübel & Zarnekow (2014)	Yes	19	2	4			x	x				
17	Laczko et al. (2019)	No				x							
18	Lin et al. (2020)	No				x							
19	Mancha & Gordon (2022)	No								x			
20	Park et al. (2020)	No								x			
21	Rohn et al. (2021)	Yes	5	2	7		x	x		x	x		
22	Ruggieri e al. (2018)	No					x						
23	Schreieck et al. (2017)	No											
24	Springer & Petrik (2021)	Yes	13	3	10			x	x				
25	Staub et al. (2021)	Yes	16	3	10		x					x	x
26	Still et al. (2017)	Yes	10	2	0	x							
27	Täuscher & Laudien (2017)	Yes	14	4	15		x	x			x	x	x
28	Täuscher & Laudien (2018)	Yes	14	4	15		x	x			x	x	x
29	Teece & Linden (2017)	No											
30	Teece (2018)	No											
31	Ven et al. (2022)	Yes	17	5	17	x				x		x	
32	Verstegen & Doorneweert (2017)	No											
33	Weking et al. (2018)	No					x			x			
34	Weking et al. (2020)	Yes	19	3	11	x		x	x	x			
		Average	**13**	**3**	**10**	∑ **10**	**12**	**11**	**4**	**8**	**5**	**5**	**5**
		Deviation	**5**	**1**	**8**								

Figure 2: Concept matrix of search results

However, the initial taxonomy derived from the concept matrix did not meet the ending conditions, as the "pricing model" dimension had a strong overlap with "price mechanism", "price discovery", and "price discrimination". Therefore, in the second iteration cycle, the dimension was deleted to avoid redundancy.

3.3 Second cycle: Meta-model and taxonomy revision

In the second iteration of taxonomy development, we created a UML class model to express the relationships of the revenue model dimensions for platform business models within the taxonomy in a transparent way. We consider this step to be useful for designing a taxonomy holistically and ensuring its meaningfulness. The metamodel in Figure 3 illustrates the relationships between eight classes depicting the dimensions of the taxonomy.

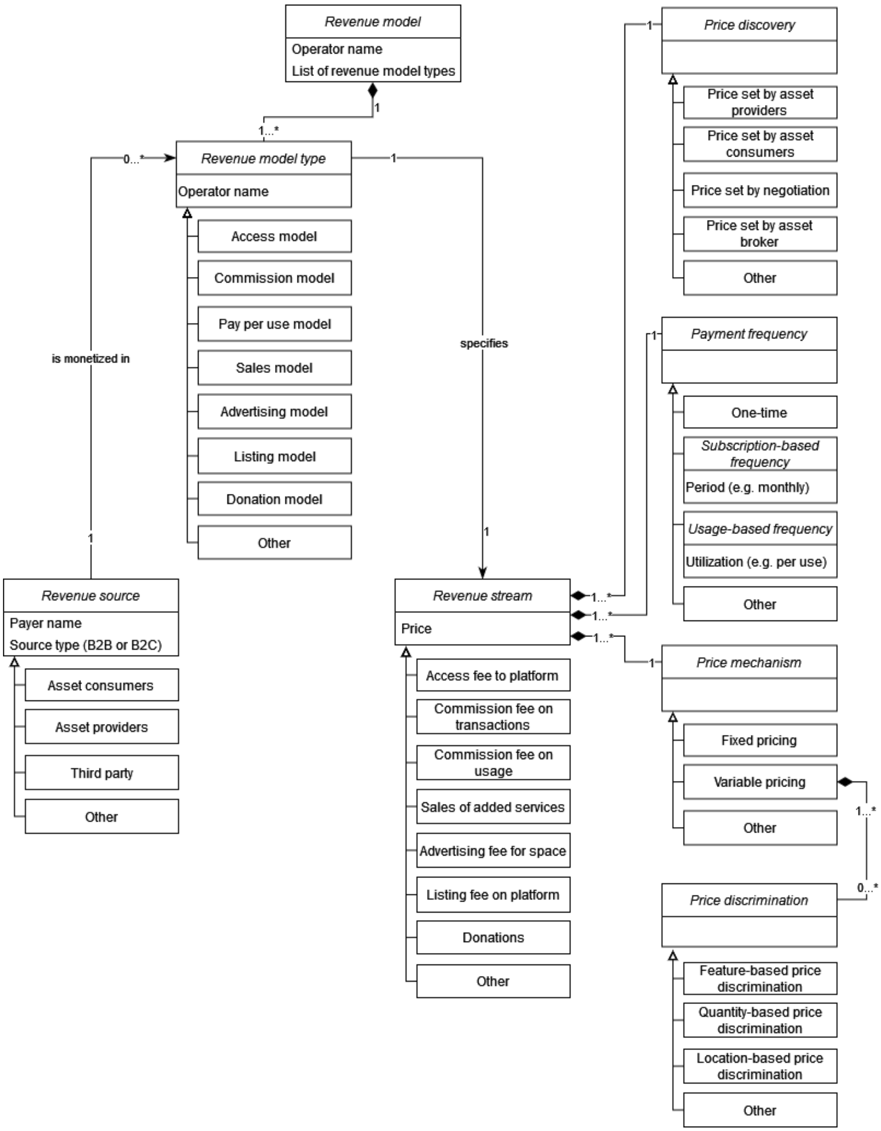

Figure 3: UML metamodel of the proposed taxonomy

An asset broker and operator of a revenue model (e.g., the platform provider of the eBay marketplace) may have multiple "revenue model types", each having a "revenue source" (*who* is monetized?) and a "revenue stream" (*how* to monetize?). This triangular relationship is crucial in our opinion and is also confirmed by the literature, as demonstrated in Figure 2. The pricing components, including "price discovery", "payment frequency", "pricing mechanism", and "price discrimination", always refer to an individual "revenue stream". The pricing model as a dimension is not explicitly included in the metamodel, as it is either redundant to the existing dimensions or can be considered as a combination. The classes shown in Figure 3 were adopted as dimensions in the second iteration.

4 Taxonomy

An asset provider (e.g., Airbnb host) aims to generate revenues through a business model of its own (e.g., renting one's own apartment to travelers), which should be viewed as a separate but relevant component for describing the overall platform business model of an asset broker (e.g., the operator of the Airbnb Lodging platform). For this, the use of a digital platform by asset providers depends on their ability to generate revenues. We concluded that a revenue model for a (two-sided) platform business model can only be described holistically if both the asset broker's revenue model and the asset provider's revenue model are represented. Consequently, the final taxonomy includes 14 dimensions, with seven dimensions covering the asset broker's perspective and the other seven dimensions covering the asset provider's perspective. The taxonomy shown in Figure 4 satisfies all relevant ending conditions.

A *revenue model type of the asset broker* (DB1) covers the revenue source and revenue stream through which the asset broker generates revenues. A *revenue stream of the asset broker* (DB2) describes how the asset broker generates revenues, i.e., the strategy the asset broker uses to monetize the revenue source through the platform. Access fees, commission fees, sale of platform services, advertising fees, listing fees, or donations may be used to generate revenue. The *revenue source of the asset broker* (DB3) describes who is monetized by the asset broker, i.e., the actor through whom the asset broker generates the revenue stream. Asset consumers, asset providers, or third parties can be monetized by the asset broker. The *payment frequency of the platform price* (DB4) describes how often payments recur for the asset broker, i.e., the frequency with which the revenue source is charged by the asset broker. Payments can appear as one-time, multiple-time, or usage-based. The *price discovery of the platform price* (DB5) describes who sets the platform price, i.e., whether the platform price is set by the asset broker, by asset providers, asset consumers, or by negotiations. The *price mechanism of the platform price* (DB6) describes the influence of supply and demand on the platform price, i.e., whether the platform price is fixed or variable. A platform price can be fixed and static or variable and dependent on further factors. If the platform price is variable, it can be subject to price discrimination. The *price discrimination of the platform price* (DB7) describes different platform prices, i.e., whether discriminatory factors influence the platform price to be paid. Platform price discrimination can take the form of location-based, quantity-based, or feature-based price differences.

Revenue model dimensions of a platform business model			Revenue model characteristics of a platform business model							
Revenue model of the asset broker	DB1	Revenue model type of the asset broker	Access model	Commission model	Pay per use model	Sales model	Advertising model	Listing model	Donation model	Other
	DB2	Revenue stream of the asset broker	Access fees to platform	Commission fees on platform transactions	Commission fees on usage	Sales model of platform services	Advertising fees for space	Listing fees on platform	Donations	Other
	DB3	Revenue source of the asset broker	Asset consumers		Asset providers			Third party		Other
	DB4	Payment frequency of the platform price	One-time		Subscription-based frequency			Usage-based frequency		Other
	DB5	Price discovery of the platform price	Platform price set by asset providers		Platform price set by asset consumers		Platform price set by negotiation		Platform price set by asset broker	Other
	DB6	Price mechanism of the platform price	Fixed platform pricing				Variable platform pricing			Other
	DB7	Price discrimination of the platform price	Feature-based price discrimination		Quantity-based price discrimination			Location-based price discrimination		Other
Revenue model of the asset provider	DP1	Revenue model type of the asset provider	Sales model		Rental model			Pay per use model		Other
	DP2	Revenue stream of the asset provider	Sales of assets		Rental fees for assets			Usage fees for assets		Other
	DP3	Revenue source of the asset provider	Asset consumers		Asset broker			Third party		Other
	DP4	Payment frequency of the asset price	One-time		Subscription-based frequency			Usage-based frequency		Other
	DP5	Price discovery of the asset price	Asset price set by asset providers		Asset price set by asset consumers		Asset price set by negotiation		Asset price set by asset broker	Other
	DP6	Price mechanism of the asset price	Fixed asset pricing				Variable asset pricing			Other
	DP7	Price discrimination of the asset price	Feature-based price discrimination		Quantity-based price discrimination			Location-based price discrimination		Other

Figure 4: Taxonomy for revenue models of platform business models

A *revenue model type of the asset provider* (DP1) covers the revenue source and revenue stream by which the asset providers generate revenues. The *revenue stream of the asset provider* (DP2) describes how the asset providers generate revenues, i.e., the strategy the asset providers use to monetize the revenue source through the platform. The asset provider can generate revenue through the platform by selling, renting, or charging a usage-based fee for the asset. The *revenue source of the asset provider* (DP3) describes who is monetized by the asset providers, i.e., the actor through which asset providers generate their revenue stream. Asset consumers, the asset broker, or third parties can generate revenue for the asset provider. The *payment frequency of the asset price* (DP4) describes how often payments recur for asset providers, i.e., the frequency with which the revenue source is charged by the asset providers. Payments for an asset can appear as one-time, multiple times, or usage-based. The *price discovery of the asset price* (DP5) describes who sets asset prices on the platform, i.e., whether asset prices are set by the asset broker, by asset providers, or by asset consumers. The *price mechanism of the asset price* (DP6) describes the influence of supply and demand on asset prices, i.e., whether asset prices on the platform are fixed or variable. The price of an asset may be fixed or variable and depend on other factors. If the price of an asset is variable, it can be subject to price discrimination. *The price discrimination of the asset price* (DP7) describes different asset prices, i.e., whether discriminatory factors influence asset prices on the platform. Asset price discrimination can take the form of location-based, quantity-based, or feature-based price differences.

5 Taxonomy applied to the SLR Platform

To ensure that our taxonomy will be applicable, we used a revenue model of a digital platform in a research project as a real-life case. This research project, called *Smarte.Land.Regionen* (SLR), aims to improve public services in rural areas through digital solutions. For this purpose, a digital ecosystem is being created that includes a digital platform at its core, called the *SLR platform*. The SLR platform follows the logic that the SLR platform operator (the asset broker) brokers digital solutions, e.g., mobility services (assets) provided by software companies (asset providers) to counties (asset consumers) and their citizens on its digital platform. The SLR platform was studied in an earlier work by Bartels & Schmitt (2022) as a use case for designing network effects for a platform business model. In this work, the SLR platform is used as a real-life object to test whether the taxonomy is suitable for representing a platform revenue model. As shown in Table 1, the SLR platform's revenue model defines that software providers who want to offer their digital solutions on the SLR platform have to pay a fixed access fee to the SLR platform operator on a monthly basis.

Table 1: Taxonomy applied to the SLR platform

Description of the SLR platform revenue model	
DB1	The SLR platform operator generates revenue through an **access model** and monetizes the providing software companies.
DB2	Revenues are generated through an **access fee** to the SLR platform.
DB3	**Software companies** that provide solutions are monetized.
DB4	Access fees accrue **monthly**.
DB5	Access fees are set by the **SLR platform operator**.
DB6	Access fees are **fixed** at 500€ and are not changeable.
DB7	There is **no price discrimination**.
DP1	The software companies generate revenue through the SLR platform by offering digital solutions based on a **pay-per-use model** and monetizing the **counties**.
DP2	Revenues are generated through a **usage fee** for the digital solutions.
DP3	**Counties that request** solutions from the SLR platform are monetized.
DP4	Usage fees are incurred each time a **digital solution is operated for a county**.
DP5	Usage fees are set by the **providing software company**.
DP6	Usage fees are **variable**.
DP7	Usage fees **depend on the functionality** of the digital solution and vary.

In our view, the combination of "access fee" (in DB2) and "monthly" frequency (in DB4) is a *subscription model*, but we can express this more precisely through the taxonomy and consider it not as a standalone revenue model, but as a variant of the "access model" (in DB1). In this way, the digital solution listed on the SLR platform can be found by counties and booked for their citizens. Software companies generate revenue by offering counties their digital solutions through the SLR platform and customizing them to meet the needs of counties and citizens.

6 Discussion, Limitations, and Future Work

The main contribution of this work is the creation of a meaningful taxonomy and metamodel in order to get a better understanding the revenue models used by platform business models. The research question of how to classify revenue models of platform business models is answered with a taxonomy of 14 dimensions and 68 characteristics. In their work, Täuscher & Laudien (2018) showed that 74% of platform business models use commission models as their core revenue model. Although this number is significant, it also indicates that much of the variation in revenue models is not fully understood yet. In our view, there are variants such as commission per transaction (e.g., a fee per eBay product sold) or commission per unit of usage (e.g., a fee per Uber mile driven). Our taxonomy is a first step towards gaining a more nuanced understanding of revenue models of platform business models. The proposed taxonomy offers a more precise way of describing different revenue models compared to other taxonomies that use a single characteristic, such as 'subscription' (as seen in Täuscher & Laudien, 2018). As shown in our real-life case, we achieve this level of detail by combining multiple dimensions: “revenue stream” (DB2) with “access model” and “payment frequency” (DB4) with “monthly” frequency.

Limitations. Our taxonomy focuses on revenue models as part of the value capture and does not address the value proposition and the value creation of a business model. Second, it focuses solely on platform business models with two-sided markets involving the asset broker and asset providers as actors with monetization intentions, and therefore cannot be used for one-sided or multi-sided platforms. Despite our transparent taxonomy development process (the research data can be found here: Bartels et al. (2023), there may still be important aspects that have gone unnoticed. An example can be seen in the *payment frequency* dimension, which is weakly backed in the existing literature and occurred only four times in our data (see concept matrix in Figure 2). However, recent work, such as the platform ontology of Derave et al. (2022), emphasizes the importance of frequency and shows that research on digital platforms and their business models is still evolving. Consequently, we may have overlooked other aspects in our taxonomy that need to be further elaborated in the future.

Future work on the proposed taxonomy should include the study of different "objects", i.e., platform revenue models, to refine or extend the existing dimensions and characteristics, as suggested by Nickerson (2013) as *an empirical-to-conceptual* process. Our initial contribution of applying the taxonomy to the SLR platform is a first step. Now, the taxonomy needs to be tested on more real-life objects. The overall goal of this research is to provide this taxonomy as a design tool for practitioners to systematically design revenue models, as proposed by Bartels & Gordijn (2022), who called this a "business model construction kit".

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References

Bartels, N., Koch, M., & Gordijn, J. (2023). Reserach data_taxonomy for revenue models of platform business models (Version V1) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.7635726

Bartels, N., & Schmitt, A. (2022). Developing network effects for digital platforms in two-sided markets – The NfX construction guide. In Digital Business (Vol. 2, Issue 2, p. 100044). Elsevier BV. https://doi.org/10.1016/j.digbus.2022.100044

Bartels, N., & Gordijn, J. (2022). A Business model construction kit for platform business models - research preview. In V. Gervasi, & A. Vogelsang (Eds.), 13216. Requirements Engineering: Foundation for Software Quality. REFSQ 2022. Lecture Notes in Computer Science. Cham: Springer. https://doi.org/10.1007/978-3-030-98464-9_14.

Curtis, S. K., & Mont, O. (2020). Sharing economy business models for sustainability. In Journal of Cleaner Production (Vol. 266, p. 121519). Elsevier BV. https://doi.org/10.1016/j.jclepro.2020.121519

Derave, T., Princes Sales, T., Gailly, F., & Poels, G. (2022). Sharing Platform Ontology Development: Proof-of-Concept. In Sustainability (Vol. 14, Issue 4, p. 2076). MDPI AG. https://doi.org/10.3390/su14042076

El Sawy, O. A., & Pereira, F. (2013). Business Modelling in the Dynamic Digital Space. In Springer, Briefs in Digital Spaces. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-31765-1

Enders, A., Hungenberg, H., Denker, H.-P., & Mauch, S. (2008). The long tail of social networking. In European Management Journal (Vol. 26, Issue 3, pp. 199–211). Elsevier BV. https://doi.org/10.1016/j.emj.2008.02.002

Freichel, C., Fieger, J., & Winkelmann, A. (2021a). Developing a Taxonomy for Digital Platforms – A Conceptual Approach. In Proceedings of the Annual Hawaii International Conference on System Sciences. Hawaii International Conference on System Sciences. Hawaii International Conference on System Sciences. https://doi.org/10.24251/hicss.2021.701

Freichel, C., Hofmann, A., Ernst, I., & Winkelmann, A. (2021b). A Platform Business Model for Collaborative Additive Manufacturing. In Proceedings of the Annual Hawaii International

Conference on System Sciences. Hawaii International Conference on System Sciences. Hawaii International Conference on System Sciences. https://doi.org/10.24251/hicss.2021.578

Ghezzi, A. (2012). Emerging business models and strategies for mobile platform providers: a reference framework. In info (Vol. 14, Issue 5, pp. 36–56). Emerald. https://doi.org/10.1108/14636691211256296

Giessmann, A., Kyas, P., Tyrvainen, P., & Stanoevska, K. (2014). Towards a Better Understanding of the Dynamics of Platform as a Service Business Models. In 2014 47th Hawaii International Conference on System Sciences. 2014 47th Hawaii International Conference on System Sciences (HICSS). IEEE. https://doi.org/10.1109/hicss.2014.127

Gordijn, J., Wieringa, R.: e3value User Guide - Designing Your Ecosystem in a Digital World. The Value Engineers, 1st edn. (2021)

Helfat, C. E., & Raubitschek, R. S. (2018). Dynamic and integrative capabilities for profiting from innovation in digital platform-based ecosystems. In Research Policy (Vol. 47, Issue 8, pp. 1391–1399). Elsevier BV. https://doi.org/10.1016/j.respol.2018.01.019

Hoyer, V., & Stanoevska-Slabeva, K. (2009). Business models for digital business ecosystems: The case of the Open Negotiation Environment (ONE) platform. In 2009 3rd IEEE International Conference on Digital Ecosystems and Technologies (DEST). https://doi.org/10.1109/dest.2009.5276683

Hyrynsalmi, S., Suominen, A., Mäkilä, T., Järvi, A., & Knuutila, T. (2012). Revenue Models of Application Developers in Android Market Ecosystem. In Lecture Notes in Business Information Processing (pp. 209–222). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-30746-1_17

Immonen, A., Palviainen, M., & Ovaska, E. (2014). Requirements of an Open Data Based Business Ecosystem. In IEEE Access (Vol. 2, pp. 88–103). Institute of Electrical and Electronics Engineers (IEEE). https://doi.org/10.1109/access.2014.2302872

Janssen, M., & Zuiderwijk, A. (2014). Infomediary Business Models for Connecting Open Data Providers and Users. In Social Science Computer Review (Vol. 32, Issue 5, pp. 694–711). SAGE Publications. https://doi.org/10.1177/0894439314525902

Kim, J. (2016). The platform business model and business ecosystem: quality management and revenue structures. In European Planning Studies (Vol. 24, Issue 12, pp. 2113–2132). Informa UK Limited. https://doi.org/10.1080/09654313.2016.1251882

Koch, M., Krohmer, D., Naab, M., Rost, D., & Trapp, M. (2022). A matter of definition: Criteria for digital ecosystem. Digital Business, 2(2). https://doi.org/10.1016/j. digbus.2022.100027

Kohler, T. (2015). Crowdsourcing-Based Business Models: How to Create and Capture Value. In California Management Review (Vol. 57, Issue 4, pp. 63–84). SAGE Publications. https://doi.org/10.1525/cmr.2015.57.4.63

Kübel, H., & Zarnekow, R. (2014). Evaluating Platform Business Models in the Telecommunications Industry via Framework-based Case Studies of Cloud and Smart Home Service Platforms. Americas Conference on Information Systems.

Laczko, P., Hullova, D., Needham, A., Rossiter, A.-M., & Battisti, M. (2019). The role of a central actor in increasing platform stickiness and stakeholder profitability: Bridging the gap between value creation and value capture in the sharing economy. In Industrial Marketing Management (Vol. 76, pp. 214–230). Elsevier BV. https://doi.org/10.1016/j.indmarman.2018.08.010

Lin, P., Zhang, X., Yan, S., & Jiang, Q. (2020). Dynamic Capabilities and Business Model Innovation of Platform Enterprise: A Case Study of DiDi Taxi. In Scientific Programming (Vol. 2020, pp. 1–12). Hindawi Limited. https://doi.org/10.1155/2020/8841368

Mancha, R., & Gordon, S. (2021). Multi-sided platform strategies for organizations: transforming the business model. In Journal of Business Strategy (Vol. 43, Issue 3, pp. 175–183). Emerald. https://doi.org/10.1108/jbs-09-2020-0203

Moore, J.F.: The Death of Competition: Leadership and Strategy in the Age of Business Ecosystems. Wiley Harper Business (1996)

Nickerson, R. C., Varshney, U., & Muntermann, J. (2013). A method for taxonomy development and its application in information systems. European Journal of Information Systems, 22(3), 336-359.

Park, H., Kim, S., Jeong, Y., & Minshall, T. (2020). Customer entrepreneurship on digital platforms: Challenges and solutions for platform business models. In Creativity and Innovation Management (Vol. 30, Issue 1, pp. 96–115). Wiley. https://doi.org/10.1111/caim.12404

Parker, G.G., Van Alstyne, M.W., Choudary, S.P.: Platform revolution: How networked markets are transforming the economy and how to make them work for you. WW Norton & Company (2016)

Rohn, D., Bican, P. M., Brem, A., Kraus, S., & Clauss, T. (2021). Digital platform-based business models – An exploration of critical success factors. In Journal of Engineering and Technology Management (Vol. 60, p. 101625). Elsevier BV. https://doi.org/10.1016/j.jengtecman.2021.101625

Ruggieri, R., Savastano, M., Scalingi, A., Bala, D., & D'Ascenzo, F. (2018). The impact of Digital Platforms on Business Models: an empirical investigation on innovative start-ups. In Management & Marketing (Vol. 13, Issue 4, pp. 1210–1225). Walter de Gruyter GmbH. https://doi.org/10.2478/mmcks-2018-0032

Schreieck, M., Wiesche, M., & Krcmar, H. (2017). The Platform Owner's Challenge to Capture Value - Insights from a Business-to-Business IT Platform. International Conference on Interaction Sciences.

Springer, V., & Petrik, D. (2021). Towards a Taxonomy of Impact Factors for Digital Platform Pricing. In Agile Processes in Software Engineering and Extreme Programming – Workshops (pp. 115–124). Springer International Publishing. https://doi.org/10.1007/978-3-030-88583-0_11

Staub, N., Haki, K., Aier, S., & Winter, R. (2021). Taxonomy of Digital Platforms: A Business Model Perspective. In Proceedings of the Annual Hawaii International Conference on System Sciences. Hawaii International Conference on System Sciences. Hawaii International Conference on System Sciences. https://doi.org/10.24251/hicss.2021.744

Still, K., Seppanen, M., Korhonen, H., Valkokari, K., Suominen, A., & Kumpulainen, M. (2017). Business Model Innovation of Startups Developing Multisided Digital Platforms. In 2017 IEEE 19th Conference on Business Informatics (CBI). 2017 IEEE 19th Conference on Business Informatics (CBI). IEEE. https://doi.org/10.1109/cbi.2017.86

Täuscher, K., & Laudien, S. (2017). Uncovering the Nature of Platform-based Business Models: An Empirical Taxonomy. Proceedings of the 50th Hawaii International Conference on System Sciences, Hawaii: USA.

Täuscher, K., & Laudien, S. M. (2018). Understanding platform business models: A mixed methods study of marketplaces. In European Management Journal (Vol. 36, Issue 3, pp. 319–329). Elsevier BV. https://doi.org/10.1016/j.emj.2017.06.005

Teece, D. J., & Linden, G. (2017). Business models, value capture, and the digital enterprise. In Journal of Organization Design (Vol. 6, Issue 1). Springer Science and Business Media LLC. https://doi.org/10.1186/s41469-017-0018-x

Teece, D. J. (2018). Profiting from innovation in the digital economy: Enabling technologies, standards, and licensing models in the wireless world. In Research Policy (Vol. 47, Issue 8, pp. 1367–1387). Elsevier BV. https://doi.org/10.1016/j.respol.2017.01.015

van de Ven, M., Abbas, A. E., Kwee, Z., & de Reuver, M. (2021). Creating a Taxonomy of Business Models for Data Marketplaces. In 34th Bled eConference Digital Support from Crisis to Progressive Change: Conference Proceedings. Digital Support from Crisis to Progressive Change. University of Maribor Press. https://doi.org/10.18690/978-961-286-485-9.23

Verstegen, J. A., & Doorneweert, B. (2017). How to build a successful business model with big data platforms?. In CEUR Workshop Proceedings (Vol. 2025).

Webster, J. and Watson, R.T. (2002). "Analyzing the past to prepare for the future: Writing aliterature review", MIS Quarterly, vol. 26, no. 2, xiii –xxiii

Weking, J., Stöcker, M., Kowalkiewicz, M., Böhm, M., & Krcmar, H. (2020). Leveraging industry 4.0 – A business model pattern framework. In International Journal of Production Economics (Vol. 225, p. 107588). Elsevier BV. https://doi.org/10.1016/j.ijpe.2019.107588

Weking, J., Hein, A., Böhm, M., & Krcmar, H. (2018). A hierarchical taxonomy of business model patterns. In Electronic Markets (Vol. 30, Issue 3, pp. 447–468). Springer Science and Business Media LLC. https://doi.org/10.1007/s12525-018-0322-5

HYPERTENSION SELF-MANAGEMENT SUCCESS IN 2 WEEKS; 3 PILOT STUDIES

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Hypertension Self-Management is more powerful when done in groups, and with daily (e)Support for maximum impact. Small intervention groups enable high degrees of personalization, interaction, and learning. We compare three Self-Management Support (SMS) pilots of two weeks duration, in which various tools and daily microlearning strategies were used. Average blood pressure improvements in the pilots were 161/112 to 129/90 mmHg, resp. 145/92 to 126/86 mmHg, and 155/95 to 139/85 mmHg. User evaluations (n=20) were collected on perceived effectiveness of the various support components. This showed the importance of core SMS components: information transfer, daily monitoring, promoting health competences and follow-up. A tentative cross-case conclusion is that more daily social learning and microlearning feedback helps build more success: for blood pressure results and for competence building.

Keywords:
hypertension, self-management support, microlearning, social learning, eHealth, employee health

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1 Introduction

Hypertension is the main risk factor for death worldwide, according to Lancet publications from the largest health study ever (Lozano, 2012, Lim, 2012). Though it is preventable and reversible, most people get hypertension before they retire (Ostchega, 2020, Zhou, 2021, Carey & Whelton, 2020). So, we need healthier lifestyles. But how do we effectively learn the required competences?

Standard advice in health care hypertension is a bit simplistic when viewed from a competence building perspective. Plus, the feedback cycle takes too long. You might hear: "Try less salt and more sports, then come back in three months to check your blood pressure again." This approach contrasts strongly with the lessons from SMS (Self-Management Support) literature for the need of individualized learning support, regular monitoring and follow up coaching (Dineen-Griffin, 2019). If we add to this the microlearning lessons on competence building (Emerson & Berge, 2018, Simons, 2015, 2020b), we can hypothesize why many people experience unsatisfactory results. Standard care provides virtually no support for competence building.

In a previous study we reported on a preliminary pilot (Simons, 2022a) showing feasibility and perceived usefulness of daily hypertension feedback. Still, a question remained: how robust are effects across cases (external validity)? Next, on a more detailed level of design analysis: which elements in the support intervention are valued most; how does this depend on the intervention context? Where is the room for improvement? In this paper we conduct an analysis across three different cases. We compare the results and user evaluations from three hypertension Self-Management Support (SMS) pilots of 2 weeks each, across different employee groups, organisations, and intervention settings.

Our Research Question is:
How do the different support elements across the three cases relate to differences in health competences, -behaviors and blood pressure outcomes?

2 Theory and concepts

Four areas of expertise form the basis for the interventions and design analyses of this paper. They are: lifestyle medicine for hypertension, persuasive technology for health, Self-Management Support (SMS), and microlearning in a multichannel support mix. It was researched elsewhere how the challenges of ***persuasive technology*** (Fogg 2003, 2009) for health are not just located in the ICT (Information- & Communication Technology) design, but also in the design of the overall service scape, including health effectiveness and coaching performance (Starr 2008, Simons 2014b). It should generate positive, mutually reinforcing service experiences across communication channels, for effective health behaviours and -results. This is reflected in the following design evaluation framework for health improvement ICT solutions (Simons 2014), see Figure 1.

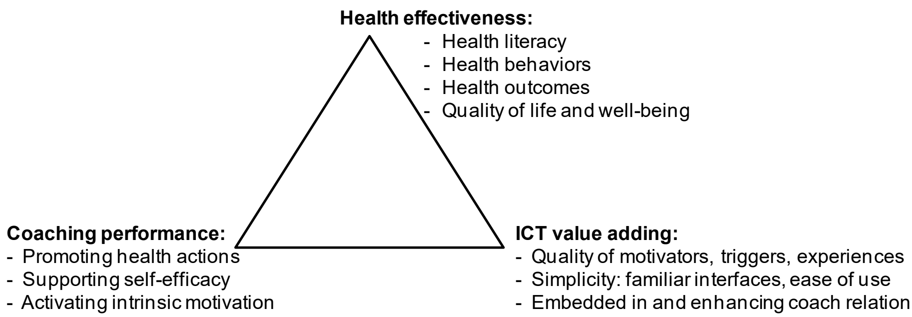

Figure 1: Design requirements for designing ICT-enabled healthy lifestyle support

Figure 1 addresses three domains to evaluate the impact of ICT-enabled health interventions: health effectiveness, coaching performance and ICT value adding. We use it as analysis framework for section 4, Results.

Lifestyle medicine for hypertension has a longstanding research tradition: overall (Roberts & Barnard, 2005) and regarding powerful short term effects on hypertension, inflammation and endothelial health of for example antioxidant foods (Franzini, 2012), flaxseed (Rodriguez-Leyva, 2013), beetroot and nitrates (Kapil, 2015), salt reduction (Dickinson, 2014) and healthy, low-fat food choices (Siervo, 2015), combined with exercise (Greger & Stone, 2016, Simons, 2022c) and stress reduction (Pickering, 2001). We translated this research into lifestyle advice to generate short term, measurable improvements for hypertension.

As discussed in more detail elsewhere (Simons, 2022a), the field of health ***Self-Management Support (SMS)*** has support process components, besides support for specific health behaviours (exercise, diet, sleep, smoking etc) and for tailoring the action plan to a participant's own context and priorities (Demark-Wahnefried, 2007, Jonkman, 2016, Dineen-Griffin, 2019, Simons, 2013, 2017, 2020a, 2021). This set of SMS process components also forms the ***evaluation framework*** we used for user evaluation in section 4:

1. **Monitoring** of symptoms (regular, active self-monitoring)
2. **Information** transfer (throughout the learning process)
3. **Competence** building, including:
    a. *Problem solving*/decision making
    b. *Plan making*: self-treatment through use of an action plan
    c. *Coping management*: skills for handling challenges, frustrations etc
    d. ***Resource utilization***: incl. social context or medication management

Finally, ***microlearning*** concepts are highly relevant to our objectives of increasing health behaviour competence levels of participants. Especially since our study took place in a (busy) work context, which creates a need for very efficient learning and rapid proof of effectiveness. "Business is about productivity, not learning. [..] *Inserting learning interventions into a busy employee's schedule is a real challenge*" (Emerson & Berge, 2018). Giurgiu (2017) states that microlearning should focus on only what you need to know. And that it should fulfil the human craving for instant gratification: satisfying short term goals that support long term goals. Gabrielli et al (2017) stress the "contextual" learning in a "conversation with the world and oneself". This conversation includes reflection, experimentation, and interpretation of results. Competence building is about *embedded learning*, where *doing* and *achieving results* are at least as important as learning (Emerson & Berge, 2018, Simons, 2010).

Multiple studies show how self-management tools and ICT (Information and Communication Technology) are useful, in a multichannel service-scape, for: goal setting based on personal preferences, ICT supported tracking and progress feedback (Kari, 2017, Lehto, 2013, Lopez, 2011, Ricciardi, 2013, Wickramasinghe, 2010). Elements like individual coaching, eTools like microlearning for health, Quantified Self (QS, Swan, 2012, 2013) progress tracking, WhatsApp groups and peer coaching in virtual support teams have all been shown to aid motivation and success (Simons, 2015, 2016, 2020b, 2022b). So does the power of group-based social learning (Bandura, 1971)

3 Methods and Materials

In a design research approach, we follow the design cycle methodology of Vaishnavi & Kuechler, (2004) which goes from problem awareness and solution suggestion to development, evaluation and conclusion. After reporting our multiple-case study results in section 4, we discuss design lessons in section 5.

The ***hybrid lifestyle intervention with twice-daily biofeedback*** consisted of:

- Telephone intake & instructions for BP home measurements
- Start- and final group sessions (2 weeks apart, face-to-face)
- Daily MS Teams eCoaching in week 1
- (Case A: individual and group; Case B: group; Case C: only email tips)
- Twice-daily BP measurements and logging email (Case A & B)
- Feedback on group progress after 1st week (Case A & B)
- Healthy recipe suggestions
- Content (portal and/or email) on health, BP, and behaviour strategies

From Nov 2021 to Feb 2023, a ***multiple-case study with three employee groups*** was conducted to evaluate real world impacts of the healthy lifestyle intervention for hypertension Self-Management in Dutch work settings. They were small scale pilots (n=8 to n=4), for three reasons. First, because we saw previously (Simons, 2022a) how robust the BP effects were across users, which enables small group sizes. Second, because we follow the design approach of multiple small tests to collect and test multiple improvement options, instead of conducting one big test (Cennamo, 2019). Third, we depended on employer organisations for volunteers. In total, n=20 volunteers participated.

Table 1: Case description and start situation

Aspects	**Case A (n=8)**[1]	**Case B (n=6)** [2]	**Case C (n=4)**
Case start	Nov '21	Nov '22	Jan '23
Participants	4 men, 4 women	3 men, 3 women	4 men
Avg. start blood pressure (mmHg)	145/92	161/112	155/95
Intervention duration	11 days	11 days	17 days
Final user evaluation	10 weeks after start	5 weeks after start	5 weeks after start
Support format specifics	Extra App for healthy menus	In week 1: longer daily e-Sessions, with more content & group interaction	*Light-weight*: * no coaching * no daily BP log-mail * info via mail instead of portal

Cases A and B were conducted with mixed groups of university groups (mostly support staff, with some academics) and Case C with ICT professionals. Their SES (Socio-Economic Status) and education levels were on the Dutch average or above. They all had hypertensive BP at start and volunteered for these 2-week in-company BP interventions. There were some cross-case differences: in the intervention service mix, group make-up, and organisational context, which enabled some interesting cross-case observations, see next section.

4 Results & Cross-Case Comparisons

A first question for our findings is: were there meaningful ***BP improvements*** across these cases? The short answer is: yes.

[1] One of the participants had a user evaluation outlier pattern, see Table 3.
[2] One of the participants had a user evaluation outlier pattern, see Table 3.

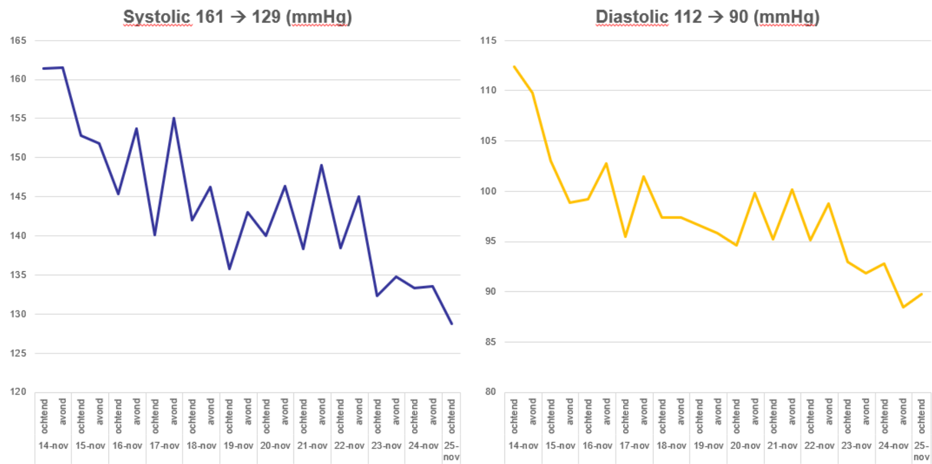

Figure 2: Average blood pressure drop in Case B (n=6)

Previously, we reported on the large BP improvements of case A (Simons, 2022a): from 145/92 down to 126/86 mmHg in 11 days (from Monday morning at start, to Friday morning in the second week). Case C also showed BP improvements, see Table 2, from 155/95 to 139/85 mmHg. The largest improvements occurred in Case B, see the BP trend line in Figure 2. Since participants measure their BP every morning and evening, an 11-day (average) 'spiky' trend line was created per pilot. The line is 'spiky' since evening BP tends to be higher than morning BP. Based on our user evaluations, we can say that participants generally find it very motivation to see their individual and collective trends: "I was positively and strongly surprised how large the impacts of our behaviour changes were." In case B, hypertension dropped from 161/112 down to 129/90 mmHg in 11 days.

A second finding is that the intended outcome of this intervention on BP occurs quite ***robustly across individuals***. (Which, on a methodological level, also enables us to work with small pilot groups and still observe robust effects per group.) The extend of BP effect robustness across individuals is indicated in Table 2, with the 'High BP Responder' percentage per case. We defined a 'High BP Responder' as a participant who had an average or above average BP improvement. This leads to a third finding: Case A and B have more 'High Responders' than Case C. Although this could be a coincidence, we propose that this is caused by the lesser degree of competence support given in Case C. This proposition is supported by our qualitative user- and case evaluations below, plus it is explored further in section 5, discussion.

Table 2: Cross-Case findings and authors' design evaluation, on design requirements from Figure 1 (authors' opinions, 5-point scale from - - to ++)

Findings	Case A (n=8)	Case B (n=6)	Case C (n=4)
Final Blood Pressure (BP, Avg. mmHg)	126/86	129/90	139/85
BP drop, mmHg	-19/-6	-32/-22	-16/-10
% of High BP Responders[3]	63%	66%	25%
Health behaviours	+ Healthier diet + Avg. 10.000 steps/day	++ Largest diet improvements ++ Highest physical activity	- No changes in intensive exercise - Most are still searching how to implement in daily patterns
Coaching performance	+ Raise efficacy + Adoption (except by some: time constraints)	++ Largest information transfer & impact from assignments ++ Largest social learning	+ Relevance of content was valued - Progress depends on user him/herself, without daily coaching
ICT value add	+ BP log mails daily; impact + Daily coaching (indiv & group) + Info in portal	+ BP log mails daily; impact + Daily digital 'day-start' sessions + Info in portal	- Portal and daily logging not used + Daily mail tips were appreciated

Table 2 shows a ***design evaluation*** across cases, based on the theory framework: health behaviours, coaching performance and ICT value add. First, regarding health, all cases showed improvements in BP and health behaviours. Case B showed the largest improvements and Case C the smallest. In our observation, this was a consequence of the second aspect: coaching. The coach assignments for behaviour

[3] This the % of participants in a case that had average or above average BP improvments. This is an indicator of robustness of BP results across participants.

improvement were more explicit in case B than A (e.g. “no cheese or meat for two weeks and at least 800 grams per day of fruits or vegetables”) and there was extensive daily group coaching and content on everyday challenges. Case C had no coaching, just a start workshop to explain people what to do, plus daily content mails until the final workshop. Thus, the extent of behaviour progress largely depended on a person’s self-management. The third design evaluation aspect, ICT value add, was higher in Case A and B, than in C: twice-daily BP logging mails, portal information on health and BP, healthy recipes, daily e-coaching in week 1 (in Case A more on the individual, in Case B more on group level learning, content, exchange of experiments and follow-up assignments) and feedback on group level BP progress after week 1. In Case C this was replaced with daily emails tips on hypertension, health, and behaviour change tactics.

From the ***user evaluations***, we discuss the perceived usefulness of the various intervention components across cases, see Table 3. Scores were given on a 7-point Likert scale, ranging from ‘totally disagree’ to ‘totally agree’, in answer to the question: ‘Which components stimulated you to adopt healthier behaviours?’ The components are clustered in the SMS process framework, even though some components support more than one SMS process.

Table 3: Components that stimulated healthier behaviours (7-point (dis)agree, Avg)

Monitoring:	**Case A**[4]	**Case B**[5]	**Case C**[6]
1. Mail triggers for blood pressure logging	4.9	6.2	n.a.
2. Daily management	5.4	5.6	6.0
3. Gaining more blood pressure control	6.3	6.4	6.5
Information transfer:			
4. Start workshop	6.4	6.4	6.8
5. Healthy menu suggestions (App/portal)	4.4	4.8	n.a.
6. Health and blood pressure information in portal/mails	5.4	5.2	6.3
7. More understanding of blood pressure & health	6.1	6.2	6.0
Competence building:			
8. Follow-up workshops	6.3	6.2	7.0
9. Individual tips and answers to my questions from the coaches	6.6	6.2	6.8
10. Doing this as a group	6.4	5.8	5.5
11. Tips in dealing with challenges	6.0	6.2	6.0

In Table 3 we see that the main perceived benefit from *Monitoring* was the blood pressure control participants gained (3.). For the second SMS process element, *Information transfer*, we see that the start workshop (4.) and increased understanding of blood pressure and health (7.) were valued most. These two intervention components (4. & 7.) were not just about information transfer, but also about increasing competences for: effective plan making and prioritizing efforts on those lifestyle choices that have the best combination of short-term effectiveness and long-term perceived attractiveness/ feasibility for a participant. The element, *Competence building*, is key for training sustainable self-management skills and coping strategies. All four components (8. to 11.) receive relatively high scores, and for case B the perceived value of doing this as a group (10.), was explicitly stressed by participants

[4] One of the participants had an outlier pattern of scoring (since she could not be present at several of the group coach sessions, due to illness plus family logistics). Table 3 displays the average scores of the other 7. (Score 4=neutral) Her scores were resp.: 6; 6; 6/3; 3; 4; 5/3; 6; 3; 3.
[5] One of the participants had an outlier pattern of scoring (she had hereditary hypertension since 18 years old and her BP values did not change, despite her best efforts). Table 3 displays the average scores of the other 5. (Score 4=neutral) Her scores were resp.: 4; 4; 4/4; 4; 4; 5/4; 4; 6; 5.
[6] n.a. = not applicable

in the joint group evaluation after 5 weeks. So, support for competence building was generally valued by the participants.

Previously, a more detailed presentation of the healthy behaviour challenges was given, as well as what helped participants to improve those behaviours (Simons, 2022a). In answer to our Research Question (How do the support elements relate to differences in health competences, -behaviours and blood pressure outcomes), several ***elements for promoting health improvements*** found previously, were confirmed in our cross-case analysis:

a. Rapid feedback: twice-daily measurement of progress
b. Achieving results and enhancing self-efficacy
c. ‘Quick results’-tips & education: which large steps for large benefits
d. Practical tips for every-day choices and practicing new behaviour patterns
e. High quality coaches and coach sessions to increase health competence
f. Doing this in a group and teaching each other
g. Coaching on coping strategies

Next, we highlight findings from the main ***cross-case differences***. After Case A, we made three adaptions to the support components, based on user feedback. First, we had rented a (commercial) mobile App for the users, with many easy and adaptable ‘hypertension-friendly’ menu options, including a ‘home-delivery’ function. However, this was hardly used and thus discarded. Besides, we relied quite a bit on individual coaching. But given the large benefits we saw from group learning in case A, we changed two other things for Case B: (1) we replaced individual coaching with longer, information-intensive daily digital group workshops as day-starters in week 1, and (2) we gave more explicit daily assignments: what experiments and behaviours to practice today. We subsequently observed larger improvements in healthy eating and exercise in Case B, see Table 2, which we propose is a consequence of these changes that were made. In Case C support was lightweight, see also Table 2, given the different organisation context and participants’ preferences for a more light-weight (and less time-intensive) approach. So, there was no coaching in between the start and final workshop, of two hours each. Besides, daily logging and portal access were not used (even though the participants did monitor their blood pressure themselves during the two weeks). Instead, they received daily email tips on health behaviours, self-management, and blood pressure.

The main finding from case C is that health behaviour changes were smaller and that only one participant achieved above-average BP improvements.

Cross-case differences confirm that most individuals find it hard to make large changes in their health choices solely based on information. Cases A and B (versus C) illustrate that ***for most participants daily support with coaching and group learning processes appear to be required to generate sufficient behaviour- and Blood Pressure (BP) improvements,*** and even daily support is not enough for every participant in Cases A and B. Next, one element stands out from the user feedback which was very similar across all three cases: ***the quality of information/tips was highly valued by participants, because it was effective for generating rapid BP improvements.*** In all three cases, the information was deemed important ("these really helped") and valued ("most useful information in years").

5 Discussion

This cross-case design analysis has several ***limitations***. Firstly, due to its small scale (in total n=20 participants across 3 cases) our research question is qualitatively answered, not quantitatively. Secondly, the BP trends are based on self-reported measures. Still, they practiced these measurements during a wash-in period of three days before the start, which helps create robustness. Thirdly, we qualitatively assessed health competence growth, changes in lifestyle behaviours, and learning strategies. In future research, we would like to use more formal and validated surveys to generate health competence improvement scores for example. However, this is not straightforward, for two reasons: (1) BP related competence is not the same as general health competence and (2) health competence was already above average in these participants at the start. Fourthly, each intervention/case tested multiple intervention components together, without control group. So, cross-case intervention differences provide some insights, but interpretations are qualitative and (inter-)subjective.

Based on the cross-case analysis, we propose ***four design lessons***.

- First, since many individuals indicate that they find it hard to make large health behaviour changes based solely on information, as stated in the findings, extra support is needed: ***daily group coaching speeds up social learning processes*** and stimulates participants to do new health experiments or try new tactics to cope with difficult situations.

- Second, ***light-weight*** support (like in Case C) only works ***if self-management competences of participants are high***. Besides, participants struggle more with establishing longer term health patterns.
- Third, the ***quality of information*** and tips must be high: it is valued (and applied) if participants recognize it as effective ***for generating rapid BP improvements***. This in turn requires daily 'proof' from BP improvements.
- Fourthly, the ***power of the 'Challenge Regime'*** was mentioned in many evaluations. The two main elements: (1) making a commitment for large health changes and experiments, (2) knowing that it is for only two weeks. This combination enhances temporary attention, motivation, effort, and willingness to experiment. The result is: more improvement, more learning, a positive experience, plus a desire to continue using some of the lessons learned in the longer run.

As a lesson on ***practical implications***, we should not forget the important added ***value of technology*** in this intervention: daily home monitoring is now feasible thanks to affordable and reliable blood pressure consumer electronics; our mail/web-based coaching portal enables real-time progress tracking by participants and coaches alike; daily MS Teams meetings enabled high quality group and individual coaching without travel- or time constraints; our portal content database supports participants with multiple lessons on blood pressure and healthy lifestyle; the healthy menu App offered even included a button to directly order/deliver the ingredients to participants' homes (even though this latter option was not used by the participants). In short, the intervention was highly dependent on these technologies and tools.

By contrast, ***microlearning*** is sometimes framed as 'a tool' or technology. But we saw that it is much more. Its value ***as an embedded learning strategy*** to create daily, relevant, and 'rich' learning instances was key in our case implementations: creating multiple, daily competence-building microlearning opportunities, also face-to-face and in group discussions.

In ***conclusion***, this intervention was attractive and feasible for the participants. It was effective for achieving blood pressure improvements in two weeks. The value was confirmed of the Self-Management Support (SMS) and microlearning approaches for competence building. Besides, our study illustrates the added value of: (a) group coaching/social learning; (b) a 'Challenge Regime' with high commitments for a short time; (c) self-efficacy growth for users from large health results within days; (d) multiple (technology-enabled) health competence building lessons each day. These options hold promise for future health Self-Management Support innovations.

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References

Bandura, A. (1971). Social learning theory (Vol. 1). Prentice Hall, Englewood cliffs.

Carey, R. M., & Whelton, P. K. (2020). Evidence for the universal blood pressure goal of< 130/80 mm Hg is strong: controversies in hypertension-pro side of the argument. Hypertension, 76(5), 1384-1390.

Cennamo, K., & Kalk, D. (2019). Real world instructional design: An iterative approach to designing learning experiences. Routledge, Oxfordshire, UK.

Demark-Wahnefried, W., Clipp, E., Lipkus, I., Lobach, D. et al. (2007). Main Outcomes of the FRESH START Trial: A Sequentially Tailored, Diet and Exercise Mailed Print Intervention Among Breast and Prostate Cancer Survivors. J Clin Oncol, 25(19), pp. 2709-2718.

Dickinson, K. M., Clifton, P. M., Burrell, L. M., Barrett, P. H. R., & Keogh, J. B. (2014). Postprandial effects of a high salt meal on serum sodium, arterial stiffness, markers of nitric oxide production and markers of endothelial function. Atherosclerosis, 232(1), 211-216.

Dineen-Griffin, S., Garcia-Cardenas, V., Williams, K., & Benrimoj, S. I. (2019). Helping patients help themselves: a systematic review of self-management support strategies in primary health care practice. PloS one, 14(8), e0220116.

Emerson, L. C., & Berge, Z. L. (2018). Microlearning: Knowledge management applications and competency-based training in the workplace. Knowledge Management & E-Learning, 10 (2), pp.125-132.

Fogg, B. J., & Fogg, G. E. (2003). Persuasive Technology: Using Computers to Change What We Think and Do. Morgan Kaufmann, San Francisco.

Fogg, B. J. (2009). A behavior model for persuasive design. Proceedings of the 4th international conference on persuasive technology. ACM, 2009.

Franzini, L., Ardigo, D., Valtuena, S., Pellegrini, N., Del Rio, D., Bianchi, M. A., ... & Zavaroni, I. (2012). Food selection based on high total antioxidant capacity improves endothelial function in a low cardiovascular risk population. Nutrition, Metabolism and Cardiovascular Diseases, 22(1), 50-57.

Gabrielli, S., Kimani, S., & Catarci, T. (2017). The design of microlearning experiences: A research agenda (on microlearning).

Giurgiu, L. (2017). Microlearning an evolving elearning trend. Scientific Bulletin, 22(1), 18-23.

Greger, M., & Stone, G. (2016). How not to die: discover the foods scientifically proven to prevent and reverse disease. Pan Macmillan, New York City.

Jonkman, N. H., Schuurmans, M. J., Jaarsma, T., Shortridge-Baggett, L. M., Hoes, A. W., & Trappenburg, J. C. (2016). Self-management interventions: proposal and validation of a new operational definition. Journal of clinical epidemiology, 80 (December 2016), 34-42. DOI: https://doi.org/10.1016/j.jclinepi.2016.08.001

Kapil, V., Khambata, R. S., Robertson, A., Caulfield, M. J., & Ahluwalia, A. (2015). Dietary nitrate provides sustained blood pressure lowering in hypertensive patients: a randomized, phase 2, double-blind, placebo-controlled study. Hypertension, 65(2), 320-327.

Kari, T., Koivunen, S., Frank, L., Makkonen, M., & Moilanen, P. (2017). The expected and perceived well-being effects of short-term self-tracking technology use. International Journal of Networking and Virtual Organisations, 17(4), 354-370.

Lozano, R., Naghavi, M., Foreman, K., Lim, S., Shibuya, K., Aboyans, V., ... & Remuzzi, G. (2012). Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. The lancet, 380(9859), 2095-2128.

Lim, S. S., Vos, T., Flaxman, A. D., Danaei, G., Shibuya, K., Adair-Rohani, H., ... & Pelizzari, P. M. (2012). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. The lancet, 380(9859), 2224-2260.

Lehto, T., Oinas-Kukkonen, H., Pätiälä, T., & Saarelma, O. (2013). Virtual health coaching for consumers: a persuasive systems design perspective. International Journal of Networking and Virtual Organisations 4, 13(1), 24-41.

Lopez, G., Shuzo, M., & Yamada, I. (2011). New healthcare society supported by wearable sensors and information mapping-based services. International Journal of Networking and Virtual Organisations, 9(3), 233-247.

Ostchega, Y., Fryar, C. D., Nwankwo, T., & Nguyen, D. T. (2020). Hypertension prevalence among adults aged 18 and over: United States, 2017–2018, NCHS, National Health and Nutrition Examination Survey, 2017–2018: https://stacks.cdc.gov/view/cdc/87559.

Pickering, T. G. (2001). Mental stress as a causal factor in the development of hypertension and cardiovascular disease. Current hypertension reports, 3(3), 249-254.

Ricciardi, F., Rossignoli, C., & De Marco, M. (2013). Participatory networks for place safety and livability: organisational success factors. International Journal of Networking and Virtual Organisations 4, 13 (1), 42-65.

Roberts, C. K., & Barnard, R. J. (2005). Effects of exercise and diet on chronic disease. Journal of applied physiology, 98(1), 3-30.

Rodriguez-Leyva, D., Weighell, W., Edel, A. L., LaVallee, R., Dibrov, E., Pinneker, R., ... & Pierce, G. N. (2013). Potent antihypertensive action of dietary flaxseed in hypertensive patients. Hypertension, 62(6), 1081-1089.

Siervo, M., Lara, J., Chowdhury, S., Ashor, A., Oggioni, C., & Mathers, J. C. (2015). Effects of the Dietary Approach to Stop Hypertension (DASH) diet on cardiovascular risk factors: a systematic review and meta-analysis. British Journal of Nutrition, 113(1), 1-15.

Simons, L. P. A., & Hampe, J. F. (2010). Service Experience Design for Healthy Living Support; Comparing an In-House with an eHealth Solution. The 23rd Bled eConference, pp. 423-440. Accessed 2010 from www.bledconference.org

Simons LPA, Hampe JF, Guldemond NA. (2013). Designing Healthy Living Support: Mobile applications added to hybrid (e)Coach Solution. Health and Technology. 3 (1) pp.85-95. DOI 10.1007/s12553-013-0052-9

Simons LPA, Hampe JF, Guldemond NA. (2014). ICT supported healthy lifestyle interventions: Design Lessons. Electronic Markets. 24 pp. 179-192. DOI 10.1007/s12525-014-0157-7.

Simons LPA, Foerster F., Bruck PA, Motiwalla L & Jonker CM. (2014b). Microlearning mApp to Improve Long Term Health Behaviours: Design and Test of Multi-Channel Service Mix. Paper presented at the 27th Bled eConference. Bled, Slovenia, Proceedings. Retrieval from www.bledconference.org and http://aisel.aisnet.org/bled2014/4

Simons LPA, Foerster F., Bruck PA, Motiwalla L & Jonker CM. (2015). Microlearning mApp Raises Health Competence: Hybrid Service Design. Health and Technology, 5 pp 35-43.

Simons, L. P., Pijl, H., Verhoef, J., Lamb, H. J. et al (2016). Intensive Lifestyle (e) Support to Reverse Diabetes-2. In Bled eConference (p. 24), accessed Dec 20, 2016 www.bledconference.org.

Simons LPA, Hafkamp MPJ, Bodegom D, Dumaij A, Jonker CM. (2017). Improving Employee Health; Lessons from an RCT. Int. J. Networking and Virtual Organisations, Vol. 17, No. 4, pp.341–353. DOI https://doi.org/10.1504/IJNVO.2017.088485

Simons, LPA, Heuvel, AC van den, Jonker CM. (2018). eHealth WhatsApp Group for Social Support; Preliminary Results, pp. 225-237, presented at the 31st Bled eConference. Bled, Slovenia, Proceedings retrieval from www.bledconference.org. ISBN-13: 978-961-286-170-4, DOI: https://doi.org/10.18690/978-961-286-170-4

Simons, LPA., van den Heuvel, W. A., & Jonker, C. M. (2019). WhatsApp Peer Coaching Lessons for eHealth. In Handbook of Research on Optimizing Healthcare Management Techniques (pp. 16-32). IGI Global, ISBN 9781799813712.

Simons, LPA, (2020a). Health 2050: Bioinformatics for Rapid Self-Repair; A Design Analysis for Future Quantified Self, pp. 247-261, 33rd Bled eConference. June 28-29, Bled, Slovenia, Proceedings retrieval from www.bledconference.org. ISBN-13: 978-961-286-362-3, DOI: https://doi.org/10.18690/978-961-286-362-3.17.

Simons, LPA, Heuvel, AC van den, Jonker CM. (2020b). eHealth WhatsApp for social support: design lessons. International Journal of Networking and Virtual Organisations, 23(2), 112-127. DOI https://doi.org/10.1504/IJNVO.2020.108857.

Simons, LPA, Neerincx MA, Jonker CM (2021). Health Literature Hybrid AI for Health Improvement; A Design Analysis for Diabetes & Hypertension, pp. 184-197, 34th Bled eConference. June 27-30, Bled, Slovenia, Proceedings retrieval from www.bledconference.org. ISBN-13: 978-961-286-385-9, DOI: https://doi.org/10.18690/978-961-286-385-9 .

Simons, LPA, Gerritsen, B, Wielaard, B, Neerincx MA (2022a). Health Self-Management Support with Microlearning to Improve Hypertension, pp. 511-524, 35th Bled eConference. June 26-29, Bled, Slovenia, Proceedings retrieval from www.bledconference.org. ISBN-13: 978-961-286-616-7, DOI: 10.18690/um/fov.4.2022

Simons, LPA, Pijl M, Verhoef J, Lamb HJ, van Ommen B, Gerritsen B, Bizino MB, Snel M, Feenstra R, Jonker CM. (2022b). e-Health Diabetes; 50 Weeks Evaluation. Int. J. Biomedical Engineering and Technology, 38(1), 81-98.

Simons, LPA, Neerincx MA, Jonker CM (2022c). Is Google Making us Smart? Health Self-Management for High Performance Employees & Organisations, International Journal of Networking and Virtual Organisations, Vol 27, No 3, pp.200-216. DOI: 10.1504/IJNVO.2022.10053605

Starr, J. (2008). The coaching manual: the definitive guide to the process, principles and skills of personal coaching. Prentice Hall, New York.

Swan, M. (2012). Health 2050: The realization of personalized medicine through crowdsourcing, the quantified self, and the participatory biocitizen. Journal of personalized medicine, 2(3), 93-118.

Swan, M. (2013). The quantified self: Fundamental disruption in big data science and biological discovery. Big data, 1(2), 85-99.

Vaishnavi, V and Kuechler, W. 2004. Design Research in Information Systems. Last updated August 16, 2009 from http://desrist.org/design-research-in-information-systems

Wickramasinghe, N., & Goldberg, S. (2010). Transforming online communities into support environments for chronic disease management through cell phones and social networks. International journal of networking and virtual organisations, 7(6), 581-591.

Zhou, B., Perel, P., Mensah, G. A., & Ezzati, M. (2021). Global epidemiology, health burden and effective interventions for elevated blood pressure and hypertension. Nature Reviews Cardiology, 18(11), 785-802.

Data Governance Capabilities; Empirical Validation in Case Studies of Large Organisations

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The exponential growth of data within organisations necessitates the implementation of effective data management practices, which in turn necessitates the establishment of data governance. The evaluation of the maturity of data governance can be carried out using maturity models. However, the existing data governance maturity models are limited in their consistency in terms of data governance capabilities used and lack empirical validation. To address this gap, this study aims to validate the set of data governance capabilities identified in prior research within large organisations. This study employs a case study research design, using semi-structured interviews with experts in data governance. As a basis for the semi-structured interviews, maturity models are designed as questionnaires to discuss the relevance of each data governance capability. The results of this study provide empirical validation of the set of data governance capabilities and contribute to the advancement of both data governance research and practice by providing a comprehensive, validated set of data governance capabilities for maturity model design to advance data governance within and between organisations.

Keywords: data governance capabilities, empirical validation, maturity model

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1 Introduction

The growing amount of data in organisations, due to the increasing digitization of processes, necessitates the implementation of proper data management (Weber et al., 2008). Data governance (DG) must be established to ensure proper data management. DG is defined as "*establishing management of data in an organisation assuring quality and access during its life-cycle to be accountable for data assets*" (J. Merkus et al., 2019). Maturity models, which are used to measure and improve organisational performance in various application areas (Rosemann et al., 2004; a. van Looy et al., 2011), aid in implementing DG.

Maturity models are based on organisational capabilities, which are the collective abilities of an organisation to carry out business processes that contribute to its performance (Brennan et al., 2018; J. R. Merkus et al., 2020). These capabilities are used to measure organisational maturity by evaluating organisational activities against staged levels of maturity (Becker et al., 2009; J. R. Merkus et al., 2020, 2021; Paulk et al., 1993). Maturity models can also focus on specific capabilities like for instance data governance. Hence, Data Governance Capabilities (DGCs) can be used to measure DG maturity (Merkus et al., 2021).

Research on Data Governance Maturity Models (DGMMs) has identified several sets of DGCs for maturity model design (J. R. Merkus et al., 2021; Olaitan et al., 2019; Permana & Suroso, 2018). However, the DGCs used in existing DGMMs are inconsistent, resulting in different sets of DGCs for each DGMM in the literature (Heredia-Vizcaíno & Nieto, 2019; Permana & Suroso, 2018; Rivera et al., 2017). Furthermore, only a few DGMMs have been validated in practice, and, when validated, they only did so in a single or small organisations (J. R. Merkus et al., 2020; Olaitan et al., 2019; Permana & Suroso, 2018; Rivera et al., 2017). Thus, there is a need for a more comprehensive DGC model validated in practice (J. R. Merkus et al., 2021).

To address this gap, we aim to empirically validate the set of 34 DGCs that we developed in our earlier, theoretical study. That study used a systematic literature review to identify DGCs from a broad range of literature (J. R. Merkus et al., 2020). However, the resulting set of DGCs was based solely on literature and requires proper validation in practice. Therefore our research question is: ***To what extent***

are the Data Governance Capabilities for Maturity Model design valid in practice?

This paper provides new knowledge through the empirical validation of the previously proposed set of DGCs, resulting in a set of DGCs that can serve as a reference for other studies in the area of Data Governance. The practical significance of this research lies in the contribution of a more comprehensive and validated set of DGCs that can serve as to assess the status quo of DG in organisations more accurately e.g. as the basis for a DG maturity model. Validated DGCs also enable more precise benchmarking with other organisations.

The remainder of this paper is structured as follows. The literature review on DGMM and DGC is presented in section 2. Then in section 3, we present our research methodology to validate our DGCs, followed by the validation results in section 4. Finally, the conclusions are presented in section 5.

2 Background

This section provides a theoretical foundation for our research. First, we define the concept of DG capabilities and subcapabilities as the cornerstone of our study. Second, we identify a gap in the literature regarding the validation of existing DGCs Third, we present the set of DGCs we developed in an earlier study and will be validated in this research.

DG Capabilities (DGCs) encompass an organisation's collective abilities to govern data assets effectively (Brennan et al., 2018; J. Merkus et al., 2019). A DGC indicates what an organisation is capable of doing concerning specific DG activities. For example, the DGC *establish data stewardship* describes an organisations ability to set up data stewardship functions. Subsequently, each DGC can be broken down into subcapabilities, a term also used by other authors (Bandara et al., n.d.). The term subcapability refers to a set of subdimensional capabilities that specifies in more detail what makes up the capability dimension.

DGCs are used in Data Governance Maturity Models (DGMM) to measure the maturity of data governance in an organisaton (J. R. Merkus et al., 2021; Rosemann et al., 2004; a. van Looy et al., 2011; A. van Looy et al., 2011). To date, only a few peer-reviewed DGMMs have been developed, with widely differing sets of DGCs selected as the basis for each model (Dasgupta et al., 2019; Heredia-Vizcaíno & Nieto, 2019; Olaitan et al., 2019; Permana & Suroso, 2018; Rivera et al., 2017). Nevertheless, there are also common DGCs in these models and the most common DGCs are: establishing policies, principles, and procedures and managing metadata. The other DGCs used vary widely and some DGCs have been used in one DGMM only. Based on this, one can conclude that there is a lack of agreement amongst researchers on a single set of DGCs. This is further illustrated by comparing existing sets of DGCs from different DGMMs, as presented in Table 1.

Despite recent progress in DG research, which has focused on DG mechanisms and DG activities between organisations, the validation of these mechanisms, activities and the capabilities to execute them is still lacking (Abraham et al., 2019; Jagals et al., 2021; Lis & Otto, 2021). A limited number of researchers have identified certain principles, activities, and critical success factors for Data Governance (DG) as Data Governance Capabilities (DGCs) (Alhassan et al., 2016, 2018, 2019). These DGCs have been validated in a few individual case studies. Other researchers have discovered DGCs as mechanisms from DG-related research area of information technology governance, aimed at planning and controlling data management activities (Abraham et al., 2019). However, these mechanisms are yet to be validated in practical settings. Recently, DG research has outlined DG activities that take place between organizations (Lis & Otto, 2021). However, the execution of these activities and the capabilities required to carry them out need to be empirically validated in practice. So, although some DGCs have been identified by recent DG research, the empirical validation of these DGCs is still limited.

In previous research, we have identified an extensive set of DGCs based on a systematic literature review (J. R. Merkus et al., 2021). Table 1 provides an overview of this set of DGCs and compares it with the DGCs that have been identified/used in other research. The vertical axis in Table 1 lists the 34 DGCs we identified in earlier research. On the horizontal axis, the existing DGMMs are mentioned. Hence, the cells in Table 1 show the mapping of the DGMMs from the literature with our set of DGCs. Green cells indicate that the DGCs in the literature are validated, and orange cells indicate those DGCs that are not validated. An empty cell means that our DGC is not found in the DGMM found in the literature. The comparison demonstrates that existing DGMMs use different sets of DGCs and none of the

DGMMs is as exhaustive as our list of DGCs. Furthermore, table 1 also illustrates the majority of these DGCs have yet to undergo empirical validation. This study aims to empirically validate the comprehensive set of 34 DGCs within large organisations. The research method applied for the validation of the DGCs is presented in the next section.

Table 1: DGMM capability sets comparison (Merkus et al., 2021)

Data Governance Capabilities Merkus et al. 2021	Rifae 2009	Rivera 2017	Permana 2018	Dasgupta 2019	Heredia 2019	Olaitan 2019
Establish Leadership						
Establish & manage Communicate						
Establish & manage Train						
Establish & manage culture		V				
Establish & manage awareness			V			
Quantify data value	NV			V		
Align with the business	NV					
Formulate data strategy				V	NV	
Make business case						
Set goals & objectives		V				
	NV					
Establish accountability	NV					
Establish decision making authority						
Establish committees						
Establish roles & responsibilities			V		NV	
Establish data stewardship			V		NV	V
Establish policies, principles & procedures		V		V	NV	V
Establish KPI's						
Establish performance management	NV					
Establish Monitoring				V		
Establish Auditing				V		
			V	V		V
Manage processes			V	V		V
Manage organisation						V
Manage data						V
Manage metadata		V	V		NV	V
Manage risk	NV			V		
Manage issues						
Establish & manage DG tools						
Establish & manage security & privacy		V				V
Establish & manage Data Technology		V		V		
			V	V	NV	
Organize people			V	V	NV	
Align & integrate data						
Contract data sharing agreements						
Comply with regulations		V		V		V
Government						
	5	3	6	10	6	8

Validated in practice

Not validated in practice

3 Method

To empirically validate the DGCs for relevance, we have selected the case study strategy as our research approach. According to Yin (2014), a case study is "an empirical method that investigates a contemporary phenomenon (the case) in-depth and within its real-world context." Using the case study approach enabled us to identify DG activities in practice (practices) that make up each of the 34 DG capabilities we derived from the literature and hence to validate the capabilities. Furthermore, other researchers in our field recommend using case studies with expert interviews to design and evaluate capability models (Legner et al., 2020).

Since validation of a single capability takes considerable time. It was decided to divide the DGCs among a group of researchers that used different organizations as case studies. The case organisations were found using convenience-based sampling, i.e. organisations in the networks of the researcher. However, each organisation should have at least 500 employees and there should be a need for data governance to participate in the research.

Semi-structured expert interviews were used as the main method for data collection. The interviewees were DG experts, which are individuals with at least five years of experience in DG, data management, or similar positions. To structure and compare the results of the interviews, pre-defined questionnaires were used, allowing open-ended questions to facilitate in-depth discussions.

To further facilitate the interview process, Maturity Models (MMs) were developed for each DGC by means of a scoping literature review. The aim of the literature review was to identify the subcapabilities of each DGC, which will form the basis of a DGC-specific MM (Munn et al., 2018). The resulting MMs have been used during the interviews to uncover DG practices, or reveal new DGCs, and thus provide experience-based information to support the validation of the DGCs. We validated each subcapability by an expert's work experience with DG practices in large organisation. By validating each subcapability, we validate the overarching DGC of which subcabilities are part of.

Finally, all empirically validated DG subcapabilities were categorised using a card sorting approach with applying the Metaplan technique (Howard, 1994; Spencer & Warfel, 2004). Using the original set of 34 DGCs as a reference, we eliminated any misconceptions that may have arisen during the scoping literature reviews. Furthermore, it helped to reveal new DGCs and hence to enrich the set of DGCs from literature with DGCs found in practice.

4 Results

A total of 16 researchers each conducted a study of one or two DGCs in 19 large organisations over the course of a five-year period. Initially, each researcher conducted a scoping literature review to identify the relevant subcapabilities for DGCs. Examples of subcapabilities found for DGC *Align and integrate external data* are (1) interaction and cooperation processes management, (2) Standardise data exchange, (3) Policies for data integration and use, (4) Data provider management, and (5) improve customer satisfaction. Next, each researcher designed an MM for their DGCs using the same design methodology and five stages of maturity levels, yielding 16 distinct MMs (Becker et al., 2009; Rosemann et al., 2004). Thirdly, three to five respondents were interviewed for the validation of each DGC, generating 70 expert interview reports, with an average interview duration of approximately two hours and up to four hours in some cases. These reports provide the basis for the validation of all DG capabilities. The interview reports are accessible from the author.

The participating organisations all employ more than 500 employees, reflecting the need for governance awareness in such large organisations. Additionally, the participating organisations represent a diverse range of business sectors, allowing for the measurement of the DGCs and DG in various business activities, and operate at various geographical scales, as indicated in Table 2 *Case organisations*.

Table 2: Case organisations

Sector \ Scale	International	National	Regional	Total
Bank	1			1
Bio industry	2			2
Education			2	2
Energy		1	1	2
Government		4		4
Insurance	1	1		2
Manufacturing	1	1		2
Retail		1		1
Wholesale	2			2
Union		1		1
Total	**7**	**9**	**3**	**19**

Additionally, DG jobs were scarce ten years ago as the field of DG only began to gain recognition in 2007 (Otto et al., 2007). As a result, some interviewed experts gained relevant experience in DG-related employment, such as data management. Despite these pragmatic adjustments, our research was carried out in accordance with the previously described methodology.

In a peer-led card sorting exercise, we categorized all 231 subcapabilities derived from the 16 substudies using the Metaplan technique described in the methodology section. To eliminate misconceptions for more unambiguous language, we reclassified 47 subcapabilities to other existing DGCs as they fit better with those DGCs. Our analysis revealed no duplicates among the subcapabilities, but six subcapabilities had to be redefined to better differentiate them from each other. Additionally, the researchers identified ten suggestions for new subcapabilities and one suggestion for a new DGC during their substudies. Card sorting revealed that all eleven suggestions were addressed in one of the other substudies. So, no additional new (sub-)capabilities were identified.

The validation of the DGCs in interviews, along with a subsequent hybrid card sorting exercise, resulted in the outcomes depicted in Table 3 *DGC validation results*. This table lists in column 1 all 34 DGCs in the DGC model, sorted according to Table 1. Column 2 lists the number of DG subcapabilities per DGC. Column 3 lists the number of case organisations where the subcapabilities have been validated. Column 4 lists the number of interviews in which a DG subcapability has been discussed. Column 5 lists the number of DG practices per DG subcapability noted during the interviews.

We empirically validated each subcapability by (a) having the researchers registered a DG expert's experience and reasoning of a DG practice happening in the organisation of his employer by the researchers during the interviews, (b) having the author analyse the transripts of the interviews for DG practices and reasoning for each subcapability after the interviews, and (c) finally, having the author discuss the findings with the peer authors. This resulted in a database of DG practices, including their reasoning when known, sorted per subcapability and the overarching DGC. So, when a DG practice occurred in a large case organisation and already one relevant DG practice was registered, the number of practices is irrelevant because we conducted qualitative research, the subcapability is empirically validated, hence empirically validating its overarching DGC.

For example, for DGC *Manage Metadata*, we revealed three subcapabilities from literature; metadata, metadata management, and data standards. Next, we validated these three subcapabilities in the form of a maturity model in three different, large case organisations during 16 interviews with one DG expert each. During those interviews, the researchers noted eight different DG practices. Examples of the DG practices for each subcapability are a.o. (a) the presence of a data dictionary, or (b) business definitions being aligned with technical data definitions by data lineage, (c) or metadata management being administered in a central system. The reasoning we found for each subcapability is resp. (a) a data dictionairy is needed to integrate processes, mutually understand what data means and align data between departments, legal requirements, and internal control reasons, and (b) integration of departments and divisions but also classification for privacy (c) to run queries. Consequently, these three DG practices validate the three subcapabilities, hence validating the DGC *Managing metadata*.

Our overall research results show that each of the 34 DGCs has been validated by at least one practice, but most DGCs are validated by many more DG practices. All 34 DGCs are validated by a total 840 DG practices.

Table 3: DGCs validation results

DG Capabilities	# DG Subcapabilitie	validated in # Cases	discussed in # interviews	# DG practices
Establish Leadership	1	1	3	3
Establish & manage culture	4	3	13	15
Establish & manage awareness	4	4	10	15
Establish & manage Train	8	3	14	36
Establish & manage Communicate	13	7	23	44
Specify data value	19	6	24	53
Set goals & objectives	6	3	11	20
Make business case	1	1	3	3
Formulate data strategy	4	4	12	13
Align with the business	14	8	24	44
Establish roles & responsibilities	13	8	24	53
Establish policies, principles, procedures	11	7	31	51
Establish performance management	3	1	5	15
Establish Monitoring	1	1	3	4
Establish KPI's	1	1	3	2
Establish decision making authority	10	8	24	35
Establish data stewardship	5	3	13	28
Establish committees	1	1	3	4
Establish Auditing	7	4	18	23
Establish accountability	1	1	5	3
Manage risk	8	6	26	36
Manage processes + lifecycle	14	6	24	43
Manage organisation	7	3	11	23
Manage metadata	3	3	16	8
Manage issues	1	1	3	4
Manage data	20	5	19	74
Setup security & privacy	11	4	18	45
Setup IT	8	5	21	24
Setup DG tools	1	1	3	1
Organize people	9	3	11	23
Contract data sharing agreements	7	2	5	34
Align & integrate data	5	5	16	21
Comply with regulations	9	6	28	36
Establish environmental response	1	1	3	4
	231			840

Significantly, the majority of 26 out of 34 DGCs have been validated with sometimes many subcapabilities and even more DG practices. The much higher number of expert DG practices in column five #DG practices is caused by the number of three to five experts being interviewed per subcapability. And although not all experts recognized each subcapability in practice, each subcapability was validated (sometimes by many experts). The many different subcapabilities in column four #DG Subcapabilities are the result of the separately conducted literature reviews. However, nine DGCs were validated by only one relevant subcapability. Based on our overall research results, we conclude that all 34 DGCs found in literature are valid in practice. Furthermore, we did not identify any new DGCs, as the new DGCs suggested in interviews were already covered by the existing DGCs. This does not imply it can be used as a normative model that is fully applicable in all situations. Local context may impact this. But it can be used as a reference providing helpful suggestions for an individual organisation.

5 Discussions, Limitations & Conclusions

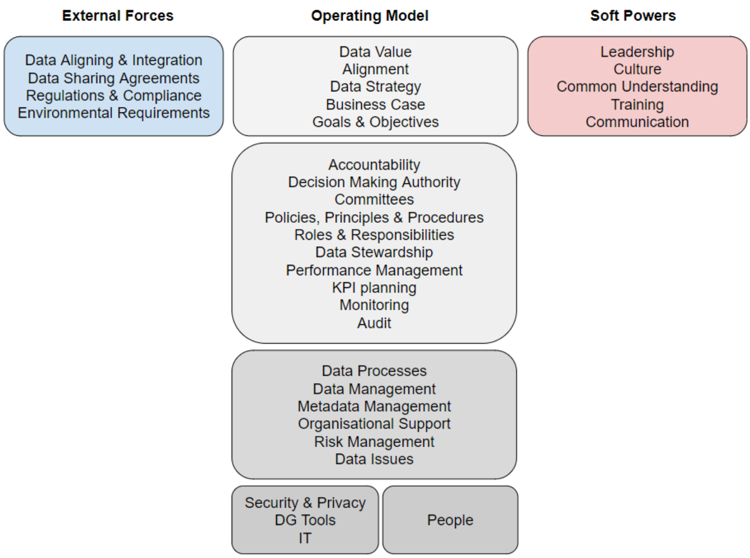
Our findings reveal the following remarkable outcomes, thereby adding new knowledge. First, the existence in the practice of large organisations of certain new DGCs which we predicted earlier based on our theoretical DGC model in Table 1 (J. R. Merkus et al., 2021). Moreover, the findings of this study align with the capability groups and clusters in that DGC model, and further validate several previously unknown capability groups such as Leadership, Culture, Communication, and Value Chain, with substantial evidence. Remarkably, none of the 17 substudies did identify any new DGCs in practice, confirming the comprehensiveness of our theoretical DGC model.

Second, the DGCs from previously unvalidated DGMMs present in literature have been subject to validation too. The results of our research have validated these DG capabilities with empirical evidence from practice. So, our research confirms the validity of the few existing, empirically unvalidated DGMMs in literature too.

Third, framing our research results against the DGC model from Table 1 results in the DGC T-model as reflected in Figure 1 *Data Governance Capabilities T-model* (J. R. Merkus et al., 2021). This model reflects the 34 DGC concepts which make up DG according to our findings. In addition, Figure 1 groups the DGC concepts in a T-shaped model according to the Generic Capabilities Reference model from our earlier research, and with a division of the DGCs into more strategic, tactical, and operational groups according to an organisational chart (J. Merkus et al., 2020; Mintzberg, 1980).

Given the limitations of our study, we have identified some shortcomings. Firstly, the internal validity of our research was improved through the use of case study methodology, and construct validity was strengthened through the scrupulous administration of the results from semi-structured questionnaires. However, each DGC was validated separately and the entire set of DGCS was not validated as a whole. And although the DGCs were selected using a reference model, the underlying concepts of each DGC are based on literature, and each DGC has been validated individually with practical evidence, the internal validity of the set of 34 DGCs as a whole could be improved in further research. Secondly, the external validity of the results could be enhanced, even though the DGCs have been validated in various organisations. Therefore, further research to validate the set of DGCs as a whole is necessary, with case studies as a suitable research strategy again.

Figure 1 Data Governance Capabilities T-model



In conclusion, we can deduce from the results of our study that all the known DGCs from literature have been validated in practice. Furthermore, no other DGCs were discovered during the empirical validation, which suggests that, although a claim for completeness can never be proven, at least the most relevant capabilities have been identified.

This set of DGCs can be used as a reference to construct a locally relevant measure or benchmark for DG e.g. a DGMM. The theoretical implication is that our research adds new knowledge with the empirically validated comprehensive set of 34 DGCs. Further research could focus on the empirical validation of this set of DGCs as a whole.

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Paragraphs were submitted to AI-based translators Grammerly, Deepl and ChatGTP for language improvement only. No content was added by the tools.

References

Abraham, R., Schneider, J., & Brocke, J. vom. (2019). Data Governance : A conceptual framework , structured review , and research agenda. International Journal of Information Management (IJIM), 49(December 2019), 424–438.

Alhassan, I., Sammon, D., & Daly, M. (2016). Data governance activities: an analysis of the literature. Journal of Decision Systems, 25(S1), 64–75.

Alhassan, I., Sammon, D., & Daly, M. (2018). Data governance activities: a comparison between scientific and practice-oriented literature. Journal of Enterprise Information Management, Vol 31(2), 300–316.

Alhassan, I., Sammon, D., & Daly, M. (2019). Critical Success Factors for Data Governance: A Theory Building Approach. Information Systems Management, 36(2), 98–110.

Bandara, W., van Looy, A., Merideth, J. C., & Meyers, L. (2020). Holistic Guidelines for Selecting and Adapting BPM Maturity Models (BPM MMs). In D. Fahland, C. Ghidini, J. Becker, & M. Dumas (Eds.), Business Process Management Forum: BPM Forum 2020 Proceedings (pp. 263–278). Springer.

Becker, J., Knackstedt, R., & Pöppelbuß, J. (2009). Developing Maturity Models for IT Management – A Procedure Model and its Application. Business & Information Systems Engineering, 1(3), 213–222.

Brennan, R., Attard, J., & Helfert, M. (2018). Management of data value chains, a value monitoring capability maturity model. ICEIS 2018 - Proceedings of the 20th International Conference on Enterprise Information Systems, 2(January), 573–584.

Dasgupta, A., Gill, A., & Hussain, F. (2019). A conceptual framework for data governance in IoT-enabled digital IS ecosystems. In Proceedings of the 8th International Conference on Data Science, Technology and Applications (DATA 2019), Data, 209–216.

Heredia-Vizcaíno, D., & Nieto, W. (2019). A Governing Framework for Data-Driven Small Organizations in Colombia. In Á. Rocha, H. Adeli, L. Reis, & S. Costanzo (Eds.), New Knowledge in Information Systems and Technologies. WorldCIST'19 2019. Advances in Intelligent Systems and Computing (Vol. 930, Issue 1, pp. 622–629). Springer.

Howard, M. S. (1994). Quality of Group Decision Support Systems: a comparison between GDSS and traditional group approaches for decision tasks. Technical University Eindhoven.

Jagals, M., Karger, E., & Ahlemann, F. (2021). Already grown-up or still in puberty? A bibliometric review of 16 years of data governance research. Corporate Ownership & Control, 19(1), 105–120.

Legner, C., Pentek, T., & Otto, B. (2020). Accumulating design knowledge with reference models: Insights from 12 years' research into data management. Journal of the Association for Information Systems, 21(3), 735–770.

Lis, D., & Otto, B. (2021). Towards a Taxonomy of Ecosystem Data Governance. In Proceedings of the 54th Hawaii International Conference on System Sciences (HICSS 2021), 6067–6076.

Merkus, J., Helms, R. W., & Kusters, R. J. (2019). Data Governance and Information Governance : Set of Definitions in Relation to Data and Information as Part of DIKW. ICEIS 2019 - Proceedings of the 21th International Conference on Enterprise Information Systems, 12.

Merkus, J. R., Helms, R. W., & Kusters, R. J. (2020). Reference Model For Generic Capabilities In Maturity Models. In Proceedings of the 2020 12th International Conference on Information Management and Engineering (ICIME 2020), 10–17.

Merkus, J. R., Helms, R. W., & Kusters, R. J. (2021). Data Governance Capabilities; Maturity Model design with Generic Capabilities Reference Model. In Proceedings of the 13th International Joint Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management (KMIS 2021), 102–109.

Mintzberg, H. (1980). Structure in 5's : A Synthesis of the Research on Organization Design. Management Science, 26(3), 322–341.

Munn, Z., Peters, M. D. J., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BMC Medical Research Methodology, 18(1), 1–7.

Olaitan, O., Herselman, M., & Wayi, N. (2019). A Data Governance Maturity Evaluation Model for government departments of the Eastern Cape province, South Africa. South African Journal of Information Management, 21(1), 1–12.

Otto, B., Wende, K., Schmidt, A., & Osl, P. (2007). Towards a Framework for Corporate Data Quality Management. In Proceedings of 18th Australasian Conference on Information Systems (ACIS 2007), Dec 2007, 916–926.

Paulk, M. C., Curtis, B., Chrissis, M. B., & Weber, C. V. (1993). wrong The capability maturity model for software. In Software Process Improvement.

Permana, R. I., & Suroso, J. S. (2018). Data Governance Maturity Assessment at PT. XYZ. Case Study: Data Management Division. In Proceedings of 2018 International Conference on Information Management and Technology (ICIMTech 2018), 15–20.

Rivera, S., Loarte, N., Raymundo, C., & Dominguez, F. (2017). Data Governance Maturity Model for Micro Financial Organizations in Peru. In Proceedings of the 19th International Conference on Enterprise Information Systems (ICEIS 2017), 203–214.

Rosemann, M., de Bruin, T., & Hueffner, T. (2004). A Model for Business Process Management Maturity. In Proceedings of 15th Australasian Conference on Information Systems (ACIS 2004), Paper 6, 1–7.

Spencer, D., & Warfel, T. (2004). Card sorting: a definitive guide. In Boxes and arrows (p. 2). http://www.iimagineservicedesign.com/wp-content/uploads/2015/07/Card-sorting-a-definitive-guide-«-Boxes-and-Arrows.pdf

van Looy, a., de Backer, M., & Poels, G. (2011). Questioning the Design of Business Process Maturity Models. In Proceedings of the 6th SIKS Conference on Enterprise Information Systems, 51–60.

van Looy, A., de Backer, M., & Poels, G. (2011). Defining business process maturity. A journey towards excellence. Total Quality Management and Business Excellence, 22(11), 1119–1137.

Weber, K., Cheong, L., Otto, B., & Chang, V. (2008). Organising Accountabilities for Data Quality Management-A Data Governance Case Study. Data Warehousing, 347–362.

THE ROLE OF DIGITALISATION IN CHANGING THE BUSINESS MODELS IN LOGISTICS: CASE OF ROPAX PORTS

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This article explores digitalisation's potential to change traditional business models in the context of RoPax (roll-on, roll-off passenger vessels) ports in four Northern European countries. The study examines digitalisation's role in addressing business model change drivers, focusing on the perspective of port authorities (PAs). While digitalisation slowly affects operations at RoPax ports and PAs' business models, the research data exhibits no radical business model innovation. Instead, the findings indicate that PAs introduce new digitalisation and business activities, potentially leading to business model renewal. However, the current digitalisation is inefficient, as technology providers lack an in-depth understanding of the port business and its ecosystem, and PAs have scarce knowledge of digitalisation's business impact. The article concludes that connecting digitalisation strongly to the business model and strategic renewal is the way to overcome this challenge.

Keywords:
port authority, business model, maritime, digitalisation

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1 Introduction

Sea logistics is known for being among the slowest to adopt digital technologies (Acciaro et al., 2018; Transport Intelligence, 2019) and relies heavily on old communication and data exchange methods. However, digitalisation is considered a disruptive driver in the industry due to the opportunities for optimising logistics and integrating actors involved in transportation chains (Tsvetkova et al., 2021). The potential benefits of aggregating and analysing data on maritime transportation are vast (Watson et al., 2021), and various digital solutions are being implemented or developed (Brümmerstedt et al., 2017; Tijan, Jović, Aksentijević, et al., 2021; Tsvetkova et al., 2021).

As critical links in sea logistics and other transport modes, ports can renew their business models through digitalisation, reducing shipping emissions (Haraldson et al., 2021) and improving supply chain efficiency. Ports have already been conceptualised as ecosystems (de Langen, 2021; Haraldson et al., 2021; Watson et al., 2021), and port authorities (PAs) are increasingly seen as ecosystem integrators or orchestrators (Caballini et al., 2009), making their critical role in leading digital transformation undisputable (von Malmborg, 2004). Passenger ports also have high public interest and are often public enterprises that local municipalities fully or partly own, making them an interesting public–private collaboration platform. They play a key role in transport digitalization and sustainable transitioning in maritime transportation (Damman & Steen, 2021; Del Giudice et al., 2021).

This article explores digitalisation's potential to change incumbent business models in a highly institutionalised, asset-heavy industry. Six RoPax (roll-on, roll-off passenger vessels) ports in four Northern European countries, handling both vehicle and passenger transportation, were interviewed on their digitalisation efforts and goals. Due to low regional transport intermodality, these ports can be seen as a continuation of road networks and can benefit from digitalisation differently than mega container ports, which have been extensively studied in light of digitalisation (Brümmerstedt et al., 2017; Port of Rotterdam, 2023).

The current study provides insight into the digitalisation process and business model innovation from PAs' perspective. Thus, our research question is, "How do incumbent firms in logistics use digitalisation in their business model innovation?"

To answer this, we explore the drivers for business model innovation in the chosen context and understand the general directions for business model change in RoPax ports. Then, we pinpoint digitalisation's role in addressing those drivers through business model innovation.

2 Literature Review

2.1 Digitalisation's Role in Changing Business Models

Business model innovation (BMI) has been defined as the designed, novel, and non-trivial changes to the key elements of a company's business model and architecture linking these elements (Foss & Saebi, 2017). The widespread diffusion of digital technologies has become one of the key drivers and enablers of BMI at the firm level (Holmström et al., 2019). Exploiting digital technologies through innovative business models has been distinguished from innovation in which new technologies are developed within the product innovation process (Caputo et al., 2021; Cozzolino et al., 2018). Furthermore, digitalisation grants opportunities for BMI beyond firm-level changes to cross multiple industries and ecosystems (Kamalaldin et al., 2021; Leminen et al., 2020; Sjödin et al., 2020).

The conceptual relationship between digitalisation and corresponding changes in business models has been extensively explored (Caputo et al., 2021); studies of digitalisation in different industrial contexts show that digitalisation and BMI is context-dependent (Benghozi & Salvador, 2015; Kamalaldin et al., 2021; Vendrell-Herrero et al., 2017). Caputo et al. (2021) note that the proliferation of new business models characterised by a high degree of digital innovation has concerned innovative and traditional sectors, which are not characterised by high degrees of technological investment. Furthermore, while BMI is often necessary to reap digitalisation's benefits, most incumbent firms across industries are ill-prepared to benefit from digital transformation (Parida et al., 2019).

Digitalisation in the maritime industry is considered slow (Acciaro et al., 2018; Transport Intelligence, 2019). Nevertheless, indications show that digitalisation in the maritime sector can change the relationships among the supply chain actors, restructure the ecosystems, and create an opportunity for new business models or changes in incumbent business models (Fruth & Teuteberg, 2017; Heikkilä et al., 2022; Tijan et al., 2021 a; Tsvetkova et al., 2021).

2.2 Business Model Innovation and Digitalisation in Ports

Ports are areas with maritime and hinterland access that have developed into logistics hubs (Van der Lugt & De Langen, 2007). Ports are managed by PAs, that often operate as landlords (World Bank, 2007). In most cases, a PA is a publicly owned company by a local municipality or state and manages and develops the port area, with income mainly based on land rent and port dues. Tenants in a port are often companies involved in port operations or logistics activities (Van der Lugt & De Langen, 2007). Thus, landlord PAs aim to balance between public (PA, municipality) and private (port industry) interests (World bank, 2007). Regulation and business environment alternations drive changes in ownership of PAs (Notteboom et al., 2022; Rönty et al., 2011), pressures come from numerous actors, such as NGOs; governments; municipalities (Verhoeven, 2010); and business partners and customers, such as logistic companies, cargo owners, and passengers (Notteboom et al., 2022, Chapter 4.1).

Furthermore, a PA's business model depends on numerous other factors, such as its traffic profile, typologies of cargo and passenger, location, existing facilities, and infrastructural conditions (Burns, 2014, p. 22; Paixão Casaca & Lyridis, 2022). Environmental, technological, geographical, and demographic changes also drive today PAs' business model evolution (Vonck et al., 2021). The mentioned factors influence a PA's strategic decision-making (Haraldson et al., 2021). Given such a changing landscape, the strategic responses are, for example, becoming full-fledged partners in the logistics chain, restricting a port's role to supporting activities or entirely disappearing from the scene (Heaver et al., 2010).

Digitalisation offers new opportunities for a PA's BMI. Scholars proved the importance of PAs' initiatives when it comes to digitalisation, considering different types of port governments models (Tijan, Jović, Panjako, et al., 2021). However, limited studies have addressed the relevance of digitalisation, the PA's business model, and ecosystem changes (Henríquez et al., 2022; Hirata et al., 2022). A major focus on port digitalisation has been set in mega and large container ports (Haezendonck & Langenus, 2019; Henríquez et al., 2022). Ports with other traffic profiles, such as RoPax ports, are scarcely reviewed. Compared to mega and large container ports, these ports are limited regarding resources and investments (Del Giudice et al., 2021; Inkinen et al., 2019; von Malmborg, 2004) and face challenges on understanding digitalisation's influence on strategic business development (Inkinen et al., 2019).

Thus, our study complements the current research agenda's gap and focus on digitalisation in RoPax ports.

3 Methodology

3.1 Research Design

The theoretical gap and emerging status of port digitalisation led researchers to adapt qualitative research with a multi-site case study approach (Creswell, 2007), where the RoPax port is considered a case studied in the diverse sites where these ports are located. A multi-site case study enables the understanding of a specific phenomenon that is merged into the context, adding to the phenomenon's complexity (Audet & d'Amboise, 2001; Gillham, 2000; Yin, 2018). Similarly, to a multiple case study, which enables comparison (Eisenhardt & Graebner, 2007; Gibbert et al., 2008; Gioia et al., 2013), the case is compared between sites with the possibility for cross-site generalisations. This comparison aims to enhance understanding digitalisation in relationship with business models in RoPax ports.

RoPax ports gained scarce research attention (see section 2.2), our ultimate research interests are commonalities in use of digitalisation. Our research logic takes an abductive approach, pursuing the iterative matching and simultaneous evolution between theories and empirical observations (Dubois & Gadde, 2002). By applying cross-site comparison (Creswell, 2007), this research approach enables identifying variations within the same case.

3.2 Selection of Sites

The study includes six RoPax ports in four Northern European countries. Each port offers regular liner traffic operated by at least two shipping lines to more than one international destination port. The ports and countries were chosen based on generic similarities such as a common trading area, ownership base, high share of short shipping services, business model and culture, and high level of national digital infrastructure readiness, integration, and adaption.

3.3 Data Collection and Analysis

The primary research data was collected with semi-structured interviews conducted with PAs, with an average duration of one hour. Secondary data served as foundation for drafting interview topics regarding business model transitions from a PA's perspective, which comprises press releases, publications, statistics, and strategic and project reports related to PAs' development. Drivers for business model, ecosystem, and activity changes were discussed during the interviews. For each selected port, one or more managerial-level representatives joined a discussion of selected topics. The interviews were recorded, transcribed, and documented. Table 1 presents the case ports' characteristics.

Table 1: Ports' Characteristics

PA	Traffic profile	Interviewees' roles	Data format
Alpha	Cargo + Passenger	Port Development Strategist	Interview
Beta	Cargo + Passenger	Technical Director Operation Manager IT Specialist	Workshop and interview
Gamma	Cargo + Passenger	Head of Business Development	Interview
Delta	Cargo+ Passenger	Development Manager	Interview
Epsilon	Passenger-dominated	Business Development	Interview
Zeta	Cargo + Passenger	Chief Operations Officer	Interview

Data analysis followed the deductive category application and further inductive category development (Mayring, 2004), which can be labelled a directed approach to content analysis aimed to support or extend the theory (Hsieh & Shannon, 2005). The labels were later compared to existing theories regarding BMI, digitalisation, and literature related to port business models. The abductive iteration involves identifying mismatched empirical-theoretical concepts, which were further studied by aligning with other theoretical explanations.

Three researchers independently analysed the interview transcripts and secondary data to attain reliable categorisation and identified content pertinent to one of the topics defined in the analysis framework. All researchers then compared notes and agreed on the categories within each topic by merging some of them and revisiting the original texts in case of dissimilarities in identified drivers or enablers for BMI.

4 Findings

4.1 Drivers for Business Model Change in RoPax Ports

Over the recent decades, combining short-sea passenger and cargo transportation has become an established and common transport concept (Marcadon, 1998). RoPax vessel design is based on roll-on and roll-off features, enabling efficient loading and unloading of wheeled commercial vehicles (trucks, trailers) and passenger cars and the capability to accommodate passengers. The case ports have short vessel turnaround times, low cargo standardisation, and are further challenged by additional services passenger transportation.

The analysis of the interviews indicates that managing and combining the flows and services of cargo and passengers leads to several specific challenges, all leading to digitalisation opportunities. On the passenger side, typical challenges are related, for instance, to non-integrated information on transport connections and services as well as crowding and queuing in the passenger terminal. Conversely, the multimodal transport chain is hampered by uncoordinated road traffic pulses and congestion at ship arrivals and departures inside the port, associated urban area, and its main approach roads. This problem is less likely to diminish with expanding residential and recreational urban areas and the associated shrinkage of the port areas. Furthermore, the vessels are likely to grow in cargo capacity, further worsening the overcrowding of the road network, while traffic jams give rise to idling and unnecessary emissions (Wahlström et al., 2022).

Further, passenger transportation forms a vital revenue source for the shipping company and the PA. Several PAs mentioned the detrimental effects of trade shocks, such as the one caused by the COVID-19 pandemic, taking passenger transportation to a total standstill, impacting shipping services availability and, in most cases, dramatic plunges in PAs' revenues with potentially long-term consequences and challenges to retain the main customers' regular fleet capacity.

4.2 Changes in the Business Models of RoPax Ports

Traditionally, RoPax ports' principal customer base comprises shipping lines and port operators. Other relevant actors encompass various authorities and land-based passenger and cargo transporting companies.

Meanwhile, passengers and road haulage companies are shipping lines' main customers. A RoPax PA's primary income derives from vessel, passenger, and cargo fees and the rental income of facilities. Conversely, the main expenditures typically include human resources costs and land leases paid to the municipality. A RoPax PA's value proposition is providing required infrastructure, facilities, and quay-side vessel services, enabling safe, efficient, and timely port calls and smooth cargo and passenger flows.

A PA's strategic renewal is largely driven by the drivers mentioned in 4.1, and manifested in changes in their business models to a varied degree. Following our inductive approach, we identified several recurring topics. The changes in the RoPax PAs' business models (see Table 2) are common for two or more studied ports and concern changes in value-creating activities, earning logic, revenue streams, and key partnerships, using resources for value creation.

As presented in the table, the most radical change concerns the ***business expansion*** and ***further integration in logistics and supply chain***. With the construction of new passenger terminals, several PAs are taking over the ownership of passenger terminals. Combined with the increasing perception of passengers as PA's customers, the ownership transition of the terminal premises brings many changes to the business models, such as new value propositions for passengers and new activities to ensure customer satisfaction. In addition, PAs are also searching for new values for existing facilities, such as using terminal buildings as a venue outside of traditional port operation use.

Table 2: Changes in PAs' Business Models

		Alpha	Beta	Gamma	Delta	Epsilon	Zeta
Business expansion	New values of port facilities		x	x		x	
	New offerings for passengers		x	x	x		
	Ownership and operation of passenger terminals		x			x	
Integration in logistics and supply chain	Enhanced communicatio n	x	x	x	x		
	Enabler of digitalisation by other port actors		x	x			
Environmental impact reduction	Green incentives for port users	x	x			x	x
	Alternative fuel infrastructure	x			x	x	x
Efficiency improvement	Cargo and passenger flows separation					x	x
	Increased facility utilisation rate	x	x	x	x	x	x
Social responsibility	Decreased human work		x		x		
	Expanding safety and security measures		x		x		

Further integration with other actors enables optimised supply and logistics chains. This entails enhanced communication of port activities and service offering for diverse logistics actors. It is worth highlighting that PAs could also become enablers and integrators of logistics chains digitalisation, as mentioned by several interviewees. Because ports are critical transport hubs that could affect the overall logistics performance.

Increased integration with other logistics actors is also crucial for ***reducing shipping's environmental impact***. There was a discussion with PA Alpha that a port's emission mitigation scope should be extended to achieve overall logistics emission reduction. Several PAs have implemented or plan to implement green incentives for its customers, such as pricing models and rebates based on the visiting vessel's environmental performance. Green corridors are considered another important initiative for shipping emission reduction; PAs play a key role in establishing those. In this vein, several PAs are planning to develop alternative fuel infrastructure.

PAs focus on **efficiency improvement** to retain competitive, enhance and maximise the utilisation rate of port infrastructure and assets, including facilities, warehouses, quays etc. Thus, automating various processes is high on the agenda. Many RoPax ports, located close to city centres, face increasing threat of space limitations, and hence a potential solution would be to geographically separate and relocate potential non-wheeled cargo from RoPax associated passenger and cargo services. Automation in operations rationalises and increases the efficiency, safety and security of various manual activities and processes, hence optimising, the workers' work conditions and safety.as part of PA's ***social responsibility***.

4.3 Digitalisation Efforts at RoPax Ports

We see different efforts and digital tools applied in ports. Our analysis indicates that PAs who have or are about to establish their digitalisation strategies or roadmaps are actively contributing to the understanding of how digitalisation could support their business activities, enabling the avoidance of a "digitalised mess", as one of the interviewees mentioned, and prioritising various ongoing and upcoming digitalisation projects.
In general, we recognised four distinct strategic areas where digitalisation was implemented or planned in the RoPax ports:

1. **Infrastructure management**: This is the traditional focus of landlord PAs. Apart from regular maintenance work, the PAs growingly face the pressure of adjusting and upgrading infrastructure in response to growing trade volumes and vessel capacities. The case PAs had developed digital solutions to help monitor and manage security in the ports. Furthermore, they

increasingly utilise port infrastructure data to improve maintenance and facility services. PAs also showed interest in developing digital twins of the port infrastructure.

2. **Traffic fluency:** Space limitation and co-existence with expanding port cities is a growing concern, driving PAs to search for automated and digitalised solutions, ensuring smooth passenger and cargo flows, efficient operations, and timely port calls. The digitalisation degree of the case PAs varied markedly. However, digitalising logistics and supply chains has increasingly pressured PAs to adopt new technologies, such as automated check-in for passengers and vehicles.
3. **Green transition:** Today, the environmental regulation of the shipping industry together with national climate goals constitutes one of the key development areas in RoPax ports. PAs have progressively shifted to electrified equipment and machinery, greener fuels, and more energy-saving infrastructure to reduce the environmental impact. Berthing vessels have been the leading emitter of carbon dioxide and other air pollutants. Hence, installing and investing in automooring and an onshore power supply have occurred in most of the interviewed ports.
4. **Data sharing between port-operation-related organisations:** PAs are introducing new digital solutions to strengthen communication, electronic trade documents sharing, customs clearance, and integration with other supply chain actors. More ambitious solutions that span across entire supply chains were mentioned, however less often. These solutions aim at improved efficiency and sustainability, amongst others.

The above digitalisation areas are summarized in Table 3.

Table 3: Major Digitalisation Areas

	Alpha	Beta	Gamma	Delta	Epsilon	Zeta
1) Improved infrastructure management						
Security monitoring and management	x	x	x	x	x	x
Digitising infrastructure data	x		x		x	
Infrastructure use management			x			
2) Enhanced traffic fluency						
Automated check-in (passengers)	x	x	x	x	x	x
Automated check-in (vehicles)		x	x			x
Intelligent traffic management	x		x	x		
Digital buoys/fairways	x					
Autonomous vehicles	x					
3) Green transition						
Monitoring emissions and air quality		x	x			
Monitoring and optimising energy use	x		x	x		
Automooring	x	x	x	x		
4) Data sharing between port-operation-related organisations						
Communication and procedures among port actors	x	x	x	x	x	x
Intelligent supply chain			x			

5 Discussion

The findings affirm that digitalisation gradually affects RoPax port's operations and business models. At the beginning of the study, we expected digitalisation to drive PAs to innovate their business models. However, the data illustrated that PAs are introducing new digitalisation and business activities, potentially leading to business model renewal. However, no radical business model innovations were identified. For instance, PA's value proposition remains the same, as most of the case ports would remain landlord ports (World Bank, 2007) also in future. Thus, the discussion focuses on drivers for business model changes and how digitalisation supports these changes rather than business model innovations.

Although some PAs implemented strategies or roadmaps for enabling the creation of a more holistic view of digitalisation. The current digitalisation is fragmented and may cause a "digitalised mess" (see section 4.3). If PAs digitalise without contextualising strategically, the actual digitalisation benefit would be limited. For example, many solutions mentioned in section 4.3 are short-term project outcomes that are not part of a PA's strategic plan.

Conversely, PAs may have limited knowledge of how digitalisation may impact and improve their efficiency and business performance, potentially prolonging the decision-making process. For instance, several PAs mentioned the inability to comprehend the true advantages that solutions such as a digital twin would bring, especially as the development and implementation are perceived to require significant resources, whilst the application's benefits may remain undisclosed.

This situation echoes previous studies on the maritime transport sector that emphasise there is a "*lack of awareness of how digital transformation may affect the business*" (Tijan, Jović, Aksentijević, et al., 2021). As the interview analysis shows, for overcoming this challenge, job positions and responsibilities are established for developing digitalisation roadmaps and embedding digitalisation in strategic planning based on individual business development needs. We could observe that connecting digitalisation with business development needs could contribute for PA's strategic business model renewal, such as acquiring relevant knowledge or planning digitalisation in a long-term context.

Despite the "digitised mess" (see Section 4.3), digitalisation enables and drives several prominent business model changes for the case PAs, namely, supporting the formation of green logistic chains or becoming a digital infrastructure owner.

Besides the more 'physical' (as opposed to digital) activities, such as developing alternative fuel infrastructure, ports provide awareness of emissions and pollution from port operations through monitoring solutions and communication with other logistic actors. Improving passenger and cargo flow efficiency through avoiding unnecessary idling, could also reduce emissions. PAs naturally achieve further integration with other actors alongside the logistic chain.
Digitalisation aids this goal in several ways. Firstly, PA could facilitate digitalising documentation and information sharing between organisations. Secondly, several optimisation solutions, such as automated check-in and flow of passengers and vehicles and intelligent traffic management, support PAs in affecting the activities beyond a RoPax terminal to enhance port operations efficiency.

PAs could also be a central digital infrastructure provider for other organisations to improve port operations performance. In line with Hollen et al. (2015), we argue that RoPax ports seemingly explore complementary roles and activities in pursuing creating strategic value as landlord ports, i.e., the value for critical actors. Digitalisation integrates interorganisational logistic activities, increases traffic flow transparency, and trace emissions – the information basis for decision-making by PAs and other logistics actors. Digital solutions like autonomous roads and intelligent supply chains also contribute to expanding the role of ports in the hinterland of logistics chains (Gonzalez Aregall et al., 2018).

In Table 4, we present the digital solutions implemented or planned to be implemented in studied RoPax ports. We also analysed digital solutions' contribution (see section 4.3) to the business model changes discussed in section 4.2. Not surprisingly, PAs predominantly invest in digital solutions that allow to increase operation efficiency. These solutions mainly concern automation in the pursuit reduction of port operations' time and costs, but also to decrease human work, thereby also addressing the changes related to social sustainability.

6 Conclusion

We contribute to the literature on the business models of ports by explicating digitalisation's role in aiding changes in the business models of RoPax ports. We also contribute empirically with an account of digitalisation efforts in RoPax ports, which are less studied in the literature on digitalisation in ports and sea logistics.

The study has several limitations. First, it focuses on a limited geographic context of Northern Europe. Further, although the change in business models is studied by discussing the current business models of ports and foreseeing changes in their business model, a more longitudinal study would be beneficial to uncover the business model evolution in this context.

Table 4: Types of Digital Solutions Planned and Implemented by RoPax PAs and Main Digitalisation Areas

Digitalisation areas	*Digital solutions*	*Contribution to business model change*				
		Business expansion	Integrat-ion in logistics chains	Environm-ental impact reduction	Efficiency improvem-ent	Social sustainabi-lity
Improved infrastructure management	Security monitoring and management				x	x
	Digitising port infrastructure data					
	Infrastructure use management				x	
Enhanced traffic fluency	Automated check-in for passengers and vehicles				x	
	Intelligent traffic management				x	
	Digital buoys/ fairways		x		x	
	Autonomous vehicles		x		x	
Green transition	Monitoring emissions and air quality			x		x
	Monitoring and optimising energy use			x		
	Automooring				x	x
Data sharing between port-operation-related organisations	Communica-tion and procedures among port actors		x		x	
	Intelligent supply chain		x	x	x	

References

Acciaro, M., Ferrari, C., Lam, J. S. L., Macario, R., Roumboutsos, A., Sys, C., Tei, A., & Vanelslander, T. (2018). Are the innovation processes in seaport terminal operations successful? 787–802.

Audet, J., & d'Amboise, G. (2001). The Multi-Site Study: An Innovative Research Methodology. The Qualitative Report, 6(2), 1–18.

Benghozi, P. J., & Salvador, E. (2015). How and where the R&D takes place in creative industries? Digital investment strategies of the book publishing sector*, 28(5), 568–582.

Brümmerstedt, K., Fiedler, R., Flitsch, V., Jahn, C., Roreger, H., Sarpong, B., Saxe, S., & Scharfenberg, B. (2017). Digitalization of Seaports - Visions of the Future (C. Jahn, S. Saxe, & Fraunhofer CML, Eds.; p. 168). Fraunhofer Verlag.

Burns, M. G. (2014). Port management and operations. CRC Press.

Caballini, C., Carpaneto, L., & Parola, F. (2009). Italian port authorities approaching the post-reform: The Ligurian Case (pp. 191–207).

Caputo, A., Pizzi, S., Pellegrini, M. M., & Dabić, M. (2021). Digitalization and business models: Where are we going? A science map of the field. Journal of Business Research, 123, 489–501.

Cozzolino, A., Verona, G., & Rothaermel, F. T. (2018). Unpacking the Disruption Process: New Technology, Business Models, and Incumbent Adaptation. Journal of Management Studies, 55(7).

Creswell, J. W. (2007). Qualitative inquiry and research design: Choosing among five approaches, 2nd ed. Sage Publications, Inc.

Damman, S., & Steen, M. (2021). A socio-technical perspective on the scope for ports to enable energy transition. Transportation Research Part D: Transport and Environment, 91, 102691.

de Langen, P. W. (2021). Seaports as Clusters of Economic Activities. In International Encyclopedia of Transportation (pp. 310–315). Elsevier.

del Giudice, M., di Vaio, A., Hassan, R., & Palladino, R. (2021). Digitalization and new technologies for sustainable business models at the ship–port interface: a bibliometric analysis. 49(3), 410–446.

Dubois, A., & Gadde, L. E. (2002). Systematic combining: An abductive approach to case research. Journal of Business Research, 55(7), 553–560.

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. Academy of Management Journal, 50(1), 25–32.

Foss, N. J., & Saebi, T. (2017). Fifteen Years of Research on Business Model Innovation: How Far Have We Come, and Where Should We Go? Journal of Management, 43(1).

Fruth, M., & Teuteberg, F. (2017). Digitization in maritime logistics—What is there and what is missing? Cogent Business and Management, 4(1).

Gibbert, M., Ruigrok, W., & Wicki, B. (2008). What passes as a rigorous case study? Strategic Management Journal, 29(13), 1465–1474.

Gillham, B. (2000). Case study research methods. Bloomsbury Publishing.

Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2013). Seeking Qualitative Rigor in Inductive Research: Notes on the Gioia Methodology. Organizational Research Methods, 16(1), 15–31.

Gonzalez Aregall, M., Bergqvist, R., & Monios, J. (2018). A global review of the hinterland dimension of green port strategies. Transportation Research Part D: Transport and Environment, 59, 23–34.

Haezendonck, E., & Langenus, M. (2019). Integrated ports clusters and competitive advantage in an extended resource pool for the Antwerp Seaport. Maritime Policy and Management, 46(1), 74–91.

Haraldson, S., Lind, M., Breitenbach, S., Croston, J. C., Karlsson, M., & Hirt, G. (2021). The Port as a Set of Socio-technical Systems: A Multi-organisational View. In Maritime Informatics (pp. 47–63).

Heaver, T., Meersman, H., Moglia, F., & van de Voorde, E. (2010). Do mergers and alliances influence European shipping and port competition? 363–373.

Heikkilä, M., Saarni, J., & Saurama, A. (2022). Innovation in Smart Ports: Future Directions of Digitalization in Container Ports. Journal of Marine Science and Engineering, 10(12).

Henríquez, R., Martínez de Osés, F. X., & Martínez Marín, J. E. (2022). Technological drivers of seaports' business model innovation: An exploratory case study on the port of Barcelona. Research in Transportation Business & Management, 43, 100803.

Hirata, E., Watanabe, D., & Lambrou, M. (2022). Shipping Digitalization and Automation for the Smart Port. Supply Chain - Recent Advances and New Perspectives in the Industry 4.0 Era [Working Title].

Hollen, R. M. A., van den Bosch, F. A. J., & Volberda, H. W. (2015). Strategic levers of port authorities for industrial ecosystem development. Maritime Economics and Logistics, 17(1), 79–96.

Holmström, J., Holweg, M., Lawson, B., Pil, F. K., & Wagner, S. M. (2019). The digitalization of operations and supply chain management: Theoretical and methodological implications. Journal of Operations Management, 65(8), 728–734.

Hsieh, H. F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. Qualitative Health Research, 15(9), 1277–1288.

Inkinen, T., Helminen, R., & Saarikoski, J. (2019). Port digitalization with open data: Challenges, opportunities, and integrations. Journal of Open Innovation: Technology, Market, and Complexity, 5(2).

Kamalaldin, A., Sjödin, D., Hullova, D., & Parida, V. (2021). Configuring ecosystem strategies for digitally enabled process innovation: A framework for equipment suppliers in the process industries. Technovation, 105, 102250.

Leminen, S., Rajahonka, M., Wendelin, R., & Westerlund, M. (2020). Industrial internet of things business models in the machine-to-machine context. Industrial Marketing Management, 84, 298–311.

Marcadon, J. (1998). L'évolution récente de l'activité maritime et portuaire dans les pays de la Baltique (Recent evolution of the maritime and port activity in the Baltic states). Bulletin de l'Association de Géographes Français, 75(4), 428–436.

Mayring, P. (2004). Qualitative content analysis. A Companion to Qualitative Research, 1(2), 159–176.

Notteboom, T., Pallis, A., & Rodrigue, J.-P. (2022). Port Economics, Management and Policy. In Port Economics, Management and Policy. Routledge.

Paixão Casaca, A. C., & Lyridis, D. v. (2022). Guest Editorial: Port Business and Green Innovation. Maritime Business Review, 7(1), 2–4.

Parida, V., Sjödin, D., & Reim, W. (2019). Reviewing literature on digitalization, business model innovation, and sustainable industry: Past achievements and future promises. In Sustainability (Switzerland) (Vol. 11, Issue 2). MDPI.

Port of Rotterdam. (2023, Feb 12). Smart shipping process. https://www.portofrotterdam.com/en/to-do-port/futureland/smart-shipping-process

Rönty, J., Nokkala, M., & Finnilä, K. (2011). Port ownership and governance models in Finland Development needs & future challenges. In VTT Technical Research Centre of Finland.

Sjödin, D., Parida, V., Jovanovic, M., & Visnjic, I. (2020). Value creation and value capture alignment in business model innovation: A process view on outcome‐based business models. Journal of Product Innovation Management, 37(2), 158‐183.

Tijan, E., Jović, M., Aksentijević, S., & Pucihar, A. (2021). Digital transformation in the maritime transport sector. Technological Forecasting and Social Change, 170, 120879.

Tijan, E., Jović, M., Panjako, A., & Žgaljić, D. (2021). The Role of Port Authority in Port Governance and Port Community System Implementation. Sustainability 2021, Vol. 13, Page 2795, 13(5), 2795.

Transport Intelligence. (2019). Global Freight Forwarding 2019.

Tsvetkova, A., Gustafsson, M., & Wikström, K. (2021). Digitalizing maritime transport: digital innovation as a catalyzer of sustainable transformation. A Modern Guide to the Digitalization of Infrastructure, 123–148.

van der Lugt, L., & de Langen, P. W. (2007). Port authority strategy: beyond the landlord–a conceptual approach. Proceedings of the 2007 IAME Conference.

Vendrell-Herrero, F., Myrthianos, V., Parry, G., & Bustinza, O. F. (2017). Digital dark matter within product service systems. Competitiveness Review, 27(1), 62–79.

Verhoeven, P. (2010). A review of port authority functions: towards a renaissance? 37(3), 247–270.

von Malmborg, F. (2004). Networking for knowledge transfer: Towards an understanding of local authority roles in regional industrial ecosystem management.

Vonck, I., Camphuijsen, R., & Jongejan, J. (2021). Europe's ports at the crossroads of transitions A Deloitte and ESPO Study.

Wahlström, I., Hellström, M., Tsvetkova, A., & Chen, Y. (2022). Greening Ferry Ports by Truck Flow Optimisation. Baltic Transport Journal.

Watson, R. T., Lind, M., Liesa, F., & Delmeire, N. (2021). Shipping: A Self-Organising Ecosystem. In Maritime Informatics (Issue 2020, pp. 13–32).

World Bank. (2007). Port Reform Tool Kit.

Yin, R. K. (2018). Case study research and applications: design and methods (Sixth edit). Sage.

THE DATA ANALYTIC CAPABILITY WHEEL: AN IMPLEMENTATION FRAMEWORK FOR DIGITALIZATION

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For mature organizations to engage in digital transformation, they first must engage in digitization and digitalization. Digitalization requires the organizations to possess data analytic capability: the ability to transform data into useful insights in a way that creates or maintains competitive advantage. The purpose of this study was to formulate a practical framework for the implementation of digitalization. For this, a qualitative approach was used. Relevant aspects of data analytic capability were identified, based on a review of the literature supplemented with semi-structured interviews with organizations currently implementing digitalization. With these findings a preliminary implementation framework entitled the "Data Analytic Capability Wheel" was formulated. The aspects encompassed by this framework included data quality, data analytics, IT infrastructure, processes, employee knowledge and skills, and management. Future research should refine and validate this framework and examine whether it leads to the successful implementation of DAC in organizations.

Keywords:
digitalization, data, analytic capability, change management, data, implementation

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1 Introduction

In an increasing complex and globalized world, digital transformation has been recognized as an important avenue for organizations to create or at least maintain competitive advantage (Hess et al., 2016). Digital transformation has been linked to improved firm performance (Popovič et al., 2018), through increased organizational agility (Ghasemaghaei et al., 2017; Gong & Ribiere, 2023). Digital transformation is defined as "*a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies*" (Vial, 2019, p. 121), where entity refers to organizations, industries, or more generally, society.

Two related phenomena are confounded with digital transformation, namely digitization and digitalization, but for the purpose of this study they will be disentangled following Machado et al.'s (2019). Digitization is defined as "*the technical process of converting analog signals into a digital form, and ultimately into binary digits*" (Legner et al., 2017, p. 301). Digitalization is defined as "*the use of the technologies and data to improve and transform the business processes*" while digital transformation is broader, "*encompassing changes in the business models, activities, processes, and competences to enable to have all benefits of the full deployment of the new technologies*" (Machado et al., 2019, p. 1114). The scope of the present study is on the process of digitalization.

Organizations benefit from digitalization in two ways: (1) by increasing their internal efficiency (e.g. through more efficient product development and/or more efficient manufacturing) and (2) by adding value for customers and other stakeholders (e.g. through more sophisticated products and services) (Björkdahl, 2020). To achieve these outcomes, organizations need to develop their Data Analytic Capability (DAC), that is the ability to turn data into actionable insights by orchestrating data assets, IT infrastructure, and human talent in such a way that they create competitive advantage (Garmaki et al., 2016; Mikalef et al., 2018).

A variety maturity models have been developed to support organizations pursuing the development of DAC, digitization and/or digital transformation (Cosic et al., 2012; E. Gökalp & Martinez, 2021; Hein-Pensel et al., 2023; Korsten et al., 2022) from the perspective of diverse disciplines. From the Information Systems (IS) perspective, several models have been developed that stem from the Capability

Maturity Model (CMM), and include the Business Analytics CMM (BACMM) (Cosic et al., 2012), the Data Science CMM (DSCMM) (M. O. Gökalp et al., 2022), the Advanced Data Analytics CMM (ADACMM) (Korsten et al., 2022) and the Advanced Analytics CMM (Social Security Administration Analytics Center of Excellence, 2020). Other maturity models developed include those of Comuzzi and Patel (2016), and Grossman (2018). In the discipline of operations management, maturity models have been developed for digitalization and digital transformation (E. Gökalp & Martinez, 2022) and industry 4.0 (Ganzarain & Errasti, 2016; Mittal et al., 2018). These maturity models encompass a variety of aspects required for the organization to develop, including organization, infrastructure, data management, analytics, and governance (Comuzzi & Patel, 2016).

These maturity models have one to three complementary purposes, namely describing the current situation, prescribing guidelines for development, and enabling organizations to benchmark their development internally and externally (Hein-Pensel et al., 2023; Pöppelbuß & Röglinger, 2011). However, a common criticism of maturity models include the lack theoretical and empirical grounding of these models, having mostly been developed by consultants and software vendors (Comuzzi & Patel, 2016; Gupta & George, 2016; Mikalef et al., 2019) and their lack of actionability for organizations due to their descriptive/ comparative nature in combination with their complexity (Barton & Court, 2012; Hein-Pensel et al., 2023). Furthermore, the majority of maturity models examined do not consider all the aspects needed to develop capabilities related to digitalization (Hein-Pensel et al., 2023).

Existing research frequently takes an information technology (IT) perspective and focuses on issues of data quality, IT infrastructure and systems (Mikalef et al., 2017). Yet, a successful development of DAC is much more complex, involving factors such as people's knowledge and skills, processes, and organizational change (Ghasemaghaei et al., 2018; Mikalef et al., 2018). Studies that have embraced a more holistic view have also recognized the importance of organizational context (Mikalef & Krogstie, 2020). Thus, much remains unexplored about how organizations can develop their DAC, given their organizational context.

The purpose of this study was to formulate a practical framework for the implementation of digitalization, taking a multi-disciplinary approach and focusing on how organizations can "*configure, orchestrate and exploit competencies, assets, and data generated from digital technologies*" (Björkdahl, 2020). As many models are perceived to be too complex (Hein-Pensel et al., 2023), the point of departure for this framework was that it needed to be relatable for practitioners. A multi-disciplinary review of the literature was used to identify relevant aspects of DAC and formulate a preliminary framework (section 2). The qualitative research approach to collecting empirical data is presented in section 3 and the findings thereof in section 4. These led to the refinement of the preliminary framework and the formulation of an implementation framework: the Data Analytic Capability Wheel presented in section 5, followed by the discussion. Limitations and recommendations for future research are detailed in section 7.

2 Review of the Literature

Digitalization is a widely used term, both in academic and professional publications, leading to ambiguity (Bloomberg, 2018). For the purpose of this study, digitalization denotes an organizations' ability to improve its processes through the use of data and/or related technologies. However, this definition only reduces the ambiguity slightly, as digitalization has been defined and operationalized differently across disciplines. The present study therefore reviews literature from several disciplines, including management, manufacturing, supply chain, and business information systems to identify relevant aspects for the implementation of digitalization.

2.1 Digitalization, Data Analytic Capability, and Industry 4.0

In the context of manufacturing, digitalization has led to the concept of Industry 4.0 or Smart Industry (Rosin et al., 2020) and "*represents the current trend of automation technologies in the manufacturing industry*" (Shahin et al., 2020, p. 2928). From this perspective, digitalization is primarily concerned with improving the efficiency of processes, by improving cost, quality, lead time and flexibility (Khanchanapong et al., 2014). In the context of supply chain management, digitalization has led to the concepts of DAC and Big Data Analytic Capability (BDAC). DAC refers to an organization's capability to deploy data, technology and people to quickly access and analyze information to support complex decision-making (Yu et al., 2021) with some authors scoping this definition to big data (Dubey et al., 2019). While there are merits to distinguishing between the two, technological developments in this area are very rapid. Due to technological developments, what was considered big data and thus challenging to deal with in the past may no longer be considered challenging a few years later, thus broadening the applicability of DAC (Kokkinou et al., 2022a).

While digitalization, Industry 4.0, and DAC are related concepts, Industry 4.0 focuses more on the application of the technologies associated with digitalization (IoT, robotics etc.) whereas DAC encompasses the pre-requisites thereof (Garmaki et al., 2016; Mikalef et al., 2018). Furthermore, the concept of DAC is more comprehensively defined and is coupled with a sounder theoretical foundation. Therefore, the remainder of this paper will focus on DAC.

2.2 Theoretical Foundations

DAC has strong theoretical foundations in the contingent Resource-Based View of the firm (RBV) (Brandon-Jones et al., 2014; Mikalef & Krogstie, 2020; Wu et al., 2006; Yu et al., 2018). According to RBV, organization's resources can be a source of sustained competitive advantage if they are valuable, rare, cannot be imitated or substituted (Barney, 1991). However, according to the contingent perspective, the potential of capabilities to lead to competitive advantage will depend on their alignment with contextual factors such as national context and culture, firm size, strategic context, and other organizational context variables (Aragón-Correa & Sharma, 2003). Thus DAC can only become a source of competitive advantage for an organization if the organization is able to configure, orchestrate and exploit the tangible, intangible, and human aspects necessary in a way that fits its unique context (Björkdahl, 2020; Ghasemaghaei et al., 2018; Mikalef & Krogstie, 2020).

2.3 Data Analytic Capability Development

The topic of how DAC should be developed has been investigated from a variety of perspectives, including industry drivers and barriers, organizational enablers, organizational readiness, and organizational maturity (Nayernia et al., 2022). On an organizational level, which is the scope of our study, several ways exist to classify the aspects that make up DAC. Gupta and George (2016) distinguished between tangible, intangible, and human resources, where tangible resources included data, technology, basic resources such as time and investment. Intangible resources included a data-driven culture and the intensity of organizational learning, and human resources included managerial skills and technical skills. Mikalef et al. (2017, 2018) further elaborated on this classification. Their review of resources needed to build DAC formed the basis of the list of relevant aspects shown in Table 1.

Table 1: Relevant aspects for DAC implementation

Data	*Access to relevant data:* Organizations need to be able to identify, access, and if necessary, acquire relevant data (Behl et al., 2019) *Data Quality :* Data needs to be complete, accurate, timely, reliable and of value (Mikalef et al., 2017, 2018). *Data Governance*: Organizations need to put in place procedures to ensure that can create, capture, store, use, retrieve and delete data (Mikalef & Krogstie, 2018; Tallon, 2013) also referred to as *Data Management* (Jha et al., 2020) *Inductive vs. Deductive Approaches:* inductive approaches to data can result in insights that are new to the organization but require large investments in data and the ability to analyze it. Conversely, a deductive approach where data are collected, processed, and visualized for specific purposes can be more effective yet lead to tunnel vision (Günther et al., 2017)
Data Analytics	*Data Analytic Tools* are typically classified in descriptive, predictive and prescriptive tools (Ghasemaghaei et al., 2017) *Tool sophistication:* more sophisticated analytical tools (e.g. machine learning and artificial intelligence) enable organizations to conduct deeper analysis (Ghasemaghaei et al., 2018)
Technology	*IT Infrastructure:* Organizations need to have at their disposal an infrastructure that can collect, analyze, store and share data (Gupta & George, 2016; Mikalef et al., 2018). *Technical support from vendor:* organizations still rely on technology providers to support them (Behl et al., 2019)
Structure and Processes	*Centralized or Decentralized Structure:* Centralization seems to facilitate the development of DAC by pooling scarce resources whereas decentralization improved collaboration between domain experts and data scientists (Günther et al., 2017)
Organizational Learning	*Organizational learning* refers to the degree to which employees are open to extending their knowledge in the face of new emerging technologies. *Training and development of employees* is an important mechanism for organizational learning (Behl et al., 2019; Kokkinou et al., 2021)

Management	*Commitment and Support:* managers need to have a long-term orientation to investments and provide resources to data analytic teams (Tabesh et al., 2019) also referred to as *Attitude of top management* (Behl et al., 2019) *Effective communication and coordination:* managers should encourage cross-functional collaboration, disseminate data-driven insights, and create a common understanding of big data goals (Tabesh et al., 2019) *Gaining managerial analytics acumen:* managers need to gain relevant analytics knowledge and help and incentive their staff (Tabesh et al., 2019; Vidgen et al., 2017)
Employee Knowledge and Skills	*Domain knowledge:* employees need a deep understanding of the procedures, facts, and processes of the organization in order to be able to solve business problems of interest to the firm (Ghasemaghaei et al., 2018) *Talent and skills to analyze and interpret data:* Employees need to be able to generate business insights from the use of data analytics (Ghasemaghaei et al., 2018), also referred to as technical skills (Behl et al., 2019)

3 Methodology

Consistent with previous research, we used qualitative approach consisting of a combination of interviews with key informants, review of company documents and thematic analysis (Jha et al., 2020). The unit of analysis for our study was organizations' implementation of digitalization, a complex phenomenon affected by internal and external factors. A qualitative research approach was therefore deemed appropriate as it allowed for an in-depth understanding of the phenomenon with the purpose of analytic generalization (Yin, 2013). We used purposive homogeneous sampling (Gray, 2014) to identify four Dutch organizations in our network that were actively engaged in digitalization projects. We conducted individual and group interviews with key informants from each organization (Jha et al., 2020), supplemented with archival research of internal company documents for one organization (see table 2) and reviewed the websites of all organizations to collect additional information about relevant contextual variables.

The use of semi-structured interview guide based on open question interview protocols allowed important topics to be addressed while giving interviewees the possibility to express their emerging insights and comments. All interviews were recorded with participants' permission, freeing up the researchers to observe and take notes and thus improving their understanding of each interview's context (Ralston & Blackhurst, 2020). The semi-structured interview guide consisted of an introductory section, a general section about the organization and the respondent. The subsequent sections were about data and IT infrastructure, processes, employee skills and training, and the role of management.

Table 2: Overview of Data Collection

Org	**Type of Organization**	**Data Collection Methods**	**Duration**
1	Production Company (W)	Project Manager (I)	70 min
2	Retail (W)	Transportation Manager (I)	80 min
3	SME in High Tech Production (W)	Management Team (GI) Project Reports (Docs)	150 min
4	Production company in High Tech Sector (W)	Process Engineer & Continuous Improvement Specialist (GI)	120 minutes

(I: individual interview, GI: group interview, W: website review, Docs: internal document review)

The transcripts and notes were analyzed using the software Atlas.ti by applying the steps of thematic analysis (Jha et al., 2020) as recommended by Braun and Clarke (2006), namely familiarization with the data, generation of deductive codes based on the literature review (based on table 1), search for themes, revision of themes and selection of illustrative codes.

4 Findings

The purpose of the study was to formulate an implementation framework for digitalization, by exploring relevant aspects for the development of DAC. The numbers in brackets (e.g. [Org#1]) refer to the organizations listed in Table 2.

Theme 1: Knowledge and skills within the organization as a pre-requisite

The organizations we interviewed were all actively developing their DAC. However, three of the four organizations recognized that there were insufficient knowledge and skills within the organization to do so in a structured way. First, a lack of awareness about digitalization inhibited the urgency for the organization to pursue development in this area. Second, a lack of knowledge of data, data analytics and data management led to difficulties imagining how data could be used to improve decision-making. In the words of a respondent: "*we fell behind [in digitalization] in the sense that the need had not been recognized in our department, and the knowledge was not there to dive into it. Since my colleague and I started working on it, the need has been recognized,. Before, no one was busy with the idea that we had to become more data-driven.*" [Org#2]

To develop their DAC, the organizations first had to introduce knowledge and expertise about data and data analytics within the organization. For organizations 1 to 3 this happened by employing interns and/or recent graduates with an interest and affinity for data analytics and ensuring management gave them space to experiment. Organizations 1 and 2 also hired consultants to work for a longer period along their employees. Organizations 3 and 4 maintained close contacts with their software vendors who provided some of the knowledge.

Theme 2: Role of management to provide leadership, support and resources

In all four organizations, management's knowledge and skills about digitalization were limited. although their interest in the topic was increasing. In organizations 1 and 2, interested and knowledgeable employees receiving the time and resources to demonstrate its added value fueled the desire to increase digitalization. Management was also willing to invest in the IT infrastructure. As an interviewee stated: "*management sees that is really important and are prepared to invest in good systems. Think of a new supply chain application, a centralized department, employees for it, and capacity to manage all of this*" [#Org. 1]

Theme 3: Evolution of structure and processes

All four organizations seemed to be undergoing extensive developments in terms of structure, responsibilities, and processes related to digitalization. Organizations 1 and 2 saw the development of a centralized department, separate from IT, consolidating knowledge and expertise of DAC. In both cases, this department was in the process of taking ownership of the data management processes of the organization and supported departmental employees and teams in their choices of IT infrastructure. In organizations 1, 2 and 4 there was a concerted effort to inventory all the applications currently in use in the organization and formulate a plan to coordinate and manage them. For example, according to organization 4: "*our senior management has appointed a task force to review the application landscape within the organization and come up with a comprehensive data management plan*"[#Org 4]. In organization 3, the need for a data management plan was increasingly felt by senior management. However, due to a lack of knowledge and skills in this area within the organization, management was encountering difficulties in formulating a plan of action and deciding how to invest in IT infrastructure. In their words: "*we keep making small steps forwards with the best intentions, but we can't say 'this is where we are going' and make big steps.*" [#Org3]

Theme 4: Missing link to strategy

For organizations 3 and 4, the pressure to digitalize was external as it was imposed on them by customers and as a requirement to remain competitive. Despite a lack of skills and expertise on the topic of DAC, management was very committed to digitalization. For example, both organizations were actively seeking cooperations with universities by participating in student projects, providing internships, and by participating in academic research activities.

A striking finding was that none of the organizations involved formulated clear objectives for the implementation of digitalization were formulated beyond the departmental level. This translated to challenges deciding what data were relevant, and what projects should be prioritized. So while management was supportive and committed, it was not able to communicate in such a way that digitalization efforts were channeled in ways that supported the strategic objectives of the firm.

5 The Data Analytic Capability Wheel as a Metaphor

The above findings show that aspects of DAC do not operate independently. Instead, they are intertwined and thus require organizations to address them in a comprehensive manner. The findings of the literature review were combined with the empirical findings to formulate a preliminary implementation framework for digitalization, using a bicycle wheel as a metaphor. Bicycle wheels consist of three main parts: the hub, the spokes and the rim. The hub of a wheel is the part at its center that gives the wheel its integrity and allows it to rotate. The hub also attaches the wheel to the rest of the bicycle. The spokes of a wheel connect the hub to the rim and are meant to support the structure of the wheel. Their invention in 2000 BC was considered a revolution as they made wheels lighter and faster (Frithowulf, 2022). The rim and tire of the wheel make contact with the environment, absorbing shocks, keeping grip on the road, while transferring the wheel's speed without slipping. Applying the wheel metaphor to DAC creates a practical and relatable framework for the implementation of DAC, as explained below.

The hub of the DAC wheel is where an organization's DAC links to its organizational strategy (the bicycle). By clearly identifying and communicating how the organization's DAC contributes to its strategy, management can ensure that efforts to develop DAC are coherent. The hub is also the point around which the wheel revolves. This translates to decision-making about which resources to invest in and which projects to prioritize. The link to strategy is essential to ensure legitimacy and coherence to managerial decision-making, answering the "why pursue digitalization?" question.

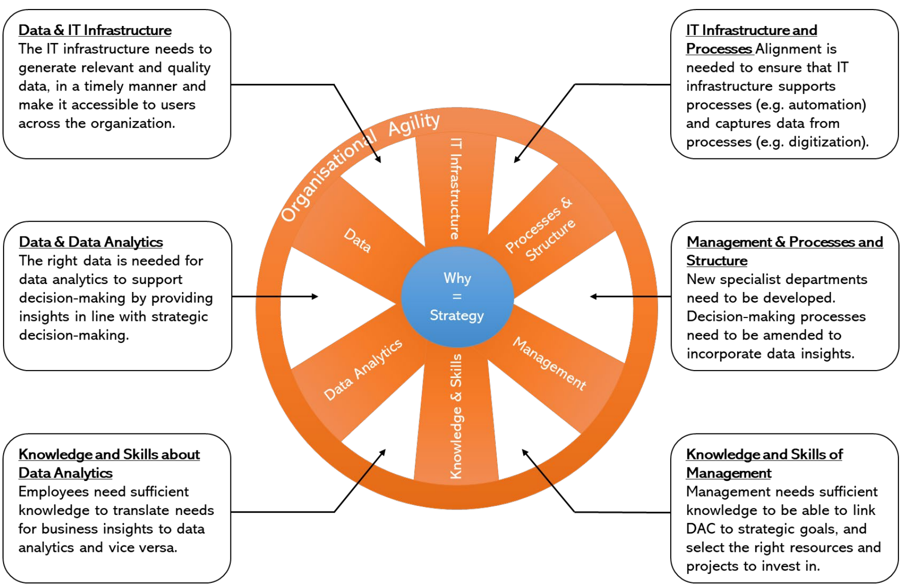

Figure 1: Implementation Framework

The spokes of the DAC Wheel are the six implementation aspects, namely Data, Data Analytics, Employee Knowledge and Skills, Management, Processes and Structure, and IT Infrastructure,. As the empirical findings show, these aspects are interrelated (see figure 1) and thus need to be considered holistically. Returning to the wheel metaphor, if spokes are of unequal length, the wheel will not turn properly and will be structurally unsound. Similarly, organizations' implementation of DAC will not be smooth or even functional if one aspect receives too much attention at the expense of the other aspects. For example, organizations that spend an outsize budget and effort on their data quality at the expense of knowledge and skills of employees will not be successful.

The rim and tire of the wheel are where the competitive advantage that DAC confers to the organization becomes apparent, by enabling the organization to sense its environment and respond quickly to changes in an effective way. The rim and tire of the DAC Wheel represent the organizational agility (Ghasemaghaei et al., 2017), defined as its "*ability to quickly respond and proactively embrace unanticipated changes in dynamic environments through effective resource reconfiguration and rapid decision-making*" (Gong & Ribiere, 2023, p. 5). Organizations that exhibit a high level of fit between different aspects such as analytical tools, data, and people will be able to better use DAC to generate organizational agility (Ghasemaghaei et al., 2017).

Just as different types of wheels are appropriate depending on the type and purpose of a bicycle, organizations will develop DAC in a way consistent with their strategy (e.g. cost leadership, customer engagement) (Sebastian et al., 2020).

5 Discussion

Despite the recognized importance of digitalization, there is a lack of understanding of how it should be implemented. Even when focusing on the better developed theoretical construct of DAC, there is a lack of empirical research focusing on implementation aspects. This is possibly due to the fact that academic research on the topic is typically conducted from the narrow perspective of a single discipline, most often information systems research (Gupta & George, 2016). Our findings show that a comprehensive perspective is necessary and that all three categories of DAC aspects defined by Gupta and George (2016) are relevant when implementing

DAC. Furthermore, our findings show that DAC aspects are strongly inter-related and thus the development of DAC needs to take a holistic approach.

Two aspects of DAC play a more prominent role, namely management and knowledge and skills. First, an initial seed of knowledge and skills within the organization is needed to create awareness and help the organization make the first steps towards developing DAC. Management plays an important role in acquiring this knowledge and expertise for the organization, and turning it into explicit and implicit organizational knowledge, either through hiring new employees, training existing employees by appealing to their intrinsic motivation (Pieters et al., 2022), or creating access to outside expertise (Behl et al., 2019; Kokkinou et al., 2021). Second, consistent with Tabesh et al. (2019), Mikalef et al. (2019) and Vidgen et al. (2017), we found that management plays an important role in orchestrating the necessary aspects of DAC. To be effective, management first need to acquire knowledge and skills themselves. Management needs to showing commitment and give support by allocating the right resources to the right people (Kokkinou et al., 2023). Furthermore, management needs to communicate the importance of DAC by linking it to the strategic objectives of the firm, a finding that parallels literature on continuous improvement implementation (Kokkinou et al., 2022b).

Consistent with IS research (Ghasemaghaei et al., 2017, 2018), we found that data and IT infrastructure received the most attention as organizations focused on collecting data of sufficient quality for data analytics projects. However, organizations were increasingly recognizing that processes and structure played an important role in ensuring that appropriate data were collected and shared across the organizations, leading to changes in the organizational structure and corresponding processes. Our study contributes to the notion that the implementation of digitalization, and specifically the development of DAC concerns complex socio-technical processes, requiring a multi-disciplinary perspective (Legner et al., 2017; Mikalef & Krogstie, 2020).

7 Limitations and Further Research

While the implementation framework presented in this paper is based on a multi-disciplinary review of the literature, this approach remains inferior to a structured review of the literature. It is therefore recommended to refine this framework through a structured review of the literature that encompasses more disciplines related to the use of data in decision-making. Similarly, four interviews are insufficient to validate the framework. Further research should adopt an action methodology to further test, validate, and refine the DAC Wheel. Finally, the study findings show similarities and overlap with literature on continuous improvement implementation. Further research should examine whether success factors of continuous improvement implementation could also apply to the implementation of digitalization.

References

Aragón-Correa, J. A., & Sharma, S. (2003). A Contingent Resource-Based View of Proactive Corporate Environmental Strategy. *The Academy of Management Review*, *28*(1), 71. https://doi.org/10.2307/30040690

Barney, J. (1991). Firm Resources and Sustained Competitive Advantage. *Journal of Management*, *17*(1), 99–120. https://doi.org/10.1177/014920639101700108

Barton, D., & Court, D. (2012). Making advanced analytics work for you. *Harvard Business Review*, *90*(10), 78–83.

Behl, A., Dutta, P., Lessmann, S., Dwivedi, Y. K., & Kar, S. (2019). A conceptual framework for the adoption of big data analytics by e-commerce startups: A case-based approach. *Information Systems and E-Business Management*, *17*(2–4), 285–318. https://doi.org/10.1007/s10257-019-00452-5

Björkdahl, J. (2020). Strategies for Digitalization in Manufacturing Firms. *California Management Review*, *62*(4), 17–36. https://doi.org/10.1177/0008125620920349

Bloomberg, J. (2018, April 29). Digitization, Digitalization, And Digital Transformation: Confuse Them At Your Peril. *Forbes*. https://www.forbes.com/sites/jasonbloomberg/2018/04/29/digitization-digitalization-and-digital-transformation-confuse-them-at-your-peril/?sh=62d90292f2c7

Brandon-Jones, E., Squire, B., Autry, C. W., & Petersen, K. J. (2014). A Contingent Resource-Based Perspective of Supply Chain Resilience and Robustness. *Journal of Supply Chain Management*, *50*(3), 55–73. https://doi.org/10.1111/jscm.12050

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Comuzzi, M., & Patel, A. (2016). How organisations leverage Big Data: A maturity model. *Industrial Management & Data Systems*, *116*(8), 1468–1492. https://doi.org/10.1108/IMDS-12-2015-0495

Cosic, R., Shanks, G., & Maynard, S. (2012). *Towards a business analytics capability maturity model.*

Dubey, R., Gunasekaran, A., & Childe, S. J. (2019). Big data analytics capability in supply chain agility: The moderating effect of organizational flexibility. *Management Decision*, *57*(8), 2092–2112. https://doi.org/10.1108/MD-01-2018-0119

Frithowulf, H. (2022, September 4). Timeline of the Wheel: History and Invention. *Malevus*. https://malevus.com/how-the-wheel-was-invented-and-developed/

Ganzarain, J., & Errasti, N. (2016). Three stage maturity model in SME's toward industry 4.0. *Journal of Industrial Engineering and Management (JIEM)*, *9*(5), 1119–1128.

Garmaki, M., Boughzala, I., & Wamba, S. F. (2016). *The effect of Big Data Analytics Capability on Firm Performance*. 301.

Ghasemaghaei, M., Ebrahimi, S., & Hassanein, K. (2018). Data analytics competency for improving firm decision making performance. *The Journal of Strategic Information Systems*, *27*(1), 101–113. https://doi.org/10.1016/j.jsis.2017.10.001

Ghasemaghaei, M., Hassanein, K., & Turel, O. (2017). Increasing firm agility through the use of data analytics: The role of fit. *Decision Support Systems*, *101*, 95–105. https://doi.org/10.1016/j.dss.2017.06.004

Gökalp, E., & Martinez, V. (2021). Digital transformation capability maturity model enabling the assessment of industrial manufacturers. *Computers in Industry*, *132*, 103522. https://doi.org/10.1016/j.compind.2021.103522

Gökalp, E., & Martinez, V. (2022). Digital transformation maturity assessment: Development of the digital transformation capability maturity model. *International Journal of Production Research*, *60*(20), 6282–6302. https://doi.org/10.1080/00207543.2021.1991020

Gökalp, M. O., Gökalp, E., Kayabay, K., Koçyiğit, A., & Eren, P. E. (2022). The development of the data science capability maturity model: A survey-based research. *Online Information Review*, *46*(3), 547–567. https://doi.org/10.1108/OIR-10-2020-0469

Gong, C., & Ribiere, V. (2023). Understanding the role of organizational agility in the context of digital transformation: An integrative literature review. *VINE Journal of Information and Knowledge Management Systems*. https://doi.org/10.1108/VJIKMS-09-2022-0312

Gray, D. E. (2014). *Doing research in the real world* (3. ed). Sage.

Grossman, R. L. (2018). A framework for evaluating the analytic maturity of an organization. *International Journal of Information Management*, *38*(1), 45–51. https://doi.org/10.1016/j.ijinfomgt.2017.08.005

Günther, W. A., Rezazade Mehrizi, M. H., Huysman, M., & Feldberg, F. (2017). Debating big data: A literature review on realizing value from big data. *The Journal of Strategic Information Systems*, *26*(3), 191–209. https://doi.org/10.1016/j.jsis.2017.07.003

Gupta, M., & George, J. F. (2016). Toward the development of a big data analytics capability. *Information & Management*, *53*(8), 1049–1064. https://doi.org/10.1016/j.im.2016.07.004

Hein-Pensel, F., Winkler, H., Brückner, A., Wölke, M., Jabs, I., Mayan, I. J., Kirschenbaum, A., Friedrich, J., & Zinke-Wehlmann, C. (2023). Maturity assessment for Industry 5.0: A review of existing maturity models. *Journal of Manufacturing Systems*, *66*, 200–210. https://doi.org/10.1016/j.jmsy.2022.12.009

Hess, T., Matt, C., Benlian, A., & Wiesböck, F. (2016). Options for formulating a digital transformation strategy. *MIS Quarterly Executive*, *15*(2).

Jha, A. K., Agi, M. A. N., & Ngai, E. W. T. (2020). A note on big data analytics capability development in supply chain. *Decision Support Systems*, *138*, 113382. https://doi.org/10.1016/j.dss.2020.113382

Khanchanapong, T., Prajogo, D., Sohal, A. S., Cooper, B. K., Yeung, A. C. L., & Cheng, T. C. E. (2014). The unique and complementary effects of manufacturing technologies and lean practices on manufacturing operational performance. *International Journal of Production Economics*, *153*, 191–203. https://doi.org/10.1016/j.ijpe.2014.02.021

Kokkinou, A., Mandemakers, A., & Mitas, O. (2022a). Data-analytic capability as a path to a resilient supply chain: An empirical investigation. *Presented at the 2022 EurOMA Conference*. EUROMA, Berlin, Germany.

Kokkinou, A., van Kollenburg, T., & Touw, P. (2022b). The road to operational excellence is scenic: Tales of continuous improvement journeys. Presented at the 2022 EurOMA Conference. European Operations Management Association (EurOMA), Berlin.

Kokkinou, A., Kollenburg, T. van, & Mandemakers, A. (2023). Development of data analytic capability in organizations. *Presented at the 2023 EUROMA Conference*. Leuven, Belgium

Kokkinou, A., van Kollenburg, T., & Touw, P. (2021). The Role of Training in the Implementation of Lean Six Sigma. *Presented at the 2021 EurOMA Conference*. European Operations Management Association (EurOMA), Berlin.

Korsten, G., Aysolmaz, B., Turetken, O., Edel, D., & Ozkan, B. (2022). *ADA-CMM: A Capability Maturity Model for Advanced Data Analytics*. Hawaii International Conference on System Sciences. https://doi.org/10.24251/HICSS.2022.032

Legner, C., Eymann, T., Hess, T., Matt, C., Böhmann, T., Drews, P., Mädche, A., Urbach, N., & Ahlemann, F. (2017). Digitalization: Opportunity and Challenge for the Business and Information Systems Engineering Community. *Business & Information Systems Engineering*, *59*(4), 301–308. https://doi.org/10.1007/s12599-017-0484-2

Machado, C. G., Winroth, M., Carlsson, D., Almström, P., Centerholt, V., & Hallin, M. (2019). Industry 4.0 readiness in manufacturing companies: Challenges and enablers towards increased digitalization. *Procedia CIRP*, *81*, 1113–1118. https://doi.org/10.1016/j.procir.2019.03.262

Mikalef, P., Boura, M., Lekakos, G., & Krogstie, J. (2019). Big data analytics and firm performance: Findings from a mixed-method approach. *Journal of Business Research*, *98*, 261–276. https://doi.org/10.1016/j.jbusres.2019.01.044

Mikalef, P., Framnes, V. A., Danielsen, F., Krogstie, J., & Olsen, D. (2017). *Big data analytics capability: Antecedents and business value. 136*.

Mikalef, P., & Krogstie, J. (2018). *Big Data Governance and Dynamic Capabilities: The Moderating effect of Environmental Uncertainty*. 206.

Mikalef, P., & Krogstie, J. (2020). Examining the interplay between big data analytics and contextual factors in driving process innovation capabilities. *European Journal of Information Systems*, *29*(3), 260–287. https://doi.org/10.1080/0960085X.2020.1740618

Mikalef, P., Pappas, I. O., Krogstie, J., & Giannakos, M. (2018). Big data analytics capabilities: A systematic literature review and research agenda. *Information Systems and E-Business Management*, *16*(3), 547–578. https://doi.org/10.1007/s10257-017-0362-y

Mittal, S., Khan, M. A., Romero, D., & Wuest, T. (2018). A critical review of smart manufacturing & Industry 4.0 maturity models: Implications for small and medium-sized enterprises (SMEs). *Journal of Manufacturing Systems*, *49*, 194–214. https://doi.org/10.1016/j.jmsy.2018.10.005

Nayernia, H., Bahemia, H., & Papagiannidis, S. (2022). A systematic review of the implementation of industry 4.0 from the organisational perspective. *International Journal of Production Research*, *60*(14), 4365–4396. https://doi.org/10.1080/00207543.2021.2002964

Pieters, J. J., Kokkinou, A., & van Kollenburg, T. (2022). Understanding Blockchain Technology Adoption by Non-experts: An Application of the Unified Theory of Acceptance and Use of Technology (UTAUT). Operations Research Forum, 3(1), 1. https://doi.org/10.1007/s43069-021-00113-9

Popovič, A., Hackney, R., Tassabehji, R., & Castelli, M. (2018). The impact of big data analytics on firms' high value business performance. *Information Systems Frontiers*, *20*(2), 209–222. https://doi.org/10.1007/s10796-016-9720-4

Pöppelbuß, J., & Röglinger, M. (2011). *What makes a useful maturity model? A framework of general design principles for maturity models and its demonstration in business process management*.

Ralston, P., & Blackhurst, J. (2020). Industry 4.0 and resilience in the supply chain: A driver of capability enhancement or capability loss? *International Journal of Production Research*, *58*(16), 5006–5019. https://doi.org/10.1080/00207543.2020.1736724

Rosin, F., Forget, P., Lamouri, S., & Pellerin, R. (2020). Impacts of Industry 4.0 technologies on Lean principles. *International Journal of Production Research*, *58*(6), 1644–1661. https://doi.org/10.1080/00207543.2019.1672902

Sebastian, I. M., Ross, J. W., Beath, C., Mocker, M., Moloney, K. G., & Fonstad, N. O. (2020). How big old companies navigate digital transformation. In *Strategic information management* (pp. 133–150). Routledge.

Shahin, M., Chen, F. F., Bouzary, H., & Krishnaiyer, K. (2020). Integration of Lean practices and Industry 4.0 technologies: Smart manufacturing for next-generation enterprises. *The International Journal of Advanced Manufacturing Technology*, *107*(5–6), 2927–2936. https://doi.org/10.1007/s00170-020-05124-0

Social Security Administration Analytics Center of Excellence (2020). https://www.ssa.gov/data/data_governance_board/ACE_A2CM2_for%20DGB.pptx.pdf

Tabesh, P., Mousavidin, E., & Hasani, S. (2019). Implementing big data strategies: A managerial perspective. *Business Horizons*, *62*(3), 347–358. https://doi.org/10.1016/j.bushor.2019.02.001

Tallon, P. P. (2013). Corporate Governance of Big Data: Perspectives on Value, Risk, and Cost. *Computer*, *46*(6), 32–38. https://doi.org/10.1109/MC.2013.155

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems*, *28*(2), 118–144. https://doi.org/10.1016/j.jsis.2019.01.003

Vidgen, R., Shaw, S., & Grant, D. B. (2017). Management challenges in creating value from business analytics. *European Journal of Operational Research*, *261*(2), 626–639. https://doi.org/10.1016/j.ejor.2017.02.023

Wu, F., Yeniyurt, S., Kim, D., & Cavusgil, S. T. (2006). The impact of information technology on supply chain capabilities and firm performance: A resource-based view. *Industrial Marketing Management*, *35*(4), 493–504. https://doi.org/10.1016/j.indmarman.2005.05.003

Yin, R. K. (2013). Validity and generalization in future case study evaluations. *Evaluation*, *19*(3), 321–332. https://doi.org/10.1177/1356389013497081

Yu, W., Chavez, R., Jacobs, M. A., & Feng, M. (2018). Data-driven supply chain capabilities and performance: A resource-based view. *Transportation Research Part E: Logistics and Transportation Review*, *114*, 371–385. https://doi.org/10.1016/j.tre.2017.04.002

Yu, W., Wong, C. Y., Chavez, R., & Jacobs, M. A. (2021). Integrating big data analytics into supply chain finance: The roles of information processing and data-driven culture. *International Journal of Production Economics*, *236*, 108135. https://doi.org/10.1016/j.ijpe.2021.108135

Unlocking the Potential of Data-Driven Business Models: An Empirical Investigation into the Role of Ecosystems and Fair Data Use

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Data-driven business models are expected to stimulate new economic growth by promoting innovation and value creation through data. However, in addition to concerns about privacy and security, there are ongoing discussions about fair data usage at both the EU and global levels. This research analyses how business model change is influenced by the expected economic benefits as well as how involvement in data ecosystems and the adoption of fair data practices can encourage data-driven innovation. We develop and test a structural equation model with a sample of 1,200 European companies. The findings suggest that organizations recognize the potential for new business and innovation opportunities with data-driven business models. Nevertheless, it is essential to engage in data ecosystems and implement fair and sustainable data usage practices in order to realize these benefits.

Keywords:
fair data practices, data-driven innovation, business model, structural equation model

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1 Introduction

Data has become an essential, multi-faceted asset of the modern global economy (Brynjolfsson et al., 2011; Jetzek et al., 2014; Saaristo & Heikkilä, 2022). New business models (BMs) for novel products and services are expected to be developed through creating, sharing, and using data. But regulations are also being put in place to safeguard against the misuse of information and potential threats to privacy and business secrets (e.g., Data Act, 2022; Krämer & Schnurr, 2021). Too strict protection may enforce monopolistic market positions, hinder innovation, increase the costs of heightened surveillance, and limit freedom of expression in the worst case (Gawer & Srnicek, 2021; Zuboff, 2019; Gandhi et al., 2011). These are pertinent issues for individuals, businesses, and governments who are constantly seeking a fair balance between restrictions and freely flowing open data. Despite the differences in viewpoints and associated risks, the data economy is projected to drive future BMs and innovations, offering ample opportunities for all stakeholders, as noted by the European Commission in 2020.

While the literature suggests that firms can leverage digitalization and their big data analytics capabilities to innovate their BMs (Bouwman et al., 2019; Ciampi et al., 2021), the experiences and outcomes of seizing these opportunities vary. Several studies have witnessed challenges in innovating from data due to poor data quality, unclear ownership, or usage rights, among other reasons (Ermakova et al., 2021; Lange et al., 2021; Rantanen et al., 2019; Eriksson & Heikkilä, 2023).

Therefore, it can be concluded that experimenting with data does not automatically translate into innovation. Recent literature, particularly in relation to Industry 4.0, suggests that to overcome these challenges, it is advisable to focus on creating data ecosystems that adopt fair and sustainable data usage practices (Azkan et al., 2022; Hubaux & Juels, 2016). Through such data ecosystems, companies can gain access to additional data sources, increase their opportunities for collaboration, and stay up-to-date on the latest trends and technologies in the industry (Oliveira et al., 2019). Moreover, to ensure that data is processed and used ethically and lawfully, practices of fair and sustainable data usage are becoming increasingly necessary (Bennett, 2019). Few empirical studies have investigated the impact of fair and sustainable data use practices and data ecosystem participation on BMs building on data-driven innovation. We fill this gap by developing a model to analyse if expected business benefits from the data economy lead to BM changes, and whether participation in data ecosystems and adoption of fair data practices can increase data-driven innovation. The empirical data are collected from 1,200 diverse European companies.

This study contributes to the literature on BMs, especially on data-driven BM, where data is a core ingredient of a company's BM (Trabucci & Buganza, 2019). Our objective is to deepen the knowledge on how changes in BMs eventually lead to increased data-driven innovation. Data-driven innovation is a representation of how BMs are implemented to enhance the overall performance of the ecosystem and individual companies within it (e.g., Jetzek et al., 2014). The rest of this paper includes a review of the literature, research hypotheses, methodology, findings, discussion, and conclusions.

2 Literature review and hypothesis

Several companies have realized the potential advantages of creating new BMs that utilize data as a crucial resource (Hartman et al., 2014). Ciampi et al. (2021) assert that a company's competence in big data analytics positively affects its ability to innovate its BM. Bouwman et al. (2019) revealed that companies that actively utilize social media, big data, and information technology can increase their performance by transforming their BMs and strengthening their capacity for innovation.

A BM describes how a company creates, delivers, and captures value (Teece, 2010). Companies respond to continuously evolving environments by modifying their BMs (Marolt et al., 2018; Pucihar et al., 2019). These **BM change**s can range from modest refinements to some BM elements to a complete overhaul of the entire BM (Saebi et al., 2017; Eriksson et al., 2022). Companies often make these changes to achieve strategic goals such as increasing profitability, expanding their business, or entering new markets (Heikkilä et al., 2018). Thus, On the basis of research literature, we could assume if a company sees **potential benefits from data**, it is motivated to change its BM (Bucherer et al., 2012; Hartmann et al., 2013; Lindgardt et al., 2009; Pohle and Chapman, 2006; Lafiti et al., 2021a,b). However, to date, there is no clear empirical evidences showing this relationship. Thus, we propose the following hypothesis (see also Fig.1):

H1. Potential benefits from data has a significant positive effect on BM change

Generating economic value via data-driven innovation is seldom achievable by a lone organization. Rather, this process is said to necessitate involvement in **data ecosystems** (Hein et al., 2019), which refer to networks of entities that interact to exchange, create, and utilize data (Oliveira and Lóscio, 2018). To unlock the potential of data-driven business, companies need to share data and collaborate with other parties such as companies, government agencies, users, and other stakeholders. By doing so, they gain access to a broader range of data, which can be used to create new products and services for markets. Furthermore, collaborating with other companies enables them to leverage complementary skills and expertise, accelerating innovation. Therefore, it is not surprising that a recent survey found that approximately one third of organizations are collaborating with partners to exchange data (MIT, 2021). There are several types of data ecosystems, which differ on their control, openness, participant interdependence and purpose (Gelhaar et al., 2021; Curry & Ojo, 2020). For instance, the data ecosystem may be centered around a keystone actor, or it can be a platform or marketplace (Gelhaar et al., 2021). They may also be collaboratively developed and influenced by various actors (De Reuver et al., 2018), such as European data ecosystem is International Data Spaces (Otto & Jarke, 2019), but a data ecosystem could also be formed between just a few companies. We expect that changes in BM would increase a company's activity in data ecosystems:

H2. BM change has a significant positive effect on participation to data ecosystems

Companies face various challenges when leveraging data-driven opportunities, such as ensuring secure data sharing, complying with privacy regulations, and controlling personal and private data (MIT, 2021). Additionally, companies must respect copyright, intellectual property, and non-disclosure requirements. To address concerns about potential data misuse, companies can combine their new BMs with practices that promote fair and sustainable data usage. These practices ensure that the company creates services and data-based products in an ethical, fair manner. In a data economy, fairness requires protecting individuals' rights, respecting businesses' rights and contracts, and taking into account the needs of all stakeholders (Parikka et al., 2021). Practices that promote fair and sustainable data usage create trust, which is often a prerequisite for accessing customer data and building long-term relationships. Researchers note that simply complying with legal requirements is insufficient, and explicit approaches and processes must be adopted to promote fair data usage (Vermanen et al., 2022). Furthermore, we anticipate that participating in data ecosystems could enhance the adoption of fair and sustainable data usage practices (Koskinen et al., 2019)."

H3. BM changes are positively related to fair & sustainable data usage practices.

H4. Participation in data ecosystems has a significant positive effect on fair & sustainable data usage practices.

Data-driven innovation refers to innovation that utilizes data as a core ingredient. The literature describes it as business innovation that is based on exploiting data and is capable of generating positive economic and social impacts (Jetzek et al., 2014). Companies utilize data to inform decision-making, improve organizational processes, or create customer value (Brynjolfsson et al., 2011). Empirical studies evidence how, for example, by collecting and analyzing data from users (Trabuchi & Buganza, 2019) or other sources (Jetzek et al., 2014), a company can gain insights into how its customers value its products and services and how the company could add even more value to the market. We aim to analyze whether changes to the BMI increase data-driven innovation directly or whether participation in data ecosystems or practicing fair and sustainable use of data leads to increased data-driven innovation:

H5. BM changes have a significant positive effect on data-driven innovation

H6. Participation in data ecosystems has a significant positive effect on data-driven innovation

H7. Fair & sustainable data usage practices have a significant positive effect on data-driven innovation

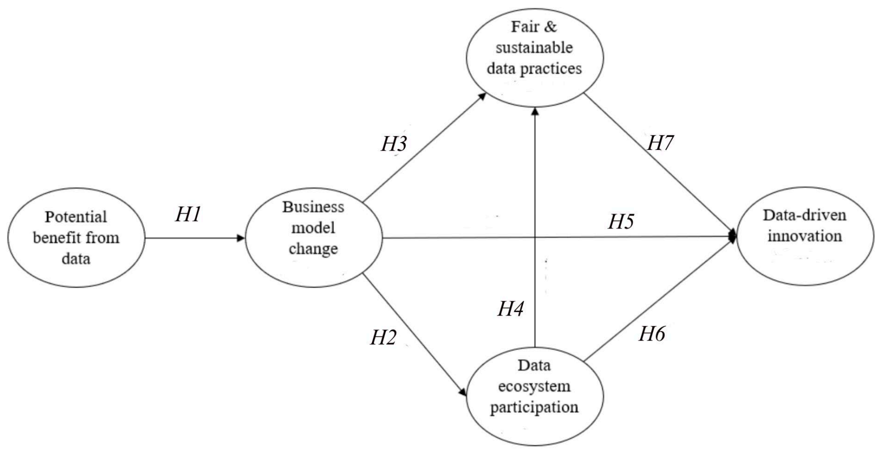

Figure 1: Research model

3 Methodology

3.1 The measures

Researchers have developed various measurement scales for assessing changes or innovations in BMs. Some scales focus on the scope of BM change, which evaluates architectural and modular changes in the BM (Spieth & Schneider, 2016; Foss & Saebi, 2017; Lafiti et al., 2021a, b; Eurostat, 2022; Bashir et al., 2023). Novelty scales, in turn, measure the degree of change in an enterprise or industry (Clauss, 2017; Marolt et al., 2018; Pucihar et al., 2019). Also, there are scales that measure disruptiveness of changes (Karimi & Walter, 2016), the novelty of digital innovation (Soluk et al., 2021), or the sustainability of changes (Bashir et al., 2022).

Many researchers link changes in a BM to changes in its components. The widely adopted BM Canvas (Osterwalder et al., 2005; Osterwalder & Pigneur, 2010) depicts customer relationships and segmentation, channels, value proposition, key activities, key resources, partners, and the revenue model as components of BM. Both researchers and practitioners use the BM Canvas to analyse BMs and changes in BMs (Lafiti et al., 2021b). Even Eurostat (2022) introduced a scale for BM change in the community innovation survey (CIS) for the first time in 2022. Therefore, this study measures BM changes (i.e., the scope of BM innovation) using a subset of seven BM components that follow the structure of the BM Canvas (Osterwalder & Pigneur, 2010).

In this study, potential benefits from data-driven innovations were measured by three items (Heikkilä et al., 2018): First, the respondents were to consider how much potential they see in data economy to *increase revenue from the current BM*; secondly, whether they can find *new revenue streams from innovations;* or, thirdly, *to save costs*. Participation in data ecosystems was inquired with questions if the company is *a partner* or *a facilitator* of data ecosystem(s). Fair and sustainable data usage practices consists of a set of eight questions measuring e.g. *ethical code of conduct*; *transparency*; *privacy*; *data sovereignty* (Parikka et al., 2021; Vermanen et al., 2022). Data-driven innovation was measured with two questions on *continuous improvement and innovation of products and services* (e.g. Boer & Gertsen, 2003), and with questions on the use of data to *enhance customer experience*, and *creating value for society, people, and environment* (Sitra, 2021). The constructs and questions are provided in Appendix.

3.2 Survey administration, sample and data collection

The survey was conducted in four countries - Finland, France, Germany, and the Netherlands - in 2021, and was commissioned by the Finnish Innovation Fund Sitra[1]. The research data was collected from a B2B decision-maker panel, consisting of professionals holding key decision-making roles, such as CxOs of data, digitalization, information systems, strategy, marketing, and business development. Table 1 provides background characteristics of the sample, with equal strata for the countries, and with close to equal number of respondents from large, medium, small, and micro-sized companies (excluding sole proprietors) in each country. No quotas were defined on industry or activity in the data economy. The raw data set is openly available from Sitra (2021).

Our interest in the potential of data economy to change BMs seems reasonable: More than 80% of the sampled companies foresaw the potential of data economy in creating a competitive edge (Saaristo & Heikkilä, 2022; Ulander et al. 2021).

[1] Sitra is a fund, which has a special national level role in Finland, because it is accountable and reports directly to the Finnish Parliament. Its capital was granted by the Finnish Parliament.

Table 1: Profile of respondents' companies

Variable	Category	%
Country	Finland	25
	France	25
	Germany	25
	The Netherlands	25
Firm size (turnover €)	Micro (under 2 million)	28.1
	Small (2 – 10 million)	26.6
	Medium (10 – 50 million)	22.1
	Large (over 50 million)	23.2
Industry sector	Service activities	15.97
	Manufacturing	11.34
	Information and communication	9.83
	Human health and social work	8.07
	Financial and insurance activities	7.98
	Wholesale and retail trade	6.64
	Other	40.17

The survey data contained some missing values, which were less than 5 % of the total values in the dataset. Therefore, the mean imputation method was used to deal with missing values (Hair et al., 2021).

Cross sectional surveys measuring both dependent and independent variables simultaneously are prone to common method variance (Kock et al., 2021), so in our study we use Harman's single factor test to assess it. The principal axis factoring based first factor accounted for the 35.73 percent of the overall variance. The small size (i.e. below 70%, Kock et al., 2021) of single factor accounted variance confirms the absence of a common method variance problem in our dataset.

4 Data analysis and findings

Partial least squares structural equation modeling (PLS-SEM) was used to test the hypotheses. The guidelines provided by Hair et al. (2021) were followed to test the hypotheses. We used SmartPLS 4.0 software for data analysis.

4.1 Reliability and validity

We tested first model's reliability (indicator reliability, Cronbach's alpha and composite reliability) and then convergent validity in Table 2 and discriminant validity in Table 3.

The factor loading for an item is recommended to be at least 0.60 (Hair et al., 2021). As shown in Table 1, all items have a higher value than the recommended threshold. Moreover, both the values of Cronbach's alpha and composite reliability are above the recommended threshold value of minimum 0.70. Thus, internal consistency and reliability are confirmed. Convergent validity was examined by computing average variance extracted (AVE). The value of at least 0.50 is suggested as a threshold (Hair et al., 2021). As Table 2 shows, all constructs passed the threshold.

For discriminant validity, the Fornell and Larcker criterion was used, which requires the square root of the AVE of each construct to be higher than its correlation with other constructs (Wong, 2013). Table 3 shows the fulfilment of this criterion and thus the establishment of discriminant validity.

Last, HTMT is used to compare the correlations between indicators measuring different constructs (heterotrait correlations) to the correlations between indicators measuring the same construct (monotrait correlations). If the heterotrait correlations are significantly higher than the monotrait correlations, it suggests that the measures are not distinct and that there may be issues with discriminant validity. HTMT values closer to 0 indicate better discriminant validity and 0.85 is often used as a conservative cut-off point, while a value of 0.90 is considered more liberal (Henseler et al., 2015). The HTMT values in Table 4 were all lower than 0.73, indicating that there were no issues with discriminant validity.

Table 2: Measurement statistics of first-order constructs

Construct	Indicator loadings	Cronbach's alpha	Composite reliability	Average variance extracted (AVE)
Potential Benefit from data		0.86	0.92	0.79
Item 1	0.90			
Item 2	0.91			
Item 3	0.85			
BM change		0.89	0.91	0.60
Item 1	0.74			
Item 2	0.75			
Item 3	0.80			
Item 4	0.79			
Item 5	0.76			
Item 6	0.78			
Item 7	0.81			
Data ecosystem participation		0.90	0.94	0.83
Item 1	0.90			
Item 2	0.91			
Item 3	0.92			
Fair & sustainable data usage practices		0.90	0.92	0.58
Item 1	0.78			
Item 2	0.82			
Item 3	0.74			
Item 4	0.75			
Item 5	0.72			
Item 6	0.73			
Item 7	0.78			
Item 8	0.73			
Data-driven innovation		0.74	0.83	0.55
Item 1	0.71			
Item 2	0.76			
Item 3	0.71			
Item 4	0.77			

Table 3: Discriminant validity of the constructs - Fornell-Larcker Criterion

	(a)	*(b)*	*(c)*	*(d)*	*(e)*
Potential benefit from data (a)	**0.887**				
BM change (b)	0.387	**0.775**			
Data ecosystem participation (c)	0.611	0.428	**0.910**		
Fair & sustainable data usage practices (d)	0.614	0.326	0.583	**0.758**	
Data-driven innovation (e)	0.594	0.349	0.515	0.651	**0.739**

Bold numbers represent the square roots of the AVEs

Table 4: Heterotrait–monotrait ratio of correlations (HTMT)

	(a)	*(b)*	*(c)*	*(d)*
Potential benefit from data (a)				
BM change (b)	0.440			
Data ecosystem participation (c)	0.694	0.479		
Fair & sustainable data usage practices (d)	0.681	0.352	0.626	
Data-driven innovation (e)	0.693	0.394	0.557	0.729

4.2 Structural model findings

Next, relationships between constructs were analysed using path coefficients and significance levels. We examined the effect size using Cohen's f^2, which reflects the effect of an exogenous variable on an endogenous variable (Cohen, 1988). f^2 values greater than 0.02, 0.15, and 0.35 indicate small, moderate, and large effect sizes, respectively. However, as noted in previous studies, finding large effect sizes is rather uncommon in management research (Mazen et al., 1987, p. 406; Strauch, 2019).

Results presented in Figure 2 confirm that all the hypotheses tested in this study are statistically significant. Firstly, we found that potential benefits from data have a clear positive correlation with BM change (H1: $\beta = 0.39$, $f^2 = 0.18$, $p < 0.001$). Secondly, BM change was found to significantly increase participation in data ecosystems (H2: $\beta=0.43$, $f^2 = 0.23$, $p < 0.001$), which, in turn, is strongly and positively correlated with fair and sustainable data usage practices (H4: $\beta=0.54$, $f^2 = 0.37$, $p < 0.001$). Thirdly, business model change is found to enhance data-driven innovation, although the effect is small (H5: $\beta=0.11$, $f^2 = 0.02$, $p < 0.001$). Finally, we observed that while data ecosystem participation has a small effect, fair and sustainable data usage practices have a large positive impact on data-driven innovation (H6: β=0.17, $f^2 = 0.03$, $p < 0.001$; H7: β=0.52, $f^2 = 0.33$, $p < 0.001$).

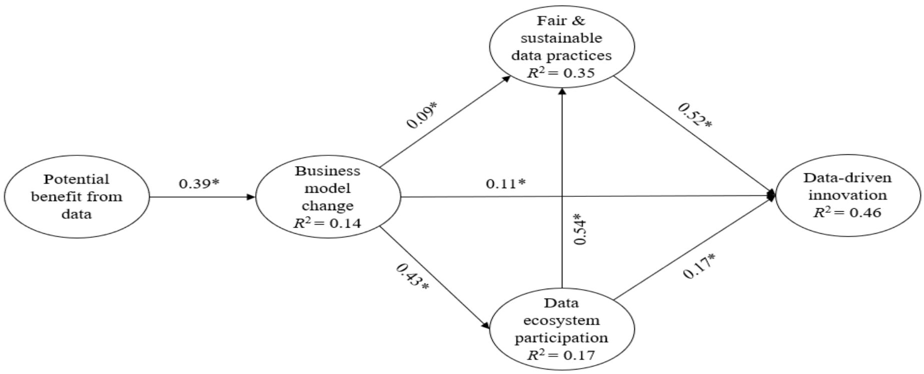

Figure 2: PLS-SEM analysis results. Notes: *p < 0.001 (two-sided test)

5 Discussion

5.1 Theoretical contributions

This article is among the first to present a comprehensive perspective on data-driven innovation in business, arguing that for companies to benefit from the data, they must first modify their BMs. Empirical evidence presented in our study corroborates prior research (MIT, 2021; Azkan et al., 2022; Hubaux & Juels, 2016; Bennett, 2019), emphasizing the critical role of BM change in driving data-driven innovation.

Moreover, our study found that the more European companies anticipate financial benefits from usage of data, the more likely they are to change their BMs. Specifically, companies expect to gain by introducing new revenue streams from innovative products or services, enhancing their revenue from existing business, or reducing costs. Thus, our empirical results confirm previous literature (Heikkilä et al., 2018) that companies' expected benefits positively relate to BM change, here in the context of the data economy.

However, making changes to BMs alone is not enough. This study underscores the importance of fair and sustainable data usage practices, as well as active engagement in data ecosystems, as key enablers of data-driven innovation in European companies. This highlights the urgent need for more research and development of IS methods, tools, and data usage that are based on principles of fair and sustainable data practices, as previously proposed in studies such as Nahr & Heikkilä (2022), Alt & Klein (2011), and Pucihar (2020). This need is becoming increasingly urgent in the context of artificial intelligence and machine learning, as noted by Seppälä et al. (2021).

5.2 Managerial implications

The findings suggest that the companies which aim at seizing the benefits from data economy by data-driven innovations should, 1) change their BM, 2) be prepared to take part in data ecosystems and 3) take measures to ensure the fair and sustainable data use. Appropriate BM, a suitable network of partners, and ethically sound practices for handling data make it possible to engage and increase innovation from data. BM tools - such as https://businessmakeover.eu/ and data-driven services card game (Breitfuss at al., 2023) - are available to define the changes in BM.

Regarding data ecosystems, there are several local, regional, national and European industry specific innovation ecosystems and data spaces that welcome companies to join and co-create data driven new services. These ecosystems provide opportunities not only to share experiences from the data economy but also to share open data among partners or provide reference architectures and interfaces to data assets, as suggested by the Digital Single Market regulatory package within the limits of privacy and intellectual property protection. In the future, sandboxed development of data-driven BMs and services will be required for conformity assessment and accreditation of the ethical and rightful treatment of data. Therefore, data ecosystems are increasingly necessary in promoting practices for fair and sustainable data usage.

6 Conclusions

This study provides evidence that the perceived economic potential from data economy serves as a motivation for a company to change its BM, which, in turn, leads to data-driven innovation through increased participation in data ecosystems and the implementation of fair and sustainable data practices. Overall, our study suggests that the data economy can provide a competitive advantage to companies, but it must be implemented in an ethical and responsible manner. These findings have important implications for businesses seeking to leverage data-driven innovation to achieve business benefits. Specifically, companies must engage in data ecosystems and adopt responsible data usage practices to comply with data protection regulations and maintain ethical use of data.

This study has some limitations that need to be taken into consideration when interpreting the results. Firstly, the data was collected from four European countries only, and therefore, the results may not be generalizable to companies in other regions, such as the United States and China, which have different regulatory environments and attitudes towards fair and sustainable data practices. Further research is required to explore how multinational companies can effectively promote ethical data usage across diverse regulatory environments. Also, it is crucial to examine the validity of ethical data practices and European data sharing ecosystems outside the scope of European legislation. Secondly, the cross-sectional nature of the survey could introduce response bias, as firms at different stages of their innovation trajectories may hold varying views on data-driven innovation. However, the inclusion of a large sample size is expected to mitigate such variance. It is important to note that this study analysed companies of all sizes. Nevertheless, it is worth mentioning that small and medium-sized enterprises (SMEs) often lag behind in digitalization and digital transformation efforts, resulting in missed opportunities for innovation. Therefore, we recommend that future research places particular emphasis on exploring data-driven innovation and business models within SMEs. Thirdly, future research could examine in more detail how participation in data ecosystems enables the development of data-driven services by companies. Although ecosystems play a significant role in generating collective intelligence and supporting the introduction of new business innovations, the priorities of such ecosystems vary (Elia et al., 2020). Therefore, it would be interesting to do qualitative studies on the reasons behind a company's participation in an ecosystem and how they can leverage collective intelligence to their benefit. Last, large data-driven organisations may utilize data governance for allocating authority and control over data and making data-related decisions (Janssen et al., 2020). This points to need for further research of data governance in the context of data-driven business, and its impact on strategies for data ecosystems and ethical data practices.

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References

Alt, R., & Klein, S. (2011). Twenty years of electronic markets research – Looking backwards towards the future. *Electronic Markets*, 21(1), 41–51. https://doi.org/10.1007/s12525-011-0057-z

Azkan, C., Möller, F., Ebel, M., Iqbal, T., Otto, B., & Poeppelbuss, J. (2022). Hunting the Treasure: Modeling Data Ecosystem Value Co-Creation, Forty-Third International Conference on Information Systems, Copenhagen 2022.

Bashir, M., Alfalih, A., & Pradhan, S. (2023). Managerial ties, business model innovation & SME performance: Moderating role of environmental turbulence. *Journal of Innovation & Knowledge*, 8(1), 100329.

Bashir, M., Alfalih, A., & Pradhan, S. (2022). Sustainable business model innovation: Scale development, validation and proof of performance. *Journal of Innovation & Knowledge*, 7(4), 100243.

Bennett, S. (2019). Governance in practice: Big data, privacy and information governance-incorporating an ethical-based assessment. *Governance Directions*, 71(5), 244-254.

Boer, H., & Gertsen, F. (2003). From continuous improvement to continuous innovation: a (retro)(per)spective. *International Journal of Technology Management*, 26(8), 805-827.

Bouwman, H., Nikou, S., & de Reuver, M. (2019). Digitalization, business models, and SMEs: How do business model innovation practices improve performance of digitalizing SMEs?. *Telecommunications Policy*, *43*(9), 101828.

Breitfuss, G., Santa-Maria, T., Fruhwirth, M., & Disch, L. (2023). Use Your Data: Design and Evaluation of a Card-Based Ideation Tool for Data-Driven Services. HICSS 2023, Retrieved from: https://scholarspace.manoa.hawaii.edu/items/b3df1410-42f5-4136-ac28-95f934a1a67c

Brynjolfsson, E., Hitt, L. M., & Kim, H. H. (2011). Strength in numbers: How does data-driven decision making affect firm performance? *SSRN Electronic Journal*, doi:10.2139/ssrn.1819486

Bucherer, E., Eisert, U. & Gassmann, O. (2012). Towards systematic business model innovation: Lessons from product innovation management. *Creativity and Innovation Management*, 21(2), pp. 183–198.

Ciampi, F., Demi, S., Magrini, A., Marzi, G., & Papa, A. (2021). Exploring the impact of big data analytics capabilities on business model innovation: The mediating role of entrepreneurial orientation. *Journal of Business Research*, 123, 1-13.

Clauss, T. (2017). Measuring business model innovation: Conceptualization, scale development, and proof of performance. *R&D Management*, 47(3), 385-403.

Cohen J. E. (1988). Statistical Power Analysis for the Behavioral Sciences. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Curry, E. & Ojo, A. (2020). Enabling Knowledge Flows in an Intelligent Systems Data Ecosystem, in Real-time Linked Dataspaces: Enabling Data Ecosystems for Intelligent Systems, E. Curry (Ed). Springer: Cham, Switzerland.

Data Act (2022). Data Act: Proposal for a Regulation on harmonised rules on fair access to and use of data. Retrieved from: https://digital-strategy.ec.europa.eu/en/library/data-act-proposal-regulation-harmonised-rules-fair-access-and-use-data

De Reuver, M., Sørensen, C., & Basole, R. C. (2018). The digital platform: a research agenda. *Journal of Information Technology*, 33(2), 124–135. https://doi.org/10.1057/s41265-016-0033-3

Elia, G., Margherita, A., & Passiante, G. (2020). Digital entrepreneurship ecosystem: How digital technologies and collective intelligence are reshaping the entrepreneurial process. *Technological Forecasting and Social Change*, 150, 119791.

Eriksson, T. & Heikkilä, M. (2023). Capabilities for data-driven innovation in B2B industrial companies, *Industrial Marketing Management*, 111, 158-172. https://doi.org/10.1016/j.indmarman.2023.04.005

Eriksson, T., Heikkilä, M. & Nummela, N. (2022). Crafting SME Business Model for International Expansion with Data-Driven Services, in Business Models and Firm Internationalisation, Christian Nielsen, Svetla T. Marinova, Marin A. Marinov (eds.) in the series of Routledge Frontiers in the Development of International Business, Management and Marketing

Ermakova, T., Blume, J., Fabian, B., Fomenko, E., Berlin, M., & Hauswirth, M. (2021). Beyond the hype: why do data-driven projects fail?. Proceedings of the 54th Hawaii International Conference on System Sciences.

European Commission. (2020). *The European Data Strategy*. Brussels: European Commission. Retrieved from https://ec.europa.eu/commission/presscorner/detail/en/fs_20_283

Eurostat (2022). Community Innovation Survey (CIS): Questionnaire library, QUESTION - Business model changes, Retrieved from https://ec.europa.eu/eurostat/cache/website/cis/Questions/Question_BUSSMOD.html

Foss, N. J., & Saebi, T. (2017). Fifteen years of research on business model innovation: How far have we come, and where should we go?. *Journal of management*, 43(1), 200-227.

Gandhi, R., Sharma, A., Mahoney, W., Sousan, W., Zhu, Q., & Laplante, P. (2011). Dimensions of cyber-attacks: Cultural, social, economic, and political. *IEEE Technology and Society Magazine*, 30(1), 28-38.

Gawer, A. & Srnicek, N. (2021). Online platforms: economic and societal effects, EPRS European Parliamentary Research Service: Brussels, Belgium Retrieved from: https://www.europarl.europa.eu/RegData/etudes/STUD/2021/656336/EPRS_STU(2021)656336_EN.pdf

Gelhaar, J., Groß, T., & Otto, B. (2021). A taxonomy for data ecosystems. Proceedings of the 54th Hawaii International Conference on System Sciences

Hair Jr, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2021). *A primer on partial least squares structural equation modeling (PLS-SEM)*. Sage publications.

Hartmann, M., Oriani, R. & Bateman, H., (2013). The performance effect of business model innovation: An empirical analysis of pension funds. Proceedings of the 35th DRUID Celebration Conference, pp. 17-19.

Hartmann, P. M., Zaki, M., Feldmann, N., & Neely, A. (2014). Big data for big business? A taxonomy of data-driven business models used by start-up firms. *Cambridge service alliance*, 1-29.

Heikkilä, M., Bouwman, H., & Heikkilä, J., (2018). From strategic goals to business model innovation paths: an exploratory study. *Journal of Small Business and Enterprise Development*, 25 (1), 107–128. https://doi.org/10.1108/JSBED-03-2017-0097.

Hein, A., Weking, J., Schreieck, M., Wiesche, M., Böhm, M., & Krcmar, H. (2019). Value co-creation practices in business-to-business platform ecosystems. *Electronic Markets*, *29*, 503-518.

Henseler, J., Ringle, C.M., Sarstedt, M., 2015. A new criterion for assessing discriminant validity in variance-based structural equation modelling. *Journal of the Academy of Marketing Science*, 43, 115–135. https://doi.org/10.1007/s11747-014-0403-8

Hubaux, J. P., & Juels, A. (2016). Privacy is dead, long live privacy. *Communications of the ACM*, 59(6), 39-41.

Janssen, M., Brous, P., Estevez, E., Barbosa, L. S., & Janowski, T. (2020). Data governance: Organizing data for trustworthy Artificial Intelligence. *Government Information Quarterly*, *37*(3), 101493.

Jetzek, T., Avital, M., & Bjorn-Andersen, N. (2014). Data-driven innovation through open government data. *Journal of Theoretical and Applied Electronic Commerce Research*, 9(2), 15-16. doi:10.4067/S0718-18762014000200008

Karimi, J., & Walter, Z. (2016). Corporate entrepreneurship, disruptive business model innovation adoption, and its performance: The case of the newspaper industry. *Long range planning*, 49(3), 342-360.

Kock, F., Berbekova, A., & Assaf, A. G. (2021). Understanding and managing the threat of common method bias: Detection, prevention and control. *Tourism Management*, 86, 104330.

Koskinen, J., Knaapi-Junnila, S. & Rantanen, M.M. (2019). What if we Had Fair, People-Centred Data Economy Ecosystems?, 2019 IEEE SmartWorld, Ubiquitous Intelligence & Computing, Advanced & Trusted Computing, Scalable Computing & Communications, Cloud & Big Data Computing, Internet of People and Smart City Innovation (SmartWorld/SCALCOM/UIC/ATC/CBDCom/IOP/SCI), Leicester, UK, 2019, pp. 329-334, doi: 10.1109/SmartWorld-UIC-ATC-SCALCOM-IOP-SCI.2019.00100.

Krämer, J. & Schnurr, D. (2021). Big data and digital markets contestability: Theory of harm and data access remedies, *Journal of Competition Law & Economics*, 18(2) 255–322, https://doi.org/10.1093/joclec/nhab015

Latifi, M. A., Bouwman, H., & Nikou, S. (2021a). ICT-Driven Business Model Innovation in SMEs: The Role of Organizational Capabilities, Firm Size and Age. BLED 2021 Proceedings

Latifi, M. A., Nikou, S., & Bouwman, H. (2021b). Business model innovation and firm performance: Exploring causal mechanisms in SMEs. *Technovation*, *107*, 102274.

Lange, H. E., Drews, P., & Höft, M. (2021). Realization of Data-Driven Business Models in Incumbent Companies: An Exploratory Study Based on the Resource-Based View. *ICIS 2021 Proceedings*.

Lindgardt, Z., Reeves, M., Stalk, G & Deimler, M. S. (2009). Business Model Innovation, When the Game Gets Tough, Change the Game, Boston: The Boston Consulting Group.

Marolt, M., Lenart, G., Borstnar, M. K., Vidmar, D., & Pucihar, A. (2018). SMEs Perspective on Business Model Innovation. 31th Bled eConference Digital Transformation – Meeting the Challenges (June 17 - 20, 2018, Bled, Slovenia).

Mazen, A. M. M., Hemmasi, M., & Lewis, M. F. (1987). Assessment of statistical power in contemporary strategy research. *Strategic Management Journal*, 8(4), 403-410.

MIT (2021). Capitalizing on the data economy. MIT Technology Review Insights, 10 p. Retrieved from https://wp.technologyreview.com/wp-content/uploads/2021/12/Capitalizing-on-the-data-economy_121521.pdf

Nahr, N., & Heikkilä, M. (2022). Uncovering the identity of Electronic Markets research through text mining techniques. *Electronic Markets*, 32(3), 1257-1277.

Oliveira, M. I. S., & Lóscio, B. F. (2018). What is a data ecosystem?. In Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age, pp.1-9.

Oliveira, M. I S., Barros Lima, G. D. F., & Farias Lóscio, B. (2019). Investigations into data ecosystems: a systematic mapping study. *Knowledge and Information Systems*, 61, 589-630.

Osterwalder, A., Pigneur, Y, & Tucci, C. (2005). Clarifying Business Models: Origins, Present, and Future of the Concept, *Communications of the Association for Information Systems*. 16(1), DOI: 10.17705/1CAIS.01601 Available at: https://aisel.aisnet.org/cais/vol16/iss1/1

Osterwalder, A., & Pigneur, Y. (2010). Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers. Wiley

Otto, B. & Jarke, M. (2019). Designing a multi-sided data platform: findings from the International Data Spaces case. *Electronic Markets*, 29, 561–580. https://doi.org/10.1007/s12525-019-00362-x

Parikka, H., Härkönen, T. & Sinipuro, J. (2021). A fair data economy is built upon collaboration, Sitra studies 191, June 2021, Retrieved from: https://www.sitra.fi/en/publications/a-fair-data-economy-is-built-upon-collaboration

Pohle, G. & Chapman, M. (2006). IBM's global CEO report 2006: business model innovation matters, *Strategy & Leadership*, 34(5), pp. 34-40.

Pucihar, A. (2020). The digital transformation journey: Content analysis of Electronic Markets articles and Bled eConference proceedings from 2012 to 2019. *Electronic Markets*, 30(1), 29–37. https://doi.org/10.1007/s12525-020-00406-7

Pucihar, A., Lenart, G., Kljajić Borštnar, M., Vidmar, D., & Marolt, M. (2019). Drivers and outcomes of business model innovation—Micro, small and medium-sized enterprises perspective. *Sustainability*, 11(2), 344.

Rantanen, M. M., Hyrynsalmi, S., & Hyrynsalmi, S. M. (2019, June). Towards ethical data ecosystems: A literature study. In 2019 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC) June, pp. 1-9.

Saaristo, A., & Heikkilä, M. (2022). A fair data-driven economy - The future of Europe, CCR Insights 2/2022, Turku School of Economics, Retrieved from: https://www.utu.fi/sites/default/files/public%3A//media/file/ccr_insights_2_2022_afairdatadriveneconomy_thefutureofeurope_v3_saavutettava%281%29.pdf

Saebi, T., Lien, L. and Foss, N. J. (2017) What drives business model adaptation? The impact of opportunities, threats and strategic orientation. *Long Range Planning*, 50 (5), pp. 567-581.

Seppälä, A., Birkstedt, T., & Mäntymäki, M. (2021). From ethical AI principles to governed AI. In Proceedings of the 42nd International Conference on Information Systems (ICIS2021).

Sitra (2021). Raw data (excel). Retrieved from : https://www.sitra.fi/en/publications/the-future-of-european-companies-in-data-economy-2021/

Soluk, J., Miroshnychenko, I., Kammerlander, N., & De Massis, A. (2021). Family influence and digital business model innovation: the enabling role of dynamic capabilities. *Entrepreneurship Theory and Practice*, 45(4), 867-905.

Spieth, P., & Schneider, S. (2016). Business model innovativeness: designing a formative measure for business model innovation. *Journal of business Economics*, 86, 671-696.

Strauch, M., Pidun, U., & zu Knyphausen-Aufseß, D. (2019). Process matters–How strategic decision-making process characteristics impact capital allocation efficiency. *Long Range Planning*, 52(2), 202-220.

Teece, D.J., (2010). Business models, business strategy and innovation. *Long Range Plan*ning. 43 (2–3), 172–194. https://doi.org/10.1016/j.lrp.2009.07.003.

Trabucchi, D. and Buganza, T. (2019). Data-driven innovation: switching the perspective on Big Data. *European Journal of Innovation Management*, 22(1), 23-40. https://doi.org/10.1108/EJIM-01-2018-0017

Ulander, M.; Vierula, T.; Ahomäki, M.; Kultanen, H. & Polifke, A. (2021). The Future of European Companies in Data Economy. Sitra. https://www.sitra.fi/en/publications/the-future-of-european-companies-in-data-economy-2021/

Vermanen, M., Rantanen, M.M., Koskinen, J. (2022). Privacy in Internet of Things Ecosystems – Prerequisite for the Ethical Data Collection and Use by Companies. In: Kreps, D., Davison, R., Komukai, T., Ishii, K. (eds) Human Choice and Digital by Default: Autonomy vs Digital Determination. HCC 2022. IFIP Advances in Information and Communication Technology, vol 656. Springer, Cham. https://doi.org/10.1007/978-3-031-15688-5_2

Wong, K. K. K. (2013). Partial least squares structural equation modeling (PLS-SEM) techniques using SmartPLS. *Marketing Bulletin*, 24(1), 1-32.

Zuboff, S. (2019). Surveillance capitalism and the challenge of collective action. In New labor forum, 28(1), pp. 10-29). Sage CA: Los Angeles, CA: SAGE Publications.

Appendix

Constructs and items

Construct	*Item*
Potential Benefit from data	**How much potential you see in the data economy to… (Scale: 1 = Strongly disagree...5 = Strongly agree)**
Item 1	Create additional revenue from current business model?
Item 2	Create new revenue streams from innovations
Item 3	Saving costs
BM change	**Has your company made significant changes in the business model (for example the following elements) during the last two years? (Scale: 1= No, none, 2= Yes, some, 3= Yes, significant)**
Item 1	Customers (Example: Traditionally we have been B2B company only but now we also/only have consumer customers.)
Item 2	Channels (Example: Traditionally we have sold our products through wholesalers but we have now opened up e-commerce site for direct access.)
Item 3	Value proposition (Example: Previously we have sold products but now we offer services where our own and others´ products are part of.)
Item 4	Activities (Example: We have stopped or started new activities - previously we have been purely a hardware company but now we have software coding also.)
Item 5	Resources (Example: We have acquired new or discarded old resources (factories, people, skills).)
Item 6	Partners (Example: We have new partners helping us in creation and production of our value proposition to our customers, e.g. offshoring, near-shoring.)
Item 7	Revenue models (Example: From one-off transactions to time-based subscription.)
Data ecosystem participation	**How well do the following statements describe the current status of your company? (Scale: 1 = does not describe at all ... 5 = describes very well)**
Item 1	Our company is part of one or more data ecosystems

Construct	***Item***
Item 2	We are planning to facilitate data ecosystems
Item 3	Our company is the facilitator of one or more data ecosystems
Fair & sustainable data usage practices	**Please indicate whether the following objectives of data use are taken into practice in your company (Scale: 1 = totally disagree ... 5 = totally agree)**
Item 1	We offer our customers easy tools to access and manage their personal and/or business data
Item 2	We communicate about the use of data in our corporate social responsibility reporting
Item 3	Data we gather from consumers is available for them to use in other services outside our company
Item 4	We have defined ethical rules for our organization for using, collecting and sharing data
Item 5	We strive to create trust by acting and behaving transparently
Item 6	Our digital services are designed to respect privacy
Item 7	Our digital services are designed to respect control over personal and business data
Item 8	Company's consideration of the rights of individuals and/or organizations exceeds statutory requirements
Data-driven innovation	**From the following data economy related statements, choose how well they describe your company's current business. (Scale 1 = does not describe at all ... 5 = describes very well)**
Item 1	In product development, we primarily invest in continuous and gradual improvements in our products.
Item 2	We wish to complement our data from several different data sources and interactive situations so that we can create the best possible experience for our customers.
Item 3	We continuously invest in the innovation of new products / services
Item 4	We create value from data, not just for our operations, but also for society, people, and environment.

DIGITALISATION IN ROPAX PORTS: THE TYPOLOGY OF AVAILABLE SOLUTIONS

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Sea logistics is slow to adopt digitalisation technologies and still relies heavily on old communication and data exchange methods. However, digitalising activities in RoPax ports can improve logistic chains. Managing and combining flows and services of cargo and passengers leads to several specific challenges, creating digitalisation opportunities. Data was gathered through desktop studies, interviews, site visits, and workshops to identify available and potential digital solutions. The research resulted in a typology of digital solutions classified based on their functional value and how much they impact logistics chains.

Keywords:
port,
digitalisation,
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1 Introduction

Digitalisation can allow companies to gain a competitive advantage, enabling new value creation (Kamalaldin et al., 2020) and opportunities for business model innovation. Business model innovation can stem from exploiting digital technologies and digital technology development at the firm (Cozzolino et al., 2018). Digitalisation's impact on business models has been covered in extensive literature reviews (Caputo et al., 2021). While many studies review the impact of the firms' capability to innovate business models with digitalisation's help or benefit from digital technologies, in this research, the perspective of digital solutions providers and developing their value propositions towards users of digital solutions interests us.

While industries face ubiquitous digitalisation in the sense it has concerned innovative and traditional sectors (Teece, 2010; Warner & Wäger, 2019), the specifics of digitalisation and emerging business models are context-specific. Studies have shown the effect of increasing digitalisation in the manufacturing industry regarding the solutions that manufacturing firms offer (Kohtamäki et al., 2019) and the specific value process the industry can gain from digitalisation (Kamalaldin et al., 2021). However, as Caputo et al. (2021) propose, continuing research is needed on different forms and archetypes of business models developed in recent years (Caputo et al., 2021).

Maritime logistics, which can be considered a network industry, faces a different set of challenges and thus can gain unique benefits from digitalisation, which brings forward the specific value digitalisation can create for business actors in the logistics chain. In particular, port authorities (PAs) are increasingly implementing digital solutions to improve coordination among many port stakeholders to make operations safer and more sustainable and efficient along logistics chains (Tijan et al., 2021; Tsvetkova, Gustafsson et al., 2021). This article explores the case of RoPax ports, referring to ports handling vessels capable of carrying wheeled cargo and passengers. Significant research has been devoted to digital solutions that large container ports have introduced (Haezendonck & Langenus, 2019; Henríquez et al., 2022). However, small to medium-sized RoPax ports face unique digitalisation challenges and opportunities that make it challenging to compare their efforts. In particular, small and medium-sized ports are limited regarding resources and investments (Del Giudice et al., 2021; Inkinen et al., 2019; von Malmborg, 2004) and have challenges in understanding digitalisation's influence on strategic business development (Inkinen et al., 2019). We are interested in the new value propositions emerging in the context of the RoPax port ecosystem and set out to explore how value is created through digitalisation in the logistics sector.

In the study of digital solutions that have been implemented or are under development in RoPax ports, we explore the various types of digital solutions regarding their functionalities and capabilities, thus value creation potential for the PAs who manage and develop the port area. Given the multitude of such solutions, understanding the differences and interrelations between these solutions is relevant, thus focusing on the digital business ecosystem that is forming and evolving (Hanelt & Schneider, 2020). This article presents the typology for relevant digital solutions for RoPax ports, forming the basis for understanding new value propositions in this underexplored empirical context. In addition to the solutions already implemented by ports and confirmed as relevant, this paper considers solutions under development through collaboration with port actors as part of the relevant digital solutions for RoPax ports.

2 Literature Review

2.1 Digitalisation and its Effect on Business Models and Ecosystems

Digitalisation facilitated transitioning the business model innovation within the same industry towards cross-industrial and ecosystem business model innovation (Kamalaldin et al., 2021; Leminen et al., 2020; Sjödin, Parida, Jovanovic et al., 2020). However, materialising digitalisation demands developed digital infrastructure, suitable technologies, and interoperability of data format.

Business model innovation and ecosystem transition go hand-by-hand. Business model innovation enabled by introducing new digital solutions often requires redefining industry structures and business ecosystems due to the change in information or operation flows (Huikkola et al., 2020; Linde et al., 2021). Hence, incumbent companies must consider ecosystem transition dynamics to stay alert for new value creation and capturing opportunities.

Regarding maritime logistics, the advent of 'smart ports' are opportunities to create more value through data-based services and data-driven business models. The general trend of 'infrastructure as a service' will likely affect ports' business models as the information about infrastructure use becomes more valuable than possessing that infrastructure (Tsvetkova et al., 2020). While coordinating activities among port stakeholders requires data sharing, more complex solutions like providing optimisation require data analysis, such as predictive and prescriptive analytics, to predict events and plan the optimal resource allocations (Haraldson et al., 2021). This brings the need for aligning value creation in multiple firms and affects incumbent actors in the port ecosystems and digital solutions providers.

2.2 Typologies for Digital Solutions in Industrial Sectors

Digitalisation-related literature focused on numerous perspectives on the types of business models and offerings stemming from digitalisation (Caputo et al., 2021; Kohtamäki et al., 2019). In particular, this literature has explicated the capabilities of digital solutions and smart products and how these capabilities enable new value creation: digital servitisation-based business models and value propositions that digitalisation can enable (Caputo et al., 2021; Coreynen et al., 2017; Porter & Heppelmann, 2014; Sjödin, Parida, Kohtamäki et al., 2020).

Digitalisation's impact on business models has been described in diverse industrial contexts. Kamaladin et al. (2021) studied digitalisation in the process industry and how it enables process innovation; Tsvetkova et al. (2021) studied maritime infrastructure digitalisation, mentioning that a digital solution's outcome differs based on the layers each solution addresses: infrastructure, service, and system layers.

Digitalisation in the maritime sector is changing the overall business and operational processes (Tsvetkova, Hellström et al., 2021). Like other areas in maritime logistics, port digitalisation's implications on the business models of relevant actors remain understudied. The current research on digitalisation in ports has been focused on phases of port digitalisation (Inkinen et al., 2021), influences of digitalisation on ports' business performance (Holmström et al., 2019), barriers for implementing digitalisation (Brunila et al., 2021), and the comparison of technological configurations (Hirata et al., 2022). Few studies approached the topic with empirical examples, mostly among large container ports, such as Amsterdam and Barcelona (Anwar et al., 2019; Heikkilä et al., 2022; Henríquez et al., 2022).

Compared to large container ports, smaller-sized ports face different difficulties concerning digitalisation (Inkinen et al., 2019). PAs have fewer resources for implementing digitalisation. Conversely, the traffic flow has a different pattern in RoPax ports due to the simultaneous involvement of passenger and cargo traffic.

Thus, the value digital solutions create is critical but unapparent regarding RoPax ports. We aim to contribute to understanding how value can be created through digitalisation in RoPax ports with our study.

3 Methodology

3.1 Research Design

The current research results from a three-year project devoted to developing digital solutions for smart RoPax ports. The project aimed to improve operation efficiency through collectively developed digital solutions for RoPax ports. Different types of actors were present: some are incumbent in the port operation ecosystem, such as PAs, shipping companies, and a set of digital solution providers, while others are new and aim to join the ecosystem based on their successful experience in another ecosystem.

We did an explorative case study (Mills et al., 2012) to develop a typology of digital solutions relevant to RoPax ports based on a systematic combining approach grounded in abductive logic. The research process was continuous and manifested in the evolution of a theoretical framework, empirical fieldwork, and case analysis (Dubois & Gadde, 2002). As we collected data on the available and planned digital solutions for RoPax ports and studied the empirical context, we iteratively improved the theoretical framework, constituting the basis for the typology of digital solutions in RoPax ports. As new data appeared, we reconsidered the typology and searched for categories allowing us to accommodate the empirical evidence. This iterative process involved six researchers and the collection of feedback from the project participants.

3.2 Data Collection and Analysis

We collected the data through desktop study, interviews (including site visits to ports), and group workshops. Data collection occurred inside and outside the focal project. We explored the available and potential digital solutions developed in the focal project. Conversely, we benchmarked six Northern European RoPax ports to identify digital solutions that PAs implemented or planned. We interviewed many relevant organisations regarding port digitalisation to support our understanding of the function and value of digital solutions. In particular, we interviewed municipality departments and digital solution providers in the urban and transportation sectors. The interviews lasted about an hour each; one or more managerial-level representatives participated in a semi-structured interview. The interviews were recorded and transcribed, and we made observation notes.

Altogether, 40 interviews were conducted during the project and were used in this paper's research. Table 1 presents a list of the primary research data. Based on the interview outcomes, we gathered additional secondary that interviewees mentioned as relevant documents.

Apart from interviews with individual actors, six field visits to ports and two workshops on identifying the types of digital solutions relevant to RoPax ports were organised. Field visits were made to the two focal project ports. One workshop focused on passenger traffic and another on cargo flow, where the participants identified the bottlenecks, goals, potential digital solutions, and collaboration steps for improving passenger and cargo traffic flows. The workshops were approximately two hours each, recorded and transcribed. Through these interactions, we better understood the current operations' challenges and development bottlenecks.

Table 1: Overview of Primary Data Sources

Companies	Informants' roles	Number of participants (number of interactions)	Form of interaction
Port authorities	PA: technical director, COO, sales and deputy managing director, and IT manager	5 (2)	Interviews
	Benchmarking RoPax ports	5 (5)	Interviews
Shipping company	Head of digitalisation	1 (2)	Interview; interview and site visit
	Head of IT group, captain, and cargo planner	4 (1)	Interview and site visit
	Terminal manager	1 (1)	Interview
	Sales manager	1 (1)	Interview
	Operative manager	1 (1)	Interview and site visit
Incumbent digital solution providers	Research leaders	2 (1)	Interview
	CEO and project manager	2 (1)	Interview
	CEO	1 (1)	Interview
	CEO and research leader	2 (1)	Interview
New digital solution providers	CPO and CFO	2 (1)	Interview
	Director and research leader	2 (1)	Interview
	CEO	1 (1)	Interview
	CEO	1 (1)	Interview
	Research leader	1 (1)	Interview
Project participants	Project update workshops	36 (9)	Workshop
Various stakeholders	Workshops devoted to identifying digital solutions	36 (2)	Workshop
Municipality, authorities, and external stakeholders	Land planning department and traffic planner	4 (1)	Interview
	Regional logistic coordinator	1 (1)	Interview
	Carbon neutral development	1 (1)	Interview
	Urban mobility developer	1 (1)	Interview
	City infostructure builder	1 (1)	Interview

	Traffic management department	1 (1)	Interview
	Road digital solution provider, CEO	1 (1)	Interview
Total		**78 (40)**	

Note: The numbers of unique participants were reported. The numbers of interviews and workshops we conducted or participated in are in parentheses.

It is important to note that a relatively bigger volume of data was collected in relation to the two ports that participated in the research project described above. The primary data regarding the other four ports included one-hour interviews with the representative of each PA. However, the secondary data such as annual reports and strategy documents have been studied to enrich the study. We acknowledge the possibility of other biases influencing the data collection process. We made efforts to minimize biases in the data collection process by including diverse perspectives and roles, using a variety of data collection methods, and continuously revising our theoretical framework. The typology was also validated with the project participants in one of the workshops and through other regular interactions, and its relevance and applicability was confirmed.

4 Findings

4.1 Challenges Faced by RoPax Ports

The coexistence of cargo, vehicle, and passenger flows in RoPax ports leads to several specific challenges, creating digitalisation opportunities. During the research project described in section 3, we have identified several recurring challenges that RoPax ports face.

Passenger flow improvement faces challenges regarding information sharing and safe travel. For instance, the unavailability of real-time intermodal traffic information causes delays along the transit journeys to and from the terminal; relevant information comprises transport connections, schedules, services, and notifications on traffic disturbances. During check-in, security, and embarkation procedures cause unnecessary crowding and queuing in the passenger terminal, which the uptake and implementation of digital solutions could alleviate. The technology could take safety and security matters to another level as tools for managing crowds and identifying passengers' unusual behaviour or unattended luggage.

The multimodal transport chain is hampered by uncoordinated road traffic pulses and congestion at ship arrivals and departures inside the port, its associated urban area, and its main approach roads – a problem less likely to diminish with residential and recreational urban areas expanding and the associated shrinkage of the port facilities and stowing areas. Furthermore, the vessels' cargo capacity will likely grow, further worsening the overcrowding of the road network. Traffic jams, in their turn, will increase idling and unnecessary emissions.

Due to relatively short distances over the sea and ship turnaround times in ports, the RoPax short sea segment is more time-sensitive concerning timely and efficient loading and unloading procedures, as delays may be difficult to compensate with speed out at sea. Accumulating trucks in the port area and using this area as a waiting or parking area long before the actual departure is another unwanted phenomenon. This is principally due to a limited number of dedicated resting and parking areas for trucks in the port's vicinity. Introducing an integral just-in-time (JIT) solution with an associated pre-parking concept offered to road haulage customers would benefit all stakeholders' operations and performance. Truck drivers would be informed and called in when their vehicle could drive to the port area through a dedicated application or another interface. To a predetermined degree, the given slot times would enhance specific trucks' orderly and timely arrival in certain batches, benefiting the actual optimal onboard stowing plan and order.

4.2 Typology Development

During the research, it became apparent that digital solutions designed for or implemented in RoPax ports provide different functions – adding value to port actors – and involve smaller or bigger constellations of actors and respective data. Considering their effect, the solutions ranged from those addressing limited activities within one port actor's boundaries to those affecting the efficiency of whole logistics chains. Certain solutions, such as those for situational awareness (SA) in ports, could provide data for other solutions that offer, for example, cargo or passenger flow optimisation.

The solutions were categorised into two dimensions. The first dimension includes six capabilities and functions of digital solutions: Communication, Visualisation, Monitoring, Control & Automation, Prediction, and Optimisation. The capabilities were inspired by the four capabilities proposed by Porter and Heppelmann (2014) and further developed with three additional capabilities. Communication refers to the ability of digital solutions to exchange information between different actors, whereas Visualisation concerns the presentation of data in an easily understandable way. Monitoring and Control & Automation capabilities allow for real-time monitoring and control of port operations, respectively. Prediction involves the use of data to anticipate events and potential problems, and Optimisation refers to the ability to improve efficiency and performance. Examples of solutions that exhibit these capabilities are digital twins of port infrastructure for Visualisation or Monitoring, traffic and cargo management systems for Control & Automation, and predictive algorithms for Prediction. The typology development includes these capabilities and functions as part of the framework for analysing and classifying digital solutions in RoPax ports.

The second dimension included three layers of digitalising port operations, following the layers of digitalisation in maritime logistics (Tsvetkova, Gustafsson et al., 2021): infrastructure, service, and system layers. The infrastructure layer includes solutions directly related to efficiently operating and maintaining maritime infrastructure, such as digital twins of port infrastructure and smart buoys, that help identify maintenance needs through predictive algorithms. The service layer includes solutions to improve how the users utilise this infrastructure. These solutions include managing the throughput of traffic and cargo and vessel flows through ports, so the maritime infrastructure is utilised efficiently, and the service quality is maximised for cargo shippers, ship operators, and other parties relying on port infrastructure. Combining the data related to maritime infrastructure and cargo flows makes it possible to achieve efficiencies on a larger scale at a system level, ensuring a smart cargo and passenger flow through digital corridors, end-to-end journeys, and optimising whole supply chains.

4.3 Analysis of Digital Solutions for RoPax Ports

We identified various solutions implemented or planned for implementation in the RoPax ports we studied (marked in blue in Figure 1) and the solutions developed or discussed within the case project (marked in yellow in Figure 1).

One finding is that RoPax ports strongly focus on digitising and improving communication among the many actors. Without digitising documentation flow and notification processes, more profound digitalisation and integration efforts across organisations is infeasible. The solutions the studied ports mention mostly focus on documentation exchange and notifications regarding cargo and vessel arrival. Several solutions relate to communication for passenger flow, creating an intriguing opportunity for improving customer satisfaction concerning passengers as customers of RoPax terminals. Moreover, using digital solutions, such as mobile applications or other interfaces, could help streamline security and embarkation procedures, reducing crowding and queuing in passenger terminals.

Regarding monitoring, ports have implemented solutions for monitoring processes directly related to the infrastructure layer, such as energy use or air quality in the port area. Naturally, security monitoring exists in any RoPax port. However, new solutions were proposed for more automated security monitoring, including, for example, automated identification of abandoned luggage or identification of crowding in the terminal. These solutions can help to address safety and security matters as discussed in section 3.1. The project also developed solutions for identifying and counting passengers and vehicles, which can provide input for several automation or optimisation solutions.

Control and automation are seemingly high on the agenda for many ports, as passenger and vehicle flow automation can save costs, improve customer satisfaction, and reduce the workload of port workers. Many overlaps between the solutions developed within the case project and solutions were implemented (often partly) or planned by RoPax ports, confirming that the value of these solutions is indisputable.

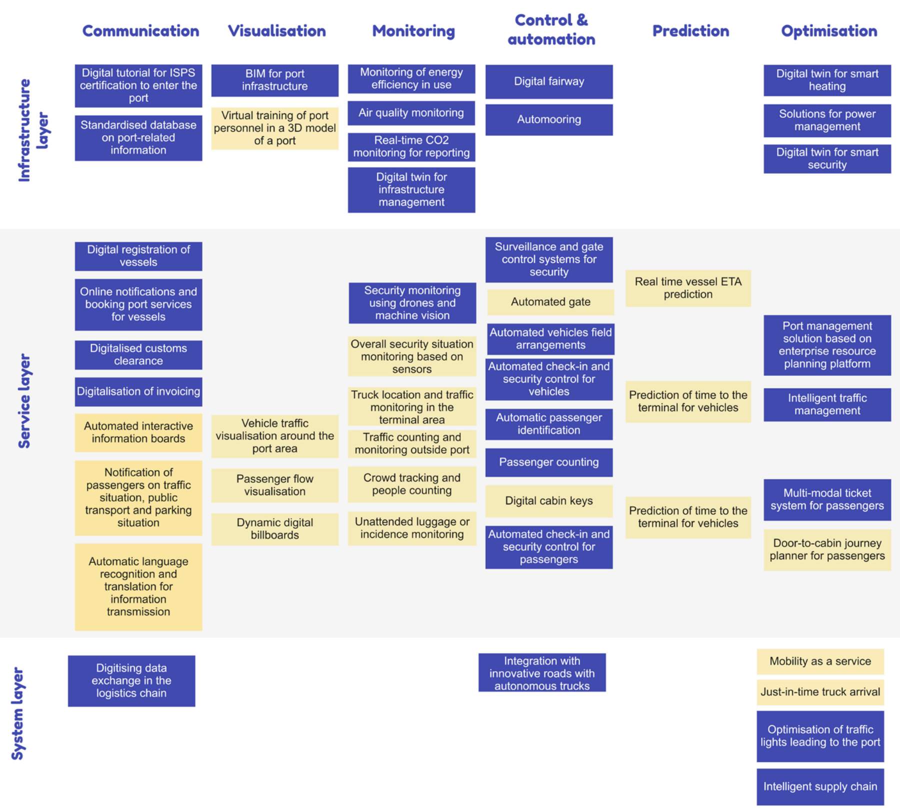

Figure 1: The typology of digital solutions in RoPax ports

Similar to visualisation, solutions falling under prediction capability are crucial for human decision-making in RoPax terminals or optimisation solutions. There are opportunities for predicting critical data points concerning passenger, vehicle, and vessel flow, which can ultimately help improve the timely and efficient loading and unloading procedures, reducing delays that may be difficult to compensate with speed out at sea.

Regarding optimisation, ports have implemented several solutions addressing the infrastructure layer and are thus limited to the scope of a RoPax port (heat and power optimisation in the terminal area, smart security). Other solutions aim at integrating several processes going beyond actual port operations. However, the system layer is addressed much less. While RoPax ports have mentioned intelligent supply chains, it has yet to be developed into a working concept. The case project has produced concepts for several optimisation solutions. For instance, passengers' end-to-end journey planner can reduce the passengers' need for private vehicles when arriving at the port, thereby alleviating traffic congestion in the port area. Another solution for integrating truck traffic flow with port and vessel operations can enhance specific trucks' orderly and timely arrival in certain batches, benefiting the actual optimal onboard stowing plan and order.

5 Discussion and Conclusions

The digitalisation of end-to-end supply chains can fundamentally change logistics and thus has implications for the future management of maritime infrastructure. Specifically, increased transparency and a better understanding of cargo and vessel flow through ports are inputs for smarter decisions regarding port infrastructure investments going forward. Combining the data related to maritime infrastructure and cargo flows makes it possible to achieve efficiencies on a larger scale at a system level, ensuring a smart cargo flow through digital corridors and optimising whole supply chains. Such synchronous modality can allow significant transport cost reductions and optimum utilisation of transport infrastructure while adhering to the respective delivery conditions (Tsvetkova, Gustafsson et al., 2021).

We observed potential differences between the technology push and market pull regarding digital solutions for the RoPax port. In particular, solutions for visualisation or prediction developed in the case project can provide valuable input for other functions, such as optimisation or control. It is necessary to understand, for example, how predictions or visualisations of terminal flows can be used in, e.g. security management or passenger and cargo flow optimisation to develop a viable business offering. Besides the unclear value proposition of such solutions, we identified another challenge related to the digitalisation in RoPax ports, namely, the difficulty of justifying investment in digital infrastructure that may not directly benefit the port authorities but require resources from them.

While earlier studies (Kohtamäki et al., 2019) focused on making typologies of different digital BMs, this study specifically addresses the value propositions of digital solutions and their place in a functioning digital business ecosystem. The typology of digital solutions for RoPax ports can be a benchmark for different solution providers to identify their solution's role and the value it can create for port actors. Simultaneously, it identifies common trends in digitalising RoPax ports, which can be a reference for PAs and port actors to discover new technological opportunities. For example, a port operator could use this typology to identify areas where they could improve their operations using digital solutions, such as optimizing cargo flows or improving situational awareness in the port. A digital solution provider, on the other hand, could use this typology to identify gaps in the market and develop new solutions that address specific capabilities or functions that are currently lacking in the market. By using this typology, both port actors and solution providers can make more informed decisions and identify new opportunities for innovation.

Further research would be needed to better understand how the structure of port business ecosystems shapes value creation. In particular, the interplay between the value captured by PAs and shipping companies from their customers is interesting regarding digitalising port operations. Further, this article's typology is based on earlier studies' proposed capabilities but adjusted with empirical evidence. While we believe it captures the current digitalisation state in RoPax ports, the evolving nature of digital solutions may necessitate future revisions. An example is the 'autonomy' capability, initially part of Porter and Heppelman's (2014) four capabilities, but omitted in this typology as no solutions provided it. Autonomous shipping may require RoPax ports to incorporate autonomous capabilities in the future. We recognize geographical limitations as our study focused solely on ports in Northern Europe. Furthermore, this typology is tailored to the RoPax shipping context, which enhances its empirical significance, but also restricts its applicability to other ports and shipping modes. A comparative study of the types of digital solutions in different shipping segments is a promising avenue for further research.

References

Anwar, M., Henesey, L., & Casalicchio, E. (2019). Digitalization in Container Terminal Logistics : A Literature Review. 1–25.

Brunila, O. P., Kunnaala-Hyrkki, V., & Inkinen, T. (2021). Hindrances in port digitalization? Identifying problems in adoption and implementation. European Transport Research Review, 13(1).

Caputo, A., Pizzi, S., Pellegrini, M. M., & Dabić, M. (2021). Digitalization and business models: Where are we going? A science map of the field. Journal of Business Research, 123, 489–501.

Coreynen, W., Matthyssens, P., & van Bockhaven, W. (2017). Boosting servitization through digitization: Pathways and dynamic resource configurations for manufacturers. Industrial Marketing Management, 60, 42–53.

Cozzolino, A., Verona, G., & Rothaermel, F. T. (2018). Unpacking the Disruption Process: New Technology, Business Models, and Incumbent Adaptation. Journal of Management Studies, 55(7), 1166–1202.

Dubois, A., & Gadde, L. E. (2002). Systematic combining: An abductive approach to case research. Journal of Business Research, 55(7), 553–560

Hanelt, A., & Schneider, S. (2020). Building Platform Ecosystems for IoT: Exploring the Impact on Industrial-Age Firms Digital Transformation View project Management of Social and Sustainable Business Models View project.

Haraldson, S., Lind, M., Breitenbach, S., Croston, J. C., Karlsson, M., & Hirt, G. (2021). The Port as a Set of Socio-technical Systems: A Multi-organisational View. In Maritime Informatics.

Heikkilä, M., Saarni, J., & Saurama, A. (2022). Innovation in Smart Ports: Future Directions of Digitalization in Container Ports. Journal of Marine Science and Engineering, 10(12).

Henríquez, R., Martínez de Osés, F. X., & Martínez Marín, J. E. (2022). Technological drivers of seaports' business model innovation: An exploratory case study on the port of Barcelona. Research in Transportation Business & Management, 43, 100803.

Hirata, E., Watanabe, D., & Lambrou, M. (2022). Shipping Digitalization and Automation for the Smart Port. Supply Chain - Recent Advances and New Perspectives in the Industry 4.0 Era [Working Title].

Holmström, J., Holweg, M., Lawson, B., Pil, F. K., & Wagner, S. M. (2019). The digitalization of operations and supply chain management: Theoretical and methodological implications. Journal of Operations Management, 65(8), 728–734.

Huikkola, T., Rabetino, R., Kohtamäki, M., & Gebauer, H. (2020). Firm boundaries in servitization: Interplay and repositioning practices. Industrial Marketing Management, 90, 90–105.

Inkinen, T., Helminen, R., & Saarikoski, J. (2019). Port digitalization with open data: Challenges, opportunities, and integrations. Journal of Open Innovation: Technology, Market, and Complexity, 5(2).

Inkinen, T., Helminen, R., & Saarikoski, J. (2021). Technological trajectories and scenarios in seaport digitalization. Research in Transportation Business and Management, 41, 2210–5395.

Kamalaldin, A., Linde, L., Sjödin, D., & Parida, V. (2020). Transforming provider-customer relationships in digital servitization: A relational view on digitalization. Industrial Marketing Management, 89, 306–325.

Kamalaldin, A., Sjödin, D., Hullova, D., & Parida, V. (2021). Configuring ecosystem strategies for digitally enabled process innovation: A framework for equipment suppliers in the process industries. Technovation, 105, 102250.

Kohtamäki, M., Parida, V., Oghazi, P., Gebauer, H., & Baines, T. (2019). Digital servitization business models in ecosystems: A theory of the firm. Journal of Business Research, 104, 380–392.

Leminen, S., Rajahonka, M., Wendelin, R., & Westerlund, M. (2020). Industrial internet of things business models in the machine-to-machine context. Industrial Marketing Management, 84, 298–311.

Linde, L., Sjödin, D., Parida, V., & Wincent, J. (2021). Dynamic capabilities for ecosystem orchestration A capability-based framework for smart city innovation initiatives. Technological Forecasting and Social Change, 166, 120614.

Mills, Al. J., Durepos, G., & Wiebe, E. (2012). Exploratory Case Study. In Encyclopedia of Case Study Research. SAGE Publications.

Porter, M. E., & Heppelmann, J. E. (2014). How Smart, Connected Products Are Transforming Competition. Harvard Business Review, 92(11), 64.

Sjödin, D., Parida, V., Jovanovic, M., & Visnjic, I. (2020). Value creation and value capture alignment in business model innovation: A process view on outcome-based business models. Journal of Product Innovation Management, 37(2), 158–183.

Sjödin, D., Parida, V., Kohtamäki, M., & Wincent, J. (2020). An agile co-creation process for digital servitization: A micro-service innovation approach. Journal of Business Research, 112, 478–491.

Teece, D. J. (2010). Business models, business strategy and innovation. Long Range Planning, 43(2–3), 172–194.

Tijan, E., Jović, M., Aksentijević, S., & Pucihar, A. (2021). Digital transformation in the maritime transport sector. Technological Forecasting and Social Change, 170, 120879.

Tsvetkova, A., Gustafsson, M., & Wikström, K. (2020). The digitalization of port infrastructure.

Tsvetkova, A., Gustafsson, M., & Wikström, K. (2021). Digitalizing maritime transport: digital innovation as a catalyzer of sustainable transformation. A Modern Guide to the Digitalization of Infrastructure, 123–148.

Tsvetkova, A., Hellström, M., & Ringbom, H. (2021). Creating value through product-service-software systems in institutionalized ecosystems – The case of autonomous ships. Industrial Marketing Management, 99, 16–27.

Warner, K. S. R., & Wäger, M. (2019). Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal. Long Range Planning, 52(3), 326–349.

MALICIOUS INSIDER THREAT TYPES – AN EMPIRICAL ANALYSIS

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Malicious insider threats represent a particular challenge not only for defense, but also for research, as it is estimated there is a high number of unreported cases. Current taxonomies and typologies usually focus on specific aspects, such as goal or motivation, and tend to have tight boundaries. A number of malicious insider threat attack scenarios were identified in our research through qualitative interviews, enhanced with a game-based creative approach. The resulting data was used to develop a malicious insider threat typology in an empirical bottom-up approach. We developed an analysis scheme from existing taxonomies and typologies and used it in an empirical analysis of malicious insider roles and attack scenarios. We were able to identify eleven archetypes of malicious insider threats considering multiple facettes. This paper describes the analysis and the identified types.

Keywords:
insider threats, typology, information security, Bled eConference, research paper

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1 Introduction

The European Union Agency for Cybersecurity (ENISA) defines an insider threat as "an action that may result in an incident, performed by someone or a group of people affiliated with or working for the potential victim" (ENISA, 2020). Insider threats can also be distinguished as accidental or malicious (intentional). In this work we take a close look at malicious insider threats. These represent a particular challenge not only for actual protection, but also for research, as it is estimated there is a high number of unreported cases. Organizations tend not to disclose information on malicious insider threats (e.g., not to lose the trust of customers or partners), and typically only cases with news value become public. Thus, the cases examined in the research are not necessarily representing the current insider threat landscape. In general, information systems literature such as the UMISPC (Moody et al., 2018) addresses the field of insider threats primarily regarding accidental insider threats while the malicious type is usually not considered.

As we collected plenty of malicious insider threat attack scenarios in our research through an interview survey and a creative approach (using the serious game "Operation Digital Butterfly" (Hofmeier, 2021), which is designed to collect plausible insider roles and attacks), we use this data to develop a malicious insider threat typology.

Current taxonomies and typologies usually focus on specific aspects, such as goal or motivation, and tend to have tight boundaries. For example, the ENISA Threat Landscape Report distinguishes five types of insider threats by rationales and objectives (ENISA, 2020): *careless workers* mishandling data, violating policies or installing unauthorized applications; *inside agents* who steal information on behalf of outsiders; *disgruntled employees* who seek to harm their organization; *malicious insiders* who use existing privileges to steal data for personal gain; *third-parties* who compromise security through intelligence, misuse or malicious access to or use of an asset. Cappelli et al. distinguish three types of insider threats by objectives in the “CERT Guide to Insider Threats” (Cappelli et al., 2012): *theft* (e.g., of intellectual property or other data), *sabotage* (malicious manipulation of data or processes or causing reputational damage) and *fraud* (e.g., stealing financial goods). The German Insurance Association (GDV) defines four perpetrator types (Bundeskriminalamt, 2020): The *crisis perpetrator* who is triggered by crisis events in private or professional life that threaten status and lifestyle; the *inconspicuous* who takes advantage of an emerging opportunity; the *perpetrator with an economic-criminological disorder* who actively seeks or creates opportunities to commit a crime, and the *dependent* who is usually hierarchically subordinate to a main offender or owes the main offender a favor and fears repression in case of refusal to cooperate. Some taxonomies and typologies distinguish by insider position (Cole & Ring, 2005; Magklaras & Furnell, 2001; Bundesamt für Sicherheit in der Informationstechnik, 2018) or attack vector (Phyo & Furnell, 2004). Homoliak et al. (2019) provide a comprehensive taxonomy with multiple aspects.

However, there are only a few empirically based typologies of malicious insider threats in terms of comprehensive archetypes. Therefore, the aim of this research is to develop archetypes of malicious insider threats using our collected data in an empirical bottom-up approach.

2 Analytical Approach

We analyzed malicious insider threat roles and attack scenarios using scheme-based content analysis to develop the typology.

2.1 Material for Analysis

The data used in this analysis is interviews and serious game results. Interviews and games were part of LIONS and NutriSafe research projects.

The interviews were conducted from December 2021 to August 2022 with 13 experts from various organizations (table 1). The experts were selected from the LIONS project research network, while the selection criterion was the possibility of points of contact with the subject of malicious insiders. The interviews were structured using an interview guide, and topics were real-world cases, plausible scenarios, and assessments of malicious insider threats. The interviews were recorded, and summarized. Summaries were then sent to the respective interview partner(s) for a review regarding correctness (and anonymization). The interview study collected 21 instances or groups of attack scenarios, subject to the analysis presented in this paper.

Table 1: Interviews used in the analysis (anonymized)

Organization	Interview partner(s)
Consulting (logistics)	Director
Energy	Senior Expert Penetration Testing
Energy	Senior Expert Cyber Forensics Senior Expert Cyber Forensics Compliance Investigations
Energy	Information Security Manager
Civil engineering	Manager Software Development
Security technology	Information Security Officer
n.a.	Information Security Expert
n.a.	People Manager
Industrial software	Managing director
Public authority	Information Technology Manager
Security software	CEO

Table 2: Serious game iterations

Date	Game board	Players	Attack Scenarios
May 2020	Meat Production	6	2
Jul 2020	Meat Production	15	4
Oct 2020	Logistics Hub	7	3
Nov 2020	Logistics Hub	15	4
Mar 2021	Logistics Hub	12	3
Sep 2021	Travel Management	12	3
Feb 2022	Travel Management	10	6
Feb 2022	Travel Management	9	6
Feb 2022	Travel Management	9	6
Jul 2022	Logistics Hub	13	3

Because interviews have limited capabilities regarding the field of malicious insiders (e.g., typically, there is no knowledge of intentions or motivations of perpetrators), a creative game-based approach was also used. The serious game "Operation Digital Butterfly" (Hofmeier, 2021) – in an earlier version "Operation Digital Ant" (Hofmeier, 2020; Hofmeier & Lechner, 2021) – was developed – using a design science approach according to Hevner et al. (2004) – to generate fictional but realistic attack scenarios by malicious insiders. "Operation Digital Butterfly" is a tabletop game with a game board in the center, depicting an infrastructure of an organization. Three to four teams compete against each other in creating roles and attacks of malicious insiders, using role cards and scene cards. The game board describes the environment wherein insider threats take place. During our research, the game has been played with three different game boards: slaughterhouse and cutting plant, logistics hub with warehouse, and travel management in a public authority. Each team develops an insider role, an attack, and a security measure using a card deck. The cards structure the team discussion and the presentation of the attack vector and security measure developed in the team discussion. The teams are instructed to answer four questions on the role card to guide the creative design of attack measures:

- Who is the insider (position in the organization)?
- What does the insider want to achieve (intention)?
- Why does the insider want that (motivation)?
- How does the insider justify this to himself/herself (neutralization)?

The attack is developed using the scene cards. The filmmaking metaphor is used to make development and descriptions of attacks easy – also for players not used to formal notations. A threat is a sequence of scenes. This way, each team can tell their fictional insider attack by using a sequence of scenes.

To make the game more fun and to raise awareness about countermeasures to insider attacks, each team fills out a security measure card. Teams are instructed to anticipate possible attacks from the other teams (the roles are known) and develop an adequate countermeasure. This measure is valid for the attack plans of all teams and is then taken into account when rating the attacks. The winning team is determined through a rating system, in which the teams rate each other by three given categories: (1) Plausibility of role, (2) plausibility of the attack story, and (3) damage potential. Each team can give up to ten points for each category to the other teams. Note that the most important category for later analyses is "plausibility". This incentivizes that the developed attacks and roles are – to some extent – realistic and fit the profile of the role. The "damage potential" category makes the teams more likely to develop attacks that cause significant damage and therefore are of particular interest in security research. The game is also accompanied by a closing discussion, focusing on possible countermeasures regarding the attack scenarios developed in the game.

The game is scientifically validated (Hofmeier & Lechner, 2021) and designed to create plausible insider roles with intention, motivation, and neutralization (Sykes & Matza, 1957) combined with according attack paths. It also features plausibility checks (e.g., through team rating criteria and following external validation) of roles and scenarios. In ten game performances from May 2020 to July 2022 with participants from research institutions, companies, and public authorities, 40 attack scenarios – with at least medium plausibility each – were developed (table 2).

2.2 Analysis Scheme

To develop types that are as complete as possible, our aim was to look at as many aspects of malicious insider threats as possible. Therefore, we prepared an analysis scheme based on various existing taxonomies (see table 3), which partly follows the comprehensive taxonomy by Homoliak et al. (2019), who examined and combined various existing taxonomies. We grouped the different type aspects in six groups of characteristics: intention(s) or outcome, motivation, insider position, attack vector, timing, and psychosocial characteristics.

2.3 Analytical Procedure

Using this scheme as a two-dimensional category system following the qualitative content analysis methodology according to Mayring (2008), we analyzed the material in two iterations. In the first iteration, the cases (from the interviews as well as from the game results) were examined one by one. Each considered case was compared with the already extracted types. In case of similarity, it was assigned to the respective type, which is sometimes also accompanied by slight changes to the type (e.g. adding information to a category); in case of contrast with the existing types, a new type with the characteristics of the given case was created. In the second iteration, the cases were examined again by another researcher and in a different order to test whether each case had an adequate counterpart in the types. Among other things, this should prevent a sequence effect as well as minimize the effect of subjectivity.

Table 3: Taxonomy-based analysis scheme

Type characteristics	**Aspects**	**Source(s)**
Intentions / outcome	theft (of IP), sabotage, fraud, miscellaneous	Cappelli et al. (2012)
	espionage, IP theft, unauthorized disclosure, sabotage, fraud, workplace violence	MITRE (2022)
	information theft, harm to orgnization, personal gain	ENISA (2020)
Motivation	levels: self-motivated, planted, recruited	Cole & Ring (2005)
	motivation: financial, political, personal	Cole & Ring (2005)
	economic-criminological disorder, crisis, opportunity, dependency	BKA (2020)
Insider position	topology: pure insider, inside associate, inside affiliate, outside affiliate	Cole & Ring (2005)
	system role: system masters, advanced users, application users, none	Magklaras & Furnell (2001)
	physical access to control systems, privileged users, third-party employees	BSI (2018)
Attack vector	manifestation level: physical world, network, operating system, application, data	Phyo & Furnell (2004)
Timing	duration: long-term, short-term, one-time	Homoliak et al. (2019)
	point in time: before job termination, after job termination	Homoliak et al. (2019)
Psychosocial characteristics	levels: psychological, social, socioeconomic	-
	indicators: disregard for authority, disgruntlement, anger management issues, confrontational behavior, disengagement, not accepting criticism, absenteeism, self-centeredness, performance, lack of dependability, personal issues, stress	Greitzer et al. (2013)
	Personal vulnerabilities: introversion, social and personal frustrations, computer dependency, ethical "flexibility", reduced loyalty, entitlement, lack of empathy	Shaw et al. (1998)

3 Malicious Insider Threat Types

Based on the analysis of the interview results as well as the attack scenarios from the game, we identified eleven insider threat types. Below, the individual types are described according to the taxonomy-based analysis scheme.

3.1 Disgruntled Employee / Disgruntled Leaver

The disgruntled employee is motivated primarily by revenge and seeking “justice”. This type is discuss in may insider threat studies – e.g., in the Insider Threat Study (Keeney et al., 2005). The wish for revenge can be based on different causes, such as being fired, having disputes with supervisors or management, a lack of recognition, unequal salary structures, or missed salary increases, which cause a - subjective - feeling of injustice. Here, we also discuss the disgruntled leaver as a subtype, which has the same characteristics except that it related to a job termination (either by the organization or the employee resulting from a perception of injustice). This insider type usually seeks to harm the organization, typically by sabotaging or causing reputational damage through physical sabotage (e.g., of products or machines) or data manipulation. A disgruntled employee is naturally an insider who has a contract with the organization, while he or she can have any position in any department within the organization. An incident is typically a one-time event at any time during employment or after job termination (disgruntled leaver).

3.2 Data Transfer to Competition

In this threat type, an insider takes data such as intellectual property (e.g., source code, blueprints) or other valuable information (e.g., customer data) with him or her when transferring to a competitor. The act is naturally a one-time event during job termination and typically based on an aim for personal gain. Still, it can also be additionally motivated by revenge or curiosity. Insiders of this type can be pure insiders or external contractors but are limited to persons with access to valuable data (e.g., files, applications, databases).

3.3 Industry Espionage

Insiders engaging in industrial espionage use given privileges to steal valuable information such as intellectual property while having any position with access to data (internal or external positions). They are typically recruited by external actors, typically using bribes. The willingness to accept bribes can be mediated by factors such as job satisfaction or financial situation. The act is usually a one-time event at any time during association with the organization.

3.4 State Espionage

Similar to the industry espionage type, insiders engaging in state espionage use given privileges to steal critical information while having any position with access to data. They are recruited by external agents, are bribed or blackmailed (e.g., after being compromised privately). The willingness to accept bribes or give in to blackmail can be mediated by additional factors such as job satisfaction, financial situation, or family circumstances. As with the industry espionage type, the act is usually a one-time event at any time.

3.5 Taking Advantage of Privileges for Personal Gain

When insiders take advantage of privileges to achieve personal gain, the motivations are manifold: in some cases, there are financial problems (e.g., through having too high lifestyle standards or depts), and others subjectively think they deserve the profit (which is not granted to them by the organization), and some are envious (e.g., of customers when it comes to expensive products or services). To achieve personal gain, these insiders either simply steal property (e.g., IT equipment) or use their access to IT systems to commit fraud. The actions (theft or fraud) often start small and then become more in case of success until the point where the actions become conspicuous. So, it is typically a series of events.

3.6 Unauthorized Inspection of Personal Data

Individuals who unauthorizedly inspect personal data are users or admins - typically pure insiders - with insights into databases (either directly or via applications). The act is usually short-term and motivated either by personal reasons (such as curiosity or having a crush on a person residing in the database) or by political agenda (e.g., looking up personal data of perceived enemies).

3.7 Intellectual Property Sale

When intellectual property is sold on black marketplaces (e.g., on the darknet), the perpetrators are usually people with technical skills, such as administrators or developers, and thus typically pure insiders. In this case, intellectual property can mean blueprints of products or source code of software products. When it comes to leaked source code, the risk of further cybersecurity incidents is also enhanced. The motivation resides in personal (financial) gain and opportunity through access to valuable data (e.g., repositories), supported by low commitment and ethical flexibility.

3.8 Whistleblowers

Whistleblowers follow their political or moral understanding and seek to publish critical data of the organization (e.g., data that are evidence immoral in the eyes of the perpetrator). These individuals identify themselves as whistleblowers - even if they aren't (according to the perceptions of the general society). They feel the organization deserves the harm and to act for the greater good. These views correspond with the neutralization techniques "denial of the victim" and "appeal to higher loyalties" (Sykes & Matza, 1957). In principle, this type of perpetrator can be anyone with access to relevant data, including third parties. In some cases, the insider might be encouraged by (external) parties. The act is usually a one-time event during affiliation with the organization.

3.9 Politically Motivated Sabotage

As with the whistleblower type, politically motivated saboteurs think that the victimized organization deserves the harm and that they act for the greater good (neutralization techniques "denial of victim" and "appeal to higher loyalties" (Sykes & Matza, 1957). But these individuals seek to actively harm the organization by (physical or digital) sabotage or causing reputational damage (e.g., by publishing compromising information) because they reject the organization. This primarily applies to public sector organizations or companies where the morality of the objectives or methods is in question. Perpetrators of this type can have any position in the organization, while the attack vector they choose depends on their position and the corresponding skills and opportunities.

3.10 Extortion

In the extortion type, insiders blackmail the organization with the help of their physical or digital access privileges. The target can be data (e.g., using ransomware) or physical goods (e.g., poisoning food in the supply chain).

These perpetrators are typically financially motivated, which can reside in financial problems. They also might have a criminal background or psychological issues. In general, they have low job commitment and might misjudge the consequences of their actions. They can have any position in the organization, while the attack vector they choose depends on their position and the corresponding skills and opportunities.

3.11 Illegal Use of IT Infrastructure

In this type, individuals use the organization's IT infrastructure for their own illegal purposes for a long time, such as using storage devices for storing and providing illegal material or using infrastructure for illegal transactions (e.g., money laundering). Naturally, this type of perpetrator requires information technology skills and access to IT infrastructure. IT staff such as system administrators are typical for this insider threat actor.

4 Conclusion

We developed an analysis scheme from existing taxonomies and typologies for extracting malicious insider threat archetypes. We identified eleven types of malicious insider threats using this scheme in an empirical analysis of real-world and fictional but realistic (and plausible) adversarial insider roles and attack scenarios. These types consider multiple facets and thus exceed existing typologies.

However, there are some limitations. The types are based on the analyzed material and the subjectivity of an analyzing researcher. Therefore, the typology may not be complete, and new types may be identified by analyzing additional material using the developed analysis scheme.

The identified types are important for risk analysis in practice (e.g., scenario-based risk assessment) and a basis for further research. In addition, we found that a creative approach (here in the form of a serious game) could extend the results, particularly regarding intentions and motivations. In comparison with existing taxonomies and typologies, the typology presented in this paper features more dimensions (especially taxonomies are typically one-dimensional) and more types (e.g., politically motivated insiders are missing in other typologies). This way, our work enables a better understanding of malicious insider threats, a better understanding of the variety of malicious insider threats, more awareness of insider threats, and a better fit of security measures to the insider threat variety.

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References

Bundesamt für Sicherheit in der Informationstechnik (2018). Industrial Control System Security – Innentäter. https://www.bsi.bund.de/SharedDocs/Downloads/Webs/ACS/DE/BSI-CS/BSI- CS_061.html.

Bundeskriminalamt (2020). Monitoringbericht Innentäter in Unternehmen 2: Aktuelle inländische Forschungsbeiträge, wesentliche Ergebnisse und Handlungsempfehlungen. Technical Report.

Cappelli, D., Moore, A., Trzeciak, R. (2012). The CERT Guide to Insider Threats: How to Prevent, Detect, and Respond to Information Technology Crimes (Theft, Sabotage, Fraud). Addison Weseley.

Cole, E., Ring, S. (2005). Insider Threat: Protecting the Enterprise From Sabotage, Spying, and Theft. Syngress.

ENISA (2020). ENISA Threat Landscape 2020 - Insider Threat. Technical Report. ENISA.

Greitzer, F. L., Kangas, L. J., Noonan, C. F., Brown, C. R., Ferryman, T. (2013). Psychosocial Modeling of Insider Threat Risk Based on Behavioral and Word Use Analysis. e-Service Journal 9, 1.

Hevner, A. R., March, S. T., Park, J., Ram, S. (2004). Design Science in Information Systems Research. Design Science in IS Research MIS Quarterly, 28(1), 75–105.

Hofmeier, M. (2020). Operation Digital Ant. https://github.com/NutriSafe-DLT/operation-digital-ant.

Hofmeier, M. (2021). Operation Digital Butterfly. https://github.com/LIONS-DLT/operation-digital-butterfly.

Hofmeier, M., Lechner, U. (2021). Operation Digital Ant - A Serious Game Approach to Collect Insider Threat Scenarios and Raise Awareness. European Interdisciplinary Cybersecurity Conference (EICC). ACM, New York.

Homoliak, I., Toffalini, F., Guarnizo, J., Elovici, Y., Ochoa, M. (2019). Insight Into Insiders and IT: A Survey of Insider Threat Taxonomies, Analysis, Modeling, and Countermeasures. Comput. Surveys 52, 2.

Keeney, M., Kowalski, E., Cappelli, D., Moore, A., Shimeall, T., Rogers, S. (2005). Insider Threat Study: Computer System Sabotage in Critical Infrastructure Sectors. Technical Report. Carnegie Mellon University.

Magklaras, G. B., Furnell, S. M. (2001). Insider Threat Prediction Tool: Evaluating the Probability of IT Misuse. Computers and Security 21, 1, 62–73.

Mayring, P. (2008). Qualitative Inhaltsanalyse: Grundlagen und Techniken. 10th Ed., Weinheim/Basel.

MITRE (2022). MITRE's Human-Focused Insider Threat Types. https: //insiderthreat.mitre.org/insider- types.

Moody, G. D., Siponen, M., Pahnila, S. (2018). Toward a Unified Model of Information Security Policy Compliance, MIS Quarterly, 42(1), pp. 285-311.

Phyo, A. H., Furnell, S. (2004). A detection-oriented classification of insider IT misuse. Proceedings of the 3rd Security Conference.

Shaw, E. D., Ruby, K., Post, J. (1998). The Insider Threat to Information Systems: The Psychology of the Dangerous Insider. Security Awareness Bulletin 2, 2–98.

Sykes, G. M., Matza, D. (1957). Techniques of Neutralization: A Theory of Delinquency. American Sociological Review 22, 6, 664–670.

Quality Dimensions for Digital Twin Maturity in the Context of Dutch Public Spatial Planning

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Digital Twin (DT) technology is being increasingly adopted by local and regional governmental organizations in the Netherlands to support spatial planning decision-making, balancing contradicting policy ambitions. These DT solutions are becoming more complex as more perspectives, based on sophisticated calculations, are added to one integrated view of the problem space. To be able to validate the quality of these DT solutions, quality dimensions are to be established. This study focuses on identifying quality dimensions for DT solutions, including legal and policy perspectives, and safeguarding public value; thereby transcending the technical focus that most contributions on quality dimensions for DTs have in the current body of knowledge. Based on empirical data collection and analysis, 15 quality dimensions were identified. Future research should focus on further operationalizing these dimensions, allowing for measuring DT solution quality on a maturity scale.

Keywords:
digital twin, maturity model, quality dimensions, dutch spatial planning, public values

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1 Introduction

DT technology is gaining attention in academia and industry, particularly in the manufacturing and asset management domains (Uhlenkamp et al., 2022), as well as in healthcare (Fuller et al., 2020) and government (Peters et al., 2022). While there is no consensus on a standardized definition of a DT, most research views it as a cyber-physical system that shares the concepts of a physical entity, a virtual model, and connections between both (Liu et al., 2022). This study adheres to the definition of a DT as "a set of linked operation data artefacts and (simulation) models, which are of suitable granularity for their intended purpose and stakeholders and evolve throughout the product life-cycle" (Boschert & Rosen, 2016). However, this definition does not fully comply with a true DT that should support bi-directional communication (Fuller et al., 2020; Liu et al., 2022).

The government sector is using DT solutions more frequently to facilitate stakeholder discussions on operational asset management and permit processing for citizens during the spatial planning process (Marcucci et al., 2020; Peters et al., 2022; Wan et al., 2019). However, the growing use of DT solutions raises concerns about their design, development, implementation, and impact on society, as well as their role in the democratic-legislative arena (Peters et al., 2022). Therefore, it is important to consider public values, particularly in the context of the ongoing climate discussion.

An increasing number of municipalities, provinces, and national governmental agencies in the Netherlands are experimenting with DT solutions to support spatial planning. However, these experiments are mostly isolated, and governmental organizations aim to collaborate to increase the effectiveness of their DT solutions by exchanging relevant DT models, such as heat stress, flood risk, nitrogen emissions, biodiversity, or land/zoning usage (CROW, 2022). This collaboration reduces redundant creation of DT models by scarce Subject Matter Experts (SMEs) who are proficient in both spatial planning and data management and science. Uniformity is also required for larger-scale benchmarking using monitors such as emission, air quality, or water quality monitors to measure policy effects.

Governmental organizations aim to increase the effectiveness of DT solutions by combining different DT models for variant analysis, simulation, and effect monitoring. Each DT model represents one or more measurable indicators related to specific policy ambitions, which may conflict with each other, such as noise level DT models relating to both mobility and quality of life (Deng et al., 2021; Ketzler et al., 2020; Schrotter & Hürzeler, 2020). Balancing these indicators in 3D spatial planning can better support scenario building and decision-making compared to printed 2D maps. The quality of DT models that curate policy ambitions into validated visualizations is the focus of this paper. To ensure the integrity of the digitalization process of policy ambitions, the Province of Utrecht is looking for ways to establish the quality of DT models made by colleagues from other Dutch governmental agencies and third parties involved in building real-estate projects.

To the knowledge of the authors no work on quality dimensions for DT models from an integrated perspective, i.e., integrating technical, legal, and public values, exists in the current body of scientific and practical knowledge. Also, it is important to include the cultural and contextual aspects in constructing quality dimensions for DT models, that, to the knowledge of the authors, has not been done before. Therefore, provided a Dutch context, our research question in this paper is as follows: '*What quality dimensions for establishing DT maturity level for spatial planning are deemed important in the context of the Dutch governmental domain and the preservation of public values?*' Because there is not much research on this topic yet, we intend to collect data for answering from observations of professionals in practice, operationalizing an empirical point-of-view.

The remainder of this paper is structured as follows. In section two, the background and related work are presented. This is followed by our research method in section three. Then, the results of our analysis are presented in section four. Next, section five discusses the limitations of this study with future research directions, which is followed by the conclusions in section six.

2 Background and Related Work

Dutch governmental agencies responsible for spatial planning, such as provinces and municipalities, use steering mechanisms to execute law and regulations for implementations and policies for localization in specific areas of planning. The related cyclic process is often referred to as the policy lifecycle (CROW, 2022) and comprises four phases, being: 1) Policy development, 2) Policy execution, 3) Policy enforcement, and 4) Policy monitoring. The policy development phase comprises the creation of spatial planning ambitions as well as more detailed spatial plans based on measurable parameters and calculation of effects. It is important to note that DT solutions are increasingly being used in this phase to assist in determining a proper trade-off between policy ambitions represented by indicators to create spatial plans for a given area in a Dutch city or region (Future Insight, 2023; Gemeente Rotterdam, 2023; Vereniging van Nederlandse Gemeenten, 2022; Witsenburg, 2020). The second phase focuses on the implementation of the policies, e.g., so that concrete ambitions and goals are applied to planning areas in city programmes. During the third phase, governmental services are provided such as online permit checkers for civilians and organisations that need to comply with these ambitions and specific goals. This third phase also entails the enforcement of policies concerning the actual physical situation where the Dutch government has the responsibility to ensure that individuals or organizations act according to the implemented policies, e.g., do not cut down protected tree species or extend buildings without official permits. Lastly, the fourth phase focuses on monitoring the extent to which policy goals and ambitions are achieved, which is an important fundament for the continuous improvement of the policies implemented. For this study, we are looking for relevant quality dimensions that assist Dutch governmental organizations in determining the quality of their DT models throughout the whole policy lifecycle. Yet, DT models are, at this moment in time, generally used in the first phase; Policy development, by civil decision-makers from Dutch provinces and municipalities such as Amsterdam, Rotterdam, Utrecht & Amersfoort.

A recent study that was performed on a large number of contributions with a broad focus on available DT Maturity Models (DTMMs) (77) revealed 31 dimensions across seven categories, albeit with a focus on production and logistics, see figure 6 in the work of (Uhlenkamp et al., 2022). We look at DTMMs as they are a good starting point and might contain relevant quality dimensions for DT models. In the context of this study, we refer to digital twin maturity levels as a hierarchical framework that describes the degree of advancement and integration of a digital twin into a system or process (Madni et al., 2019; Shahzad et al., 2022; Uhlenkamp et al., 2022). The analysis presented by Uhlenkamp et al., (2022) is recent, thorough and is entirely covering the technical perspective of a DTMM, e.g., levels of cognition, model maintenance, and computing capabilities, while largely lacking the consideration of explicit legal, policy, and preserving public values and the FAIR translation of indicators into the DTs. Results from our own narrative style literature review (Paré et al., 2015) reveal a similar direction, where contributions on DTMMs seem to predominantly focus on the technical capabilities of a DT and its underlying DT models, e.g., in the work of (Enders & Hoßbach, 2019; Fuller et al., 2020; Lim et al., 2020; Rasheed et al., 2020). Also, one should take into account that many DTMMs available in the current body of knowledge are designed to be either specifically tailored for a domain, e.g., manufacturing, healthcare or aerospace or designed to be universally applicable (also referred to as cross-domain), see table 3 in the work of (Uhlenkamp et al., 2022).

From a legal and policy point of view, it is important that the DT model is validated and holds when a decision made by spatial planners using a DT solution is disputed by individuals or organizations in court or permit processes. Challenges concerning this decision-making process are revealed to be numerous (Peters et al., 2021, 2022) and given the importance of legally-grounded technology (Peters et al., 2022), which represents important public values such as transparency, safety or fairness, the legal aspect should be taken into consideration when determining the value of DT model integration.

For the successful implementation of DT solutions, acceptance by stakeholders in the context the DT is applied is deemed "extremely critical" (Rasheed et al., 2020). This involves trust from the spatial planners, decision-makers, legal advisors as well as the individuals impacted by the decisions made based on the DT models in the DT solution. Trust in the DT solution is the umbrella term here, but it comprises a combination of many public values (Voas et al., 2021) represented by the DT solution, which also differs per stakeholder group. Because of this pluriformity, it is not sensible to explore all of these integrally in this study, at least not at this stage. As the maturity of the research domain is low, this stage should focus on identifying constructs and their relations (Edmondson & McManus, 2007). Therefore, we focus on exploring the concept of public value for policymakers and decision-makers in a legal and policy arena where disputes about climate goals, housing and SDGs are becoming increasingly severe and digital means are becoming part of the political arena. Public values are those providing normative consensus about 1) the rights, benefits, and prerogatives to which citizens should (and should not) be entitled, 2) the obligations of citizens to society, the state and one another; and 3) the principles on which governments and policies should be based (Bozeman, 2007). As can be derived from the above definition, the normative consensus on the mentioned aspects in itself represent values relevant for individuals, e.g., privacy, equality, democracy, integrity, and honesty. A set of validated principles commonly used in the combination of ICT, the governmental domain and the use of DT solutions is FAIR. The FAIR framework is an abbreviation for 1) Findability, 2) Accessibility, 3) Interoperability and 4) Reusability (GoFAIR.org, 2016). It is used as a framework by different Dutch governmental agencies guiding the use of technology, thus also covering the use of DT solutions. Because of this we utilize the FAIR framework as a central framework to identify relevant public values to determine DT model quality, and with this its maturity.

3 Research Method

The main aim of this study is to identify quality dimensions for determining DT maturity in the Dutch governmental domain. The maturity of research in this area is considered low, particularly for DT maturity research focusing on non-technical capabilities. Therefore, an exploratory and inductive approach is chosen (Edmondson & McManus, 2007) to extract relevant quality dimensions from practice, as an increasing number of Dutch provinces and municipalities are using DT models in the policy development phase.

3.1 Data Collection

We focused on exploring the opinions of SMEs concerning two aspects: 1) which quality dimensions are relevant in establishing DT maturity? And 2) what criteria are relevant in the context of the quality dimensions identified? For this study, secondary data was used, originating from the end of 2020 until the end of 2022. In total, thirteen SME sessions with an average duration of 1,5 hours were included in the dataset, which were all in Dutch. In these digital sessions, Dutch SMEs discussed DT cases that were developed and applied in the Netherlands, predominantly in the context of the Dutch government. The SMEs were mostly employed at Dutch governmental agencies, though the expert sessions also hosted several other interested participants such as researchers, semi-governmental experts and commercial DT model suppliers. In total, 15 hours of video footage was collected.

The sessions were organized in a presentation style setting in which two to four presenters digitally presented to a crowd after which Q&A was organized and discussion about the DT model ensued. In total, an average of 45 participants were present during each of the sessions. Not all participants could interact with the speakers given the large number of participants and limited time for each expert session, however. In addition to the expert sessions, two documents were coded. These official documents were produced with and by the provincial council of Utrecht together with other SMEs focused on how to further develop their DT models to support spatial planning.

3.2 Data Analysis

The data was analyzed using a thematic coding approach. Three coding cycles similar to Strauss and Corbin's (1990) process of 1) open coding, 2) axial coding, and 3) selective coding was used. The first round, open coding, involved analyzing significant participant statements. In this process, we tried to identify what Boyatzis (1998) refers to as "codable observations". Thus, we coded the data by identifying statements (both written and in audio) that discussed quality dimensions for DT models. For example, codable observations were: "*Most suppliers of Digital Twin platforms and models are built and offered in a closed sourcing agreement.*", and "*Depending on the policy phase the model supports, you need static or dynamic data.*" Synonyms as well as redundant codes were all registered to ensure completeness. This process was conducted in several steps of which the first step was to ensure high intercoder reliability among the three research team members. Three researchers coded the first expert session separately from each other during the first step. This resulted in a similarity of 0.759 using the Krippendorfs Alpha coefficient, which is acceptable given the fact that the study is explorative (Lombard et al., 2004; Yeaton & Wortman, 1993). Because of this, two coders proceeded with distributing the data and coding them separately from each other. Additionally, the two coders compared one more random expert session from the data together to compare the results to see whether coder reliability was maintained, which was the case.

Subsequently, we conducted axial coding. In this round, we categorized the open coding results so that quality dimensions can be identified. For example, we coded the following five codes under the quality dimension **Visualisation capabilities**: *"Visualisation of real-time data is better when done in symbols because textual information is* *rather slow."*, *"Visualisation of fictive settings must be possible next to realistic visualisation because of the closeness for the affected user."*, *"Visualisation in a virtual reality"*, *"One must deliberately choose which data to visualise and which data to omit depending on each stakeholder involved"*, and *"Changing between 2-D and 3-D map layers"*. This process was conducted by two researchers and resulted in 20 Digital Twin Quality Dimensions (DTQDs).

Lastly, we conducted selective coding to normalize the identified categories as well as to re-assess codes that could not be attributed to any of the existing DTMMs, in which approximately 50 codes could be assigned given the discussion involving the context in which a statement has been made. The normalization was discussed between the two researchers involved in the coding during rounds one and two. This process resulted in the recategorization of five DTQDs into existing ones. For example, the quality dimension 'Level of detail capabilities' has been merged with the quality dimension 'Visualisation capabilities' because, when analysing the context of the statements and semantics of the codes we learned that it concerns a visualisation criterion and does not warrant a separate quality dimension. In total, 103 codes were deemed not suitable enough to be included as supporting existing or new DTQDs after three rounds of thematic coding. The results of this stepwise process are presented in the next section.

4 Results

Based on our analysis we identified 15 DT quality dimensions, which are further detailed in this section. The dimensions are sorted by the number of codes identified. Furthermore, we clustered the dimensions using 1) Technical, 2) Governance, or 3) legal labels. Figure 1 provides a visual summary of the identified DTQDs.

Technical	Governance	Legal
Visualisation capabilities	DT model application area	DT model, data & algorithm integrity
DT model, data & algorithm openness	Governance and collaboration	Public value by explainability
Simulation and prediction capabilities	Knowledge and competencies	Stakeholder participation and expectation management
Infrastructure capabilities		Temporality
Perspective capabilities		Privacy sensitivity
Interaction capabilities		
Standarization capabilities		

Figure 1: Identified DTQDs

Governance - DT model application area(s) and goal(s) (220 codes)
The model in a DT for a certain area in a city or region consists of policy themes. The DT model itself serves the goal of balancing the policy themes and ambitions and covers a perspective, based on one or multiple data sources, that constitute indicators and their mutual interaction in business rules and the foundation for these rules, which must be made explicit. Examples of thematic indicators are air quality, road infrastructure, soil structure, elevation level, water storage, biodiversity, light emission, energy usage, social participation, public transport mobility, economic building function, etc.

Technical - Visualisation capabilities (149 codes)

Because DT models enable the visualisation of multiple integrated perspectives, knowledge elicitation and communication become more effective and efficient. SMEs state that, although not always required given the type of data, 3-D visualisation helps manage complexity for all stakeholders. Part of that complexity is the inherent capability of adjacency, where sound affects health, given a specific distance between source and housing quarters, for example. Many calculations among different indicators are set as regulations and permit requirements. Also, being able to work with different levels of detail is deemed important. Effective visualisation when integrating data in one view includes appropriate colouring, layers, dashboards and graphs. Also, augmented and virtual reality technology are mentioned as contributors towards the quality of visualisation by SMEs. An example of this is where 3-D above and below-ground data is integrated into one view using different colour markings for types of infrastructure. Using this visualisation has lowered the error margin for building accidents by 3-5%.

Technical – DT model, data, algorithm openness capabilities (141 codes)

Often mentioned by SMEs is that DT models and data should be openly maintained and shared. This increases transparency towards and auditability by stakeholders. Openness is a multi-faceted concept that could relate to the data being publicly available, availability of the calculation algorithm, open sensors to facilitate citizen science, re-use of data and DT models, etc. Other important criteria mentioned were, in a technical sense, the quality of the data and how data could be safely shared. Also, SMEs want to be able to modify and further develop third-party DT models themselves after implementing them. For example, SMEs stated that most DT models currently being released are closed source, not enabling proper collaboration, which is deemed inefficient especially because Dutch governmental organizations should collaborate to achieve targets and policy ambitions at higher administration levels (i.e., ministries) as well as to meet with public expectations.

Technical - Simulation and prediction capabilities (120 codes)

One of the core additions to the spatial planning policy lifecycle using DTs is its ability to simulate scenarios and predict outcomes. SMEs state that civil servants rely on simulating effects, probability calculations, stress testing, impact-assessment, etc. It is also important for them to be able to work with KPIs and thresholds so that the effectiveness of the simulation of the scenario can be established. Underlying the simulation and prediction is the promise of increasingly more effective and efficient utilization of artificial intelligence. An example mentioned is the ability to predict water damage in a city when riverbanks are flooded during storms, where mobility, demographics and weather data are included in the predictions.

Technical - Infrastructure capabilities (104 codes)

Using (a combination of) DT model(s) with large datasets in a 3-D environment requires proper infrastructure. SMEs urge that the DT platform and its infrastructure should support large sensor networks and APIs to interface web-based services and datasets used in the DT models. The amount of processing power of a DT model is also mentioned as an important criterion by SMEs because current DT models do not seem to scale appropriately. There is often a trade-off between the level of detail and the size of the area covered in the DT. The larger the size, the harder it becomes to maintain the same level of detail for that area. Also, depending on which policy lifecycle phase must be supported by the DT model, either static or dynamic data must be used. The update frequency of data is high when policies are monitored using automated sensor networks creating a near real-time datastream, requiring different resources compared to one-time-only imports of historical data. An example of an infrastructure choice is about how to provide the DT model to stakeholders, either web-based or in a client-server (local) configuration. This choice impacts the required infrastructure capabilities for governmental bodies.

Technical - Perspective integration capabilities (100 codes)

A (3D) DT platform offers the possibility to combine multiple perspectives in one overview. SMEs state that spatial planning complexity becomes more transparent once multiple layers of data are combined, on a technical level. This in turn improves their ability to consider different indicators as well as to decrease error margins created by misalignment between planning and execution. For example, by combining noise, green and mobility data, one can use an assessment framework to balance a decrease in quality of life for occupants living near busy roads, keeping city segments accessible for public transport, maintaining biodiversity, and reducing heat-stress in the city, amongst other policy ambitions. SMEs stress that combining physical and social data, amongst others, is very important for efficient and effective spatial planning policy design.

Legal - DT model/data legal integrity (93 codes)

Using DT technology to support policy lifecycle management in spatial planning requires the DT model and data to be reliable and validated. SMEs stress that the DT model and its underlying data must have the legal power to hold up in court, or else it cannot be used effectively in spatial planning. Legal foundation is also multi-faceted because one could refer to the sensors used, the dataset itself or the algorithm used to represent an indicator, e.g., nitrogen pollution. For example, some SMEs stated that DT models published by scientific national knowledge institutes are preferred over, e.g., commercial third-party organizations or from citizen science, while others pose that such data is just as sound.

Legal – public value by explainability (65 codes)

Each DT model inherently represents a combination of ambitions with indicators. SMEs stated that these indicators should be made explicit so that the users of the DT model can use the DT model in a way that these indicators are all considered in an assessment framework that is used to ground spatial planning decisions. For example, SMEs find that the DT models and underlying ambitions and indicators considered should be explicitly communicated and made explainable when presenting spatial planning policy decisions. Such an approach also forces third-party/commercial DT model developers to be transparent about indicators served by their DT models as well as to take public values into account by design.

Governance – Governance and collaboration (63 codes)

Governance proved to be multi-faceted, however, is deemed an important cornerstone for SMEs. It is important that, when collaborating with other organizations, governmental bodies explicitly manage ownership of DT platforms, DT models and data. Also, because of the call for standardization, the governance around the standardised components must be clear. Furthermore, governmental bodies aim to collaborate in a quadruple helix setting, which adds to the complexity of governance around DT models. For example, when a standardised federative national DT platform would enforce a standardised approach, it must be clear what local autonomy the governmental bodies have in building their own DT models.

Technical - Interaction capabilities (59 codes)

In addition to the visualisation capabilities of a DT model, SMEs also stressed the importance of interaction capabilities. Because multiple perspectives are combined, SMES find it useful to interact with the data so that layers of data can be enabled or disabled. Changing levels of detail by zooming or selecting specific areas on maps are examples of how interaction helps stakeholders utilize the data to support scenario building and simulations. SMEs also mentioned augmented and virtual reality, e.g., with a hololens, as ways to more realistically interact with the DT model. Other examples of using these technologies are walking, driving or flying through the DT.

Legal - Stakeholder participation and expectation management (56 codes)

Different stakeholders are involved during the policy lifecycle. SMEs state the importance of explicitly taking into account when each type of stakeholder is involved and to what extent. For example, involving citizens during the policy design phase provides them with the opportunity to influence the design of their neighbourhood, while it could also be the case that citizens are merely informed about the plans using the DT at a stage in which they could not influence the design at all. The way participation is perceived is also based on a few other criteria such as the level of detail, the fictiveness of the visualisation, and what data is presented.

Technical - Standardization capabilities (34 codes)

One dimension that is similar yet distinct from the openness of a DT model is that of standardisation. SMEs stated that for them to be able to effectively collaborate, DT models and data should be interchangeable as well as their platforms be interoperable as much as possible. SMEs expressed their needs toward a national standard or principles, e.g., using an Object Type Library, reference architecture, and definition libraries. Using a more standardized approach enables importing DT models, standard building blocks, and more plug-and-play working using DT platforms. For example, because of the current lack of standardisation, DT models between most Dutch cities are not interchangeable, hampering collaboration between them.

Governance - Knowledge and competencies (16 codes)

When DT models are introduced, their integration within the DT platform and interpretation of the data must be secured. SMEs declared that to be able to do so, people must have the right competencies. Also, knowledge about the DT platform and models must be retained by the governmental bodies using the DT for spatial planning, as employees leaving organizations causes a knowledge drain. To guarantee proper competency development and knowledge management, SMEs think it is important to collaborate with universities, domain standardisation agencies, and other partners. Additionally, decision-makers must be trained in using DT technology for spatial planning purposes in a value-sensitive way.

Legal – Temporal capabilities (13 codes)

Again, using a DT model for spatial planning decision-making requires it to be recognized as a legal foundation. However, decision-making processes commonly take a long time and data changes over time as well, which requires the DT platform and model to support proper archival capabilities. The moment a decision is made by stakeholders, its context, data, and algorithm used should be saved so that it can be reproduced when governmental bodies are requested to explain the decision in a later stage of the policy lifecycle. For example, SMEs want to be able to explain to citizens what circumstances (and data) were relevant at the time when the decision was made. This is especially relevant given the increasing level of monitoring of policy effects as part of the legal obligations of governments. There is a need for semantic consistency between policy ambitions and policy effects.

Legal - Privacy sensitivity (9 codes)

A combination of different datasets could lead to undesirable traceability towards individuals. SMEs stated that this could harm the privacy of individuals, especially when the data is accessible to the public. This risk is higher when data from the social domain is included in the model. An example would be where demographic health data is used to signify differences between streets, which could also be used to trace personal information towards a specific household or individual.

5 Discussion and future research

The findings in this study have to be seen in light of some limitations. The first limitation concerns the depth of our empirical exploration of quality dimensions of DT models intending to construct a DTMM. While we established a list of dimensions with possible criteria for each dimension, based on the current data we cannot quantify a level of maturity on these dimensions, yet. Future research should further operationalize our findings and derive possible dependencies between them. The same holds for dependencies across the quality dimensions, which is an important aspect when constructing MMs (Mettler et al., 2010). The second limitation concerns the data that is used to arrive at the DTQDs presented in this paper. We used secondary data as our primary data source. This presents a disadvantage over data primarily collected for this study, because of its potential lack of focus during the SME sessions as well as that coverage of all relevant DTQDs cannot be guaranteed. While theoretically, this is correct, our data analysis revealed that saturation was reached rather quickly when coding towards DTQDs in round two, meaning that most of the independent discussion amongst SMEs limited itself towards the concepts discussed in this paper. Another advantage of this approach is that it prevents some bias types. Future research should therefore include a larger scale direct approach in which SMEs are questioned about the DTQDs and their importance to determine the weight of the DTQDs at a later stage of development.

Concerning our coding approach, some limitations could affect the validity of the DTQDs presented in this paper. In total three research team members engaged in coding, of which two primarily coded the data. Future research should focus on increasing the number of independent coders. On multiple occasions, we identified a large consensus amongst the audience on certain statements, which we could not explicitly code due to the online setting of the meetings. Therefore we argue that our codes could have more empirical value than the absolute number of counts in our dataset implies. Whether this is the case should be further explored in future research.

6 Conclusion

To conclude this paper we revisit our research question: 'What quality dimensions for establishing DT maturity level for spatial planning are deemed important in the context of the Dutch governmental domain and the preservation of public values?' Based on a thorough analysis of secondary data featuring rich debate amongst SMEs in the context of the Dutch government we were able to derive 15 DTQDs along with possible criteria that constitute maturity. There are similarities between our findings and the results presented in the study presented in (Uhlenkamp et al., 2022). These similarities are predominantly focused on the technical dimensions of maturity, while the dimension of human-machine interaction is also present, though described at a high level of abstraction. Interestingly, the legal aspect as discussed in our data is not or barely mentioned in other studies related to DTQDs and should be further explored and operationalized in future research.

From a theoretical perspective, this study presents new knowledge about the empirical point-of-view that SMEs have in the Dutch context. It also adds to the knowledge about how the maturity of DT models can be measured as, to the knowledge of the authors, most contributions fully or predominantly focus on technical aspects of maturity. This study identified explicit empiric evidence concerning, e.g., the legal integrity of DT models, participation capabilities, and explicitation of policy ambitions. The legal integrity dimension points to two areas for further research. On the one hand, it is observed that effect monitoring gradually becomes a new standard in legislation, which in turn generates a push for consistency between policy design and policy output in the democratic arena. Citizens demand that politicians achieve what they have promised, and DT solutions seem to provide the means. On the other hand, we observe a merger between article or text-based legislation regarding those policy goals and the object-based area of application (effect). Further substantiation could support the theory that DT technologies enable such a merger between unstructured text-based administration and more object-oriented spatial data infrastructures as we already have observed with Inspire and Natura 2000 (Peters et al., 2009; Peters, 2016). This Merger implies a different approach towards legal processes from document versioning towards agile software development, This, in turn, requires a completely different approach or culture towards legislation. From a practical perspective, this study contributes towards Dutch governmental bodies about where to measure DT model quality on. Revealing the spectrum of DT model quality enables government agencies as well as SMEs responsible for integrating DT models in DT platforms to start and guide the discussion with regards to their approach of collaborating with others on integrating increasingly larger (combinations of) DT models underlying the policy lifecycle and spatial planning decision-making process.

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References

Boschert, S., & Rosen, R. (2016). Digital Twin—The Simulation Aspect. In Mechatronic Futures (pp. 59–74). Springer International Publishing. https://doi.org/10.1007/978-3-319-32156-1_5

Boyatzis, R. E. (1998). Transforming qualitative information: Thematic analysis and code development. SAGE Publication.

Bozeman, B. (2007). Public Values and Public Interest: Counterbalancing Economic Individualism. Georgetown University Press.

CROW. (2022). Routekaart Provincies en Datagedreven Assetmanagement - Interprovinciale Digitale Agenda. https://www.ipo.nl/media/533fo4yt/routekaart-en-datagedreven-assetmanagement.pdf

Deng, T., Zhang, K., & Shen, Z.-J. (Max). (2021). A systematic review of a digital twin city: A new pattern of urban governance toward smart cities. Journal of Management Science and Engineering, 6(2), 125–134. https://doi.org/10.1016/j.jmse.2021.03.003

Edmondson, A. C., & McManus, S. E. (2007). Methodological Fit in Management Field Research. Academy of Management Review, 32(4), 1246–1264.

Enders, M. R., & Hoßbach, N. (2019). Dimensions of digital twin applications-a literature review. AMCIS 2019 Proceedings, 20.

Fuller, A., Fan, Z., Day, C., & Barlowc C. (2020). Digital Twin: Enabling Technologies, Challenges and Open Research. IEEE Access, 8, 952–971.

Future Insight. (2023). Groningen: 3D Digital Twin belangrijk instrument om grote ruimtelijke vraagstukken mee te behandelen. https://futureinsight.nl/nieuws/groningen-3d-digital-twin-belangrijk-instrument-om-grote-ruimtelijke-vraagstukken-mee-te-behandelen/

Gemeente Rotterdam. (2023). Samenwerken aan de 3D Digital Twin. https://www.rotterdam.nl/digitale-stad

GoFAIR.org. (2016). FAIR principles. https://www.go-fair.org/fair-principles/

Ketzler, B., Naserentin, V., Latino, F., Zangelidis, C., Thuvander, L., & Logg, A. (2020). Digital Twins for Cities: A State of the Art Review. Built Environment, 46(4), 547–573. https://doi.org/10.2148/benv.46.4.547

Lim, H. K. Y., Zheng, P., & Chen, C. H. (2020). A state-of-the-art survey of digital twin: Techniques, engineering product lifecycle management and business innovation perspectives. Intelligent Manufacturing, 31, 1313–1337.

Liu, Y. K., Ong, S. K., & Nee, A. Y. C. (2022). State-of-the-art survey on digital twin implementations. Advances in Manufacturing, 10(1), 1–23.

Lombard, M., Snyder-Duch, J., & Bracken, C. (2004). Intercoder Reliability in Content Analysis. Retrieved April, 2002, 1–18.

Madni, A. M., Madni, C. C., & Lucero, S. D. (2019). Leveraging digital twin technology in model-based systems engineering. Systems, 7(1).

Marcucci, E., Gatta, V., Le Pira, M., Hansson, L., & Bråthen, S. (2020). Digital Twins: A Critical Discussion on Their Potential for Supporting Policy-Making and Planning in Urban Logistics. Sustainability, 12(24), 10623. https://doi.org/10.3390/su122410623

Mettler, T., Rohner, P., & Winter, R. (2010). Towards a Classification of Maturity Models in Information Systems. In Management of the Interconnected World (pp. 333–340). Physica-Verlag HD. https://doi.org/10.1007/978-3-7908-2404-9_39

Paré, G., Trudel, M.-C., Jaana, M., & Kitsiou, S. (2015). Synthesizing information systems knowledge: A typology of literature reviews. Information & Management, 52(2), 183–199. https://doi.org/10.1016/j.im.2014.08.008

Peters, R., Hoekstra, R., van Engers, T., & Hupkes, E. (2009). Legal Simcity; Legislative Maps and Semantic Web Supporting Conflict Resolution. SDI Convergence, 63.

Peters, R. M. (2016). The Law, the Map and the Citizen: Designing a legal service infrastructure where rules make sense again. Universiteit van Amsterdam.

Peters, R., Smit, K., & Versendaal, J. (2021). Responsible AI and Power: Investigating the System Level Bureaucrat in the Legal Planning Process. 34th Bled EConference.

Peters, R., Smit, K., & Versendaal, J. (2022). Validation Challenges for Legal Digital Twins in Dutch Climate Governance. EGOV-CeDEM-EPart, 22.

Rasheed, A., San, O., & Kvamsdal, T. (2020). Digital Twin: Values, Challenges and Enablers From a Modeling Perspective. IEEE Access, 8, 21980–22012. https://doi.org/10.1109/ACCESS.2020.2970143

Schrotter, G., & Hürzeler, C. (2020). The digital twin of the City of Zurich for urban planning. Journal of Photogrammetry, Remote Sensing and Geoinformation Sci-Ence, 88(1), 99–112.

Shahzad, M., Shafiq, M. T., Douglas, D., & Kassem, M. (2022). Digital Twins in Built Environments: An Investigation of the Characteristics, Applications, and Challenges. Buildings, 12(2), 120. https://doi.org/10.3390/buildings12020120

Strauss, A., & Corbin, J. M. (1990). Basics of qualitative research: Grounded theory procedures and techniques. Sage Publications, Inc.

Uhlenkamp, J. F., Hauge, J. B., Broda, E., Lütjen, M., Freitag, M., & Thoben, K. D. (2022). Digital twins: A maturity model for their classification and evaluation. IEEE Access, 10, 69605–69635.

Vereniging van Nederlandse Gemeenten. (2022). Digital twin voor alle gemeenten. https://vng.nl/praktijkvoorbeelden/digital-twin-voor-alle-gemeenten

Voas, J., Mell, P., & Piroumian, V. (2021). Considerations for digital twin technology and emerging standards. https://nvlpubs.nist.gov/nistpubs/ir/2021/NIST.IR.8356-draft.pdf

Wan, L., Nochta, T., & Schooling, J. M. (2019). Developing a city-level digital twin–propositions and a case study. International Conference on Smart Infrastructure and Construction, 187–194.

Witsenburg, F. (2020). Digital twin helpt bij ontwerp klimaatadaptief stationsgebied Amersfoort. https://www.gebiedsontwikkeling.nu/artikelen/digital-twin-helpt-bij-ontwerp-klimaatadaptief-stationsgebied-amersfoort/

Yeaton, W. H., & Wortman, P. M. (1993). On the Reliability of Meta-Analytic Reviews. Evaluation Review, 17(3), 292–309. https://doi.org/10.1177/0193841X9301700303

Tools and Technologies Utilized in Data-Related Positions: An Empirical Study of Job Advertisements

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Role, value and amount of data and related tools, technologies, companies and professions in society is rising. Since the required skills for data-related professions are predicted to experience changes, and labor market mismatches create challenges for stakeholders, this research focuses on changes in the required tools and technologies for data-related positions. The presented research defines trends and changes in frequencies of the tools utilized in the data-related professions by applying quantitative content analysis on collected data from job advertisements of Finland, Denmark and Poland. The research findings show that tools used in data-related professions experience significant changes over time. For example, AI and cloud computing-related skills, and SQL started to be required more, whereas Excel, SPSS and similar tools are less expected from the candidates. Furthermore, while R programming language utilization rises in analytics related positions, Python is more common in positions related to data science.

Keywords:
data analytics, data science, data professions, skill requirements, labor market, job advertisements

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1 Introduction

Data volumes have an increasing trend influenced by automation, technological shifts and pandemic (Sheng et al., 2020), which makes it crucial to study big data, related tools and professions. Furthermore, organizations have started to utilize big data, related technologies and Artificial Intelligence (AI) more extensively compelled by pandemic regulations (McKinsey, 2021). As a result, data context and labor market have started to experience significant shifts (McKinsey, 2021). Field experts and related studies indicate that technologies utilized in the workplace for accomplishing tasks, and corresponding required skills, are experiencing changes, and predicted to change in the future on a wider scale (Musazade, 2022, World Economic Forum, 2020). In other words, digitalization drives uncertainty regarding the tools and skills required for professions in the future (Koh, 2020). For example, increasing data volume and unstructured data requires working on new technologies, such as cloud computing (Marr, 2019), and corresponding skills therefore. Some professions, e.g. data entrance clerks, are expected to be completely replaced by emerging technologies (World Economic Forum, 2020). As a result of distribution of some work to machines, the emergence of different professions (e.g. AI specialist) specialized in the new tools and possessing corresponding skills can be observed (World Economic Forum, 2020).

Human resource management in organizations experiences challenges in recruiting to vacant positions because of the existence of skill gaps (Koh, 2020). Furthermore, data-related professions have common definition deficiency, as they are typically specified via personal perspectives of different specialists, which increases the knowledge gap (Miller, 2014, Granville, 2014). This is also a problem sporadically addressed in the literature (Granville, 2014). In other words, there is evident need for the study of data-related professions, their role in organizations, as well as related tools that are utilized by them. Another factor that increases the relevance of this study is the rising trend of data companies (Cattaneo et al., 2020). Furthermore, data volume has a continuous rising trend, which generates the need for usage of advanced tools that are capable of processing big data (Power & Heavin, 2017, Sheng et al., 2020, Kenett & Redman, 2019). While there are some existing studies on this topic, they are focused on specific markets with limited data analysis techniques.

This study concentrates on the Danish, Polish and Finnish labor markets, and aims to answer following research questions:

RQ1: What are the most important skills organizations look for when hiring data professionals?

RQ2: How have the skills required by companies for data-related positions changed in the recent years?

The rest of the paper is structured as follows. Section 2 presents the literature review on the previous similar research in the domain. In Section 3, the research methodology, data and data analysis are described. Section 4 discusses trends and the findings of the study, and Section 5 summarizes the study, and presents contributions and limitations.

2 Literature Review

Data-related positions have been previously analyzed by researchers as listed in Appendix A, typically by means of empirical data collected from job advertisements by web scraping and analyzes have been performed with different techniques of text analytics. For example, the study of De Mauro et al. (2018) shows that big data developer (BDD) and engineer (BDE), business analyst (BA) and data scientist (DS) are related professions in the big data domain. Furthermore, research done by Verma et al. (2019) compares data analyst (DA) and DS, and BA and business intelligence (BI) positions, and concludes that a DS profession requires more technical skills. Yet, in the findings of these two articles there is a mismatch (e.g. in coding skill requirements).

Organization, Excel, SQL, Reporting are the skills that have been found required for the DA profession in multiple studies (Verma et al., 2019, Jiang & Chen, 2021). At the same time, Python and R programming languages, Teamwork and Statistics are the common required skills for DS positions (Verma et al., 2019, Jiang & Chen, 2021). For the BA profession, teamwork, management and project management, testing and analytics are the keywords that studies have identified in job advertisements (De Mauro et al., 2018, Verma et al., 2019, Jiang & Chen, 2021).

Persaud (2020) has analyzed big data analytics-related professions with the aim of defining main in demand competencies and provision of students with them. The study has utilized both quantitative and qualitative research methodology, including text mining of job advertisements and education institutions' courses, and interviewing senior executives. The framework presented consists of cognitive, functional, meta-competence and social competence extensions. Python, SQL, Spark, Hadoop are some of the tools, teamwork, customer relationships, business domain knowledge, communication, presentation skills the research found to be required from candidates. Moreover, for entry-level vacant positions, candidates are required to have a degree from quantitative field, as well as experience in relevant positions. Yet, the research presents general findings without detailed description of the frequencies of the skills.

In a similar research, Smaldone et al. (2022) analyzed job advertisements of the US market. After data preprocessing and text analysis, skills have been categorized in thematic groups. Similar to the study of the Persaud (2020), skills have been classified into different groups, whereas in the research of Persaud (2020) the themes have been compared with the particular theoretical framework. Moreover, Smaldone et al. (2022) queried only the presence of "data science" during data collection. Big data, data processing and AI are the top three frequent terms. Topic modeling has resulted in five topics, including generic skills, hard skills, big data and AI, analytical and team-related skills. Python, R, data analysis, deep learning, communication, teamwork, problem-solving, data management and data mining are some of the skills that research has found existing in job advertisements. Fang and Zhou (2021) have analyzed DA positions in China's market via data collection from recruitment websites and applying text mining. Data have been collected during 2017. Among the programming languages, Python, R and Java have been found as most utilized in DA positions, whereas authors underline R as the most demanded language. Furthermore, Hadoop, Spark, SQL, Hive, Oracle, SPSS, MATLAB, TABLEAU and SAS are other tools that have been found having high frequency in the job postings, whereas the highest is Excel among the tools that serve for "visualization of statistical analysis" or "application" (i.e. latter four tools) as defined by authors. Yet, soft skills and other domain-related terms are completely missing in the study.

Another research, in which data have been collected from Chinese websites, is conducted by Cao and Zhang (2021). The search query has been limited to the "data mining" and "data science" keywords. In the research named entity recognition, as well as Bert-BILSTM-CRF model has been built and trained for extraction of information or named entities. Based on the findings, Computer Science, Statistics and Mathematics are the most required and co-occurred majors by recruiters, based on the data collected in 2020. Yet, majors such as Economic, Finance, Management, Electronics, Information Management, Physics also exist in the requirement list of some advertisements, which mostly co-occur with the mentioned top three majors. Findings indicate that communication, teamwork, logical thinking and responsibility, as well as SQL, Python, R, SPSS, Excel tools are having highest frequencies in the job postings. Furthermore, authors have categorized positions into three groups, which are big data mining, data analysis and data administration, data based on the findings in advertisements, that differ based on the programming languages and softwares (e.g., for data processing and management).

The studies present considerably differing findings. To compare findings, SPSS has only around 4% and SAS 11% frequency in the study of Verma et al. (2019) for the DA profession, whereas they are in the most required skill list in the study of Fang and Zhou (2021). Moreover, different from other studies, Excel keyword lacks in presented findings of Smaldone et al. (2022) and Fang and Zhou (2020). Although two studies, in which data have been collected from China's job advertisements, have analyzed similar positions, the search query and the data collection years have been different. Yet, all the skills that are described in the study of Fang and Zhou (2021) are mentioned in the study of Cao and Zhang (2021), except Matlab and Tableau. Non-existence of precise frequencies in the studies unable to make accurate observations on the change of or variations in skill requirements.

As a summary, while previous studies have concentrated on current labor market requirements, this study expands literature by focusing on additional different perspectives. Among others, lack of accurate information on frequencies of skills, focus mostly on US and China's markets, existence of mismatches among the previous studies' findings have been the rationale of this study.

3 Methodology

3.1 Content analysis and data collection

In total, eight different data-related professions have been studied in the research, as shown in Figure 1.

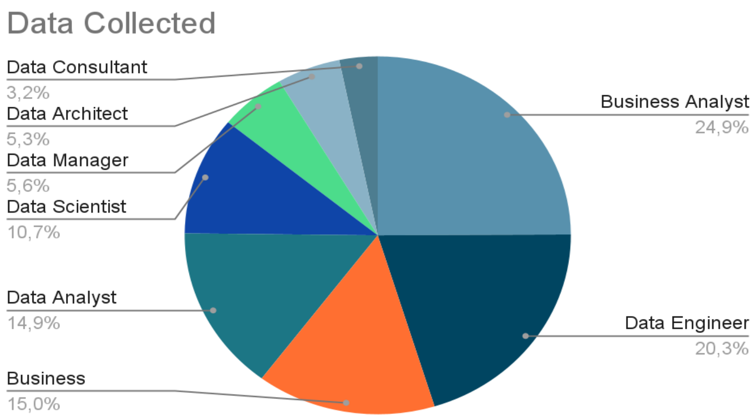

Figure 1: Studied positions

Query and data have been limited to the existence of the term in the title of vacancy advertisements. The titles have been selected by referring to the previous studies, Future of Jobs Report (World Economic Forum, 2020) and LinkedIn's (2020) career explorer portal. Derived from the domain problems that are listed above, including lack of common definition, personal interpretations in the literature and similarity of the professions, frequency technique of quantitative content analysis has been utilized for conducting the research.

Quantitative content analysis has enabled generalization of the findings and elimination of possible biases, caused by subjective interpretations of the positions by field experts, of qualitative analysis (White & Marsh, 2006, Macnamara, 2018). Moreover, the research has been designed to find changes in required skills and utilized tools by differentiating study results with the previous research, and authors of previous research utilized content analysis and job advertisements as a methodology and research data, correspondingly.

Factors, such as permission requirement for web scraping, usage commonness or number of advertisements, technical feasibility or architecture simplicity of the website, have been decisive for choosing Indeed.com job portal as a data source. Data have been collected between November 2021 and January 2022 by utilizing Python programming language and BeautifulSoup library (i.e. web scraping). Common libraries, such as "requests", "numpy" and "pandas", have been deployed during data collection, preparation and processing. In total, 2658 advertisements of Denmark, Finland and Poland have been extracted.

3.2 Data Analysis

As shown in Figure 2, data analysis has been conducted in three interrelated stages based on the research questions and objective. Skills and tools have been collected from previous studies. Among eight studied positions, six of the titles have matched with the titles from the previous research. Subsequently, Spacy library (i.e. Matcher class) has been applied to the collected data for retrieving frequencies of the tools and skills in the job advertisements.

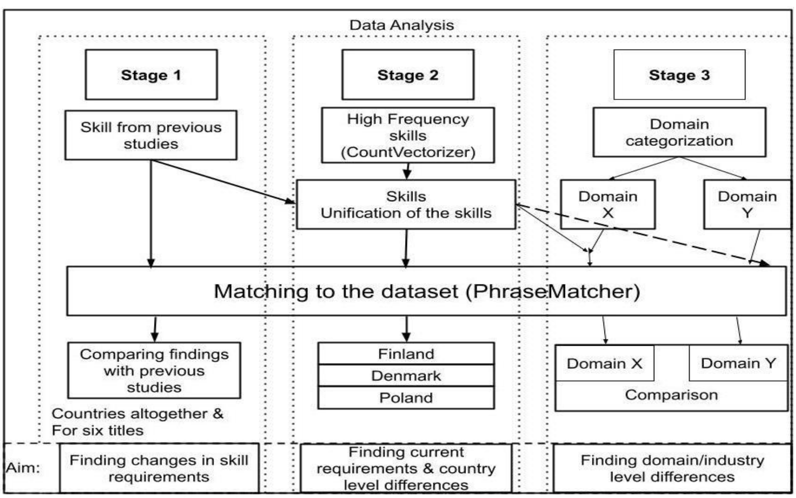

Figure 2: Data Analysis Process

4 Discussion and Result

The study focuses on understanding the required skills for data-related professions, changes in required skills, as well as actual skill requirements in the market. The results show that utilized tools have changed considerably. For instance, AI, cloud computing, Hadoop and SQL skills requirements started to rise, whereas Excel, SPSS, SAS and similar tools less expected from the candidates. Moreover, Python is more common in data science related professions, while R programming language usage increases in analytics related positions.

4.1 Falling trends

An analysis of job advertisements shows that the demand for some skills has decreased. For instance, Microsoft Excel has become less required for data professionals, particularly for DA and BI occupations. In contrast, most of the previous studies indicate Excel as one of the most required tools (e.g., Jiang & Chen, 2021; Verma et al., 2019; Cao & Zhang, 2021; Fang & Zhou, 2021). Based on research, some tools and programs, including Microsoft Word or Office, SPSS, and SAS, are being utilized less frequently in data-related jobs, as evidenced by a decrease in their requirement frequencies in job vacancies. For instance, in the study by Verma et al. (2019), SPSS has a frequency of around 4% for DA positions, while in this study it has a frequency of around 1%. Similarly, SAS has a frequency of 11% in Verma et al.'s study, and around 5% in this study. However, Fang and Zhou (2021), who studied China's market, found these tools to be among the most required for DA positions. A similar trend is applicable for Microsoft Office and PPT.

4.2 Rising trends

In contrast, the requirement for some skills and tools has shown an increasing trend. The matching trend to the utilization of cloud computing by data professionals is the rise of usage of keyword “cloud” in job advertisements, in particular for data engineer (DE) and DAR professions. Not only the “cloud” keyword, but also specific cloud-based database management systems, e.g., Azure and AWS, have increased their presence in the job advertisements, in particular for the DAR and DE positions.

The findings show that AI, cloud, deep learning, Mathematica, R, and Python have started to appear in one or more data-related vacancies, which is different from all of the previous studies except for the most recent US market study by Smaldone et al. (2022). In the study by Smaldone et al. (2022), "artificial intelligence" is the third most commonly appearing keyword after "big data" and "data processing," whereas it appears in only around one-third of advertisements in this study. While "deep learning" in Smaldone et al.'s study has a higher frequency than Python, in this study, around 20% of advertisements include "deep learning" compared to 87% for Python. The same trend applies to the term "machine learning." A possible interpretation of this differentiation is that tasks directly related to big data and AI have become the main duties and requirements for data scientists in the US market in recent years.

In addition, Power BI and Tableau have become required and utilized more frequently in DA, BA and BI positions. Fog computing’s components and big data tools Spark and Hadoop have started to be utilized more as well, especially in DS, DE and DAR positions. Persaud (2020) lists Spark and Hadoop as one of the most required tools in the data related professions. Increase in the utilization of Hadoop may also be a sign of more extensive application of predictive analytics by organizations, since it is one of the enabling tools of predictive analytics (Pathak et al., 2018). The latter hypothesis is compatible with Power and Heavins’ (2017) findings, in which they identify more incorporation of predictive analytics into organizational operations and decision makings.

4.3 Differing trends of programming languages (R, Python, SQL)

There are tools, in particular programming languages, that have become more required for some professions, while less demanded in other data-related positions. To elaborate, Python programming language has become more required in DS and DE positions; R programming language has become more in demand in BI and DA positions; Structured Query Language (SQL) requirement has a rising trend in DS, DE and DA positions.

Jiang and Chen (2021) have found R in one in two job postings, whereas Python in three of four job postings titled as a “data scientist”. In China’s job advertisements, for DA positions R is more required than Python (Fang and Zhou, 2021), whereas job postings with "data science" or "data mining" keywords have higher frequency for Python than R (Cao & Zhang, 2021). In other words, inferences match with the findings of Musazade (2022).

Findings of Smaldone et al. (2022) and Verma et al. (2019) shows that R programming language appears more in advertisements than Python. For instance, in the study of Verma et al. (2019) R is higher in the Statistics skill category, whereas Python is higher in the Programming skill category of data scientist positions. Topic modelling of Smaldone et al. (2022) shows that R more frequently appears with the analytics, data management and business intelligence keywords, whereas Python more appears with the keywords such as data mining and processing, or artificial intelligence.

4.4 Background requirement/specialization

In addition to the particular tools, the study shows that "technical", "engineering" and "computer science" terms have started to appear less in vacancies of data related positions compared to previous studies (e.g., Verma et al., 2019, Jiang & Chen, 2021), which may imply a diminishing role of technical background in data professionals. For instance, for DE positions "computer science" term has 22% frequency, whereas in the study of Jiang and Chen (2021) the term appears in half of the advertisements. The study of Cao and Zhang (2021) has defined "computer science" and other related terms (e.g., mathematics, statistics) as one of the required background majors from candidates. Keyword "statistics" for the DS profession has started to appear 10-15% less: it has around 60% frequency in study of Verma et al. (2019) and Cao and Zhang (2021). Moreover, the study suggests that data professionals have started to be required to possess a narrower competence and specialization in particular common, unique and extensive tools and technologies. For instance, different from findings of previous research, Python and Python libraries (e.g. Pytorch) have started to occur more frequently in advertisements. Yet, for a business intelligence role, for instance, the same judgment cannot be applied, in which tools utilized are distributed more broadly and shifts are more thorough.

4.5 Grouping of professions

Based on the findings on required tools some professions can be categorized. Firstly, DAR, consultant and partly DE positions involve extensive labor on databases and different cloud platforms. Jiang and Chen's (2021) findings are similar with the findings of this study, except instead of a data consultant position, data scientist profession is a part of the group. Secondly, professions such as DA and BI frequently use BI, data visualization and analytics products, such as Tableau or Power BI. Thirdly, SQL and Python programming languages are frequently used in DE, DS and DA positions. Findings indicate that BI and DA professions are similar to each other in terms of skills they require. Verma et al. (2019) analyze the existence of similarity between DS and DA positions, and between BI and BA professions, whereas the study lacks comparison of positions all together. Finally, both findings of this research and Jiang and Chen (2021) indicate the distinctiveness of the BA profession, which may not be fully matched to a particular category.

5 Conclusions

The research findings show that the skills required and tools utilized in data-related professions have experienced substantial changes in the last two-four years. As the presented results address RQ1, while some tools have common trends in most or all of the data-related professions, differences in frequencies of skills and tools, and of particular tools' trends may enable differentiation between similar data-related professions. Furthermore, regarding RQ2, this study shows that skill requirements for data related positions have changed in the last two-four years, which may imply the change of tools and technologies used in data-related positions, as well as usage objectives of big data by organizations. For example, since Python and machine learning are highly correlated in job ads (Smaldone., 2022), the rising requirement for Python may suggest the rising usage of big data for machine learning. Falling trend of most of the tools belonging to the statistics category defined by Verma et al. (2019), such as Excel, SAS, SPSS may imply less usage of big data for statistical analysis only.

More specifically, cloud computing tools, AI and deep learning skills and knowledge have started to be required more from candidates. SQL, Power BI, R and Tableau have become more common in the job postings for analytics related professions.

Moreover, SQL, Spark, Hadoop and Python have become more in demand for data scientist and engineer professions. However, Microsoft Word or Office, SPSS, SAS, Excel have started to be utilized less in data related positions. Although comparison of finding with the previous studies' results and of results of previous studies outline existence of differences in required tools (e.g. Excel), some common observations can be derived. For example, SQL both in this study and in previous studies is the most required database management tool. While Python is mostly used in data scientist and related positions, data analyst and similar professions utilize R more than Python.

Firstly, the research contributes to the literature by expanding study of data-related professions to the new geographical area and studying the labor market of three countries: Denmark, Finland and Poland. Secondly, the study not only defines current market requirements, but also studies and defines an approach for exploring changes in the market. Thirdly, findings of the research may assist authors in accurate definition of data-related professions based on the skill required for them. Finally, our results can also help in recognizing the importance of the existence of human resources and skills, in addition to the cost, scalability and functionality, security and availability, as the component of multi-criteria decision-making task of tool and system selection (Kachaoui & Belangour, 2019, Grandhi & Wibowo, 2018).

Findings of the research may contribute to the closing skill gap, re-skilling, correctly defining data-related positions by the job advertisers, specialization for a particular data-related profession, search of relevant vacancies based on the possessed skills by candidates, as well as up-skilling for the professions in the field. Furthermore, education institutions may utilize findings in defining curriculum for the studied specializations based on the market requirements and trends.

Shifts in the skill requirements can be influenced by country-level variations, considering previous studies have been conducted in other markets. Frequency of the words may be influenced by the terms in the language of the advertisements. Moreover, real expectations of recruiters may be represented incompletely or inaccurate in the job postings. Number of collected data for some professions may be considered insufficient. Finally, utilization only quantitative analysis may inhibit possible interpretation of terms, in particular soft skills, and conjunctions among terms have been dismissed.

Future research may study possessed (i.e. supplied) skills for refining the existing skill gap. Secondly, studying each high in demand tool and relationships between them, may present insights on usage objectives of the tools and possible need for a shift between them. Thirdly, categorization of job advertisements based on the position level, company size and different industries may depict a clear picture of the current required skills for each specialization, as well as possible differences depending on listed or other variables. This paper focused on a limited number of professions, whereas the number studied positions can be extended to other professions.

References

Cao, L., & Zhang, J. (2021, April 1). Skill Requirements Analysis for Data Analysts Based on Named Entities Recognition. IEEE Xplore. https://doi.org/10.1109/ICBDIE52740.2021.00023

Cattaneo, G., Micheletti, G., Glennon, M., La Croce, C., & Mitta, C. (2020). The European data market monitoring tool : key facts & figures, first policy conclusions, data landscape and quantified stories : d2.9 final study report. Publications Office of the European Union.

De Mauro, A., Greco, M., Grimaldi, M., & Ritala, P. (2018). Human resources for Big Data professions: A systematic classification of job roles and required skill sets. Information Processing & Management, 54(5), 807–817. https://doi.org/10.1016/j.ipm.2017.05.004

Fang, F., & Zhou, Y. (2021). A Study on Recruitment of Data Analyst Based on Text Mining and Visualization Technology. Journal of Physics: Conference Series, 1952(4), 042017. https://doi.org/10.1088/1742-6596/1952/4/042017

Gardiner, A., Aasheim, C., Rutner, P., & Williams, S. (2018). Skill Requirements in Big Data: A Content Analysis of Job Advertisements. Journal of Computer Information Systems, 58(4), 374–384. https://doi.org/10.1080/08874417.2017.1289354

Grandhi, S., & Wibowo, S. (2018). A Multi-criteria Group Decision Making Method for Selecting Big Data Visualization Tools. Journal of Telecommunication, Electronic and Computer Engineering (JTEC), 10(1-8), 67–72. Retrieved from https://jtec.utem.edu.my/jtec/article/view/3737

Granville, V. (2014). Developing analytic talent: Becoming a data scientist. John Wiley & Sons, Inc.

Jiang, H., & Chen, C. (2021). Data Science Skills and Graduate Certificates: A Quantitative Text Analysis. Journal of Computer Information Systems, 1–17. https://doi.org/10.1080/08874417.2020.1852628

Kachaoui, J., & Belangour, A. (2019). A Multi-criteria Group Decision Making Method for Big Data Storage Selection. Networked Systems, 381–386. https://doi.org/10.1007/978-3-030-31277-0_25

Kenett, R., & Redman, T. C. (2019). The real work of data science : turning data into information, better decisions, and stronger organizations. Wiley.

Koh, A. (2020). Anticipating and preparing for the future—one example from higher education: The Singapore Management University (SMU) experience. In B. Panth & R. Maclean (Eds.), Anticipating and Preparing for Emerging Skills and Jobs: Key Issues, Concerns, and Prospects (pp. 41–46). Springer. https://doi.org/10.1007/978-981-15- 7018-6_6

LinkedIn. (2020). https://linkedin.github.io/career-explorer/. Linkedin.github.io. https://linkedin.github.io/career-explorer/ 88

Macnamara, J. (2018). 11. Content Analysis. Mediated Communication, 191–212. https://doi.org/10.1515/9783110481129-012 Retrieved from: https://www.researchgate.net/publication/327910121_Content_Analysis

Marr, B. (2019). Artificial intelligence in practice: How 50 successful companies used artificial intelligence to solve problems (First Edition). Wiley.

McKinsey. (2021). The future of work after COVID-19. Retrieved October 23, 2021, from https://www.mckinsey.com/featured-insights/future-of-work/the-future-of-workafter-covid-19

Miller, S. (2014). Collaborative approaches needed to close the big data skills gap. Journal of Organization Design, 3(1), 26–30. https://doi.org/10.7146/jod.9823 89

Musazade, N. (2022). Understanding the relevant skills for data analytics-related positions: An empirical study of job advertisements. www.doria.fi. https://urn.fi/URN:NBN:fi-fe2022031323297

Pathak, A. R., Pandey, M., & Rautaray, S. (2018). Construing the big data based on taxonomy, analytics and approaches. Iran Journal of Computer Science, 1(4), 237–259. https://doi.org/10.1007/s42044-018-0024-3

Persaud, A. (2020). Key competencies for big data analytics professions: a multimethod study. Information Technology & People, ahead-of-print(ahead-of-print). https://doi.org/10.1108/itp-06-2019-0290

Power, D. J., & Heavin, C. (2017). Decision support, analytics, and business intelligence. Business Expert Press.

Sheng, J., Amankwah-Amoah, J., Khan, Z., & Wang, X. (2020). Covid-19 pandemic in the new era of big data analytics: Methodological innovations and future research directions. British Journal of Management, 32(4), 1164–1183. https://doi.org/10.1111/1467-8551.12441

Smaldone, F., Ippolito, A., Lagger, J., & Pellicano, M. (2022). Employability skills: Profiling data scientists in the digital labour market. European Management Journal, 40(5). https://doi.org/10.1016/j.emj.2022.05.005

Verma, A., Yurov, K. M., Lane, P. L., & Yurova, Y. V. (2019). An investigation of skill requirements for business and data analytics positions: A content analysis of job advertisements. Journal of Education for Business, 94(4), 243–250. https://doi.org/10.1080/08832323.2018.1520685

White, M. D., & Marsh, E. E. (2006). Content Analysis: A Flexible Methodology. Library Trends, 55(1), 22–45. https://doi.org/10.1353/lib.2006.0053

World Economic Forum. (2020). The Future of Jobs Report 2020. https://www3.weforum.org/docs/WEF_Future_of_Jobs_2020.pdf

Appendix A: Literature Review of Data-related Positions

Study - Scope or "Title"	Methodology (tools)	Study focus or findings	Frequent tools
Smaldone et al. (2022) - DS	Web Scraping (Octoparse), Text Mining (R), LDA, Total frequency (TF), Network analysis	Thematic areas for skills, correlated skills, top skills	Python, R
Verma et al. (2019) - DS, DA, BI, BA	Experts for skills' categories, Content analysis, Web scraping (R)	Skills and their categories' comparative importance, comparison of professions	SAS, R, Python, SQL, Excel
Persaud (2020) -Big DA-related professions	Web crawling, text analysis (job postings, university programs), Interviews, semantic relationships (Leximancer)	Domain knowledge, kinds of skills are expected, e.g., social, functional, cognitive, technical.	Hadoop, sql, python, spark
Jiang & Chen (2021) - DA, BA, DAR, DE, DS, DS Researcher	Text analysis with the created list of dictionary, total frequency (Python SpaCy)	Overlapping skills and grouping of professions, match of skills of graduate certificated with the labor market requirements, comparison of top skills of professions	SQL, Excel, R, Python

Fang & Zhou (2021) - DA	Crawling (Bazhuayu), Text mining (dictionary) (Python -Jieba)	Top skills	R, Python, Java, MySQL, Hive, Spark, Oracle, MATLAB, Hadoop, SPSS, Tableau, SAS
Cao & Zhang (2021) - “data science”, “data mining”	Web crawler, BERT - BiLSTM -CRF for NER (Python)	Required majors and their cooccurance, soft and hard skills, kinds and comparisons of positions.	Excel, SQL, SPSS, Python, R, hive, PPT, SPARK, Haddop, Java, SAS;
De Mauro et al., (2018) - “Big Data”	Web Scraping (Portia), Text mining and expert judgment, LDA (R)	Identifying and comparing job families, skill sets and their match with each job family	Hadoop, SQL, Azure, AWS, Python, SQL, Java, Ruby, R, SAS, MATLAB
Gardiner et al. (2018) - “big data”	Text analysis (R), Consensus pile-sort protocol with domain experts	Defining frequent terms and studying term or skills categorization per concept, presenting developed framework	Hadoop, Java;

Customers' QR Code Usage Barriers in a Brick-and-Mortar Store: A Qualitative Study

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The purpose of this study is to explore the factors that hinder customers from utilizing QR codes when they visit brick-and-mortar (B&M) stores. The research was conducted at a Finnish fashion retailer, where three types of QR codes were displayed for customers to use. In order to identify the barriers that customers face, two different sets of data were collected and analyzed: open-ended survey data (n = 101) and interview data (n = 16). The findings showed two main categories of barriers, customer and company related, with seven sub-barriers. The customer-related barriers included lack of interest in QR codes, user-related usage issues, desire for a device-free B&M store, and dislike toward QR codes. The company-related barriers included unnoticeable QR codes in the B&M store, service personnel in the B&M store, and QR code-related technical problems.

Keywords:
QR codes, omnichannel, channel, retail, customer perspective, commerce, QR code barriers, usage barrier, brick-and-mortar store, B&M, Finland

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1 Introduction

The customer journey is going through a digital transformation (Zimmermann, 2016), and due to the change from a multichannel to omnichannel environment, the digital and physical worlds are evolving into an single entity instead of being separate channels. Physical channels, such as brick-and-mortar (B&M) stores, include digital elements, such as electronic displays (Roggeveen et al., 2016) and quick response (QR) codes (Tiwari, 2016) to name a few. QR codes are becoming more and more common, as they allow for easy and quick access to value via a smartphone. Thus, QR codes are a way to guide customers to engage with the digital world as part of their shopping experience in a B&M store, but customers are not utilizing this opportunity (Lau et al., 2022).

Previous research on customers' QR code usage has focused on QR codes' visual appearance (Gao et al., 2015; Tsai & Peng, 2023); acceptance (Kim & Woo, 2016); use alongside with mobile trust and technology acceptance in omnichannel (Lawry & Choi, 2013); perceptions of codes on milk packages (Lau et al., 2022); impact on customer satisfaction and purchase intention (Hossain et al., 2018); customer experience (Shin et al., 2012); and print advertisements with codes (Trivedi et al., 2019). Even though QR codes have been investigated from multiple perspectives, there is a gap in our understanding of why customers do not use QR codes in B&M stores. This knowledge may help companies to understand the customers' perspective and make strategic decisions when implementing QR codes as a source of value in B&M stores to enable omnichannel shopping. Hence, this study focuses on identifying the barriers that prevent customers from using QR codes while shopping in B&M stores. The research was conducted at a Finnish fashion retailer, where three types of QR codes were displayed for customers to use. To gather information about the challenges that customers face when using QR codes, we collected and analyzed two sets of data: open-ended survey data (n = 101) and interview data (n = 16).

2 Literature Review

A QR code is a two-dimensional matrix code which enables high-speed decoding via a smartphone's built-in camera. It was developed in 1994 by Denso Wave (a Toyota subsidiary) to track vehicle parts, and it has been implemented in marketing campaigns since 2011 (Tiwari, 2016). Ever since, QR codes have been a way for customers to navigate to the desired digital end point.

The visual appeal of QR codes has been noted as a usage barrier, as Gao et al. (2015) criticized that the tedious black-and-white code distracts from the quality of the advertisement. Thus, beautified (Tsai & Peng, 2023), invisible (Gao et al., 2015), stylized aesthetic (Xu et al., 2019), and colorful and decorated QR codes have been invented in an attempt to make the codes more attractive (Lin et al., 2013). In the luxury context, the visual appeal of QR codes was linked to customers' QR code scanning intentions (Lawry & Choi, 2013). Additionally, Singhal and Pavithr (2015) explained that the optimal size of a QR code for scanning should be calculated.

Sometimes, QR codes are not accepted by customers. Shin et al. (2012) studied QR code acceptance and found that while users might have a positive perception toward QR code features, this does not lead to QR code usage because confirmation of what will happen upon scanning the QR code is missing. The major technology acceptance drivers are perceived usefulness, enjoyment, and usability (Pucihar, 2020). Scanning intentions can prevent acceptance of QR codes and lead to their rejection. Lawry and Choi (2013) found that mobile trust was not related to QR code scanning intentions in the luxury retail context and called for experimental studies in real-life retail settings. Oppositely, Liébana-Cabanillas et al. (2015) found that attitude, innovation, and subjective norms were linked with intentions to use QR codes in the future in the context of mobile payment acceptance. Similarly, Kim and Woo (2016) found that customers have a positive intention toward using QR codes as an information tool. Additionally, QR codes have been criticized as unclear and cumbersome from customers' perspectives. Lau et al. (2022) found that in low-cost items (e.g., milk), the 'hassle cost' of scanning many QR codes to get a discount was too much effort. The study found that the perceived value of or trust toward QR codes did not lead to scanning and that the novelty of QR codes resulted in a lack of interest toward them.

Some studies have confirmed QR codes' feasibility. QR code promotions with product information in magazines were found to be motivating for customers (Ertekin & Pelton, 2014). Also, QR codes can be a bridge to move traditional push-based marketing (e.g., print) to a digitalized environment (Trivedi et al., 2019). This idea for using QR codes follows the omnichannel logic by Brynjolfsson et al. (2013), in which digital and physical spaces become one entity instead of channel clutter. Internal and external touchpoints in the customer journey can support each other (Mali et al., 2022; Paananen et al., 2022a; Holkkola, 2022a) with the aim of creating a seamless customer experience (Lemon & Verhoef, 2016). Digital transformation might increase the familiarity of QR codes. A study by Zhong and Moon (2022) found that the COVID-19 pandemic increased the use of contactless services, leading to familiarity with contactless technologies, such as QR codes, which are most likely to continue being used after the pandemic. Additionally, Rotsios et al. (2022) found that QR codes' contents can be entertaining and enriching for customers. The problem lies in QR code scanning barriers, which previous research has failed to address. As there are justified reasons for using QR codes, such as omnichannel operations, it is crucial to understand what prevents the use of QR codes in B&M stores.

3 Methodology

To map customers' real-life experiences of QR code usage barriers during a B&M store visit, we put QR codes on display at one of the case company's B&M stores and asked about customers' thoughts on them. The case company was a Finnish fashion retail company and clothing brand. Three different types of QR codes (see Appendix A) were on display from May 2022 to September 2022:

1. The first type of QR code was placed next to a clothing rack that contained the brand ambassador's (long term influencer) favorite items. The QR code led to the ambassador's Instagram post about the company's products.
2. The second type of QR code was placed next to jackets and trousers. The QR code led to the product page of the company's online store.
3. The third type of QR code was placed close to a sale outlet clothing rack, inside the fitting booth, at the checkout, and at the front door. In addition, the salesperson placed a promotional leaflet with the QR code on it in the shopping bag with the purchased items. The QR code led to the survey.

The survey data collection was carried out using both a pen-and-paper survey and an online survey that was implemented with the LimeSurvey service and could be accessed by either entering a web address or scanning a QR code. The survey questionnaires of both the surveys were identical and inquired the customers about their background information, B&M store visit frequency, use of the brand's other channels, customer experience, previous QR code use experience, and QR code usage during the B&M store visit. Those who answered that they had not used a QR code during the B&M store visit were asked why via an open question. After filling out the survey, customers could take part in prize drawing of a €50 gift card and, also, volunteer for an interview to receive an additional reward (a bag valued at €40) and tell their experience in more depth.

The interview data collection was carried out using semi-structured interviews with 16 selected volunteers (see Appendix B): three males and 13 females (referred to as Participants 1–16: P1–P16). The selection criteria were persons who had visited the B&M store between May 2022 and September 2022 while the QR codes were on display (see Appendix C). Data saturation was reached after 16 interviews, when new information was no longer obtained. One test interview was conducted. The interviews were conducted via Microsoft Teams in September 2022 with an average duration of 59 minutes. The participants were asked to describe their shopping experiences when visiting the B&M store, their IT skills, their QR code usage before and during the visit, and their general brand relationship with the company. The order of the interview questions was not strictly defined in advance, which enabled additional questions, following Myers and Newman's (2007) advice for semi-structured interviews. All the interviews were recorded and transcribed. The quotes were translated from Finnish to English.

Inductive coding was selected to process the data (Thomas, 2003). The survey data showed the themes, and the interviews explained them. First, the survey data's open answers to why customers did not use QR codes in the B&M store (i.e., usage barriers) were imported into Microsoft Excel starting with collecting the QR code usage related barriers. Second, after multiple rounds, two main categories were identified: company-related and customer-related QR code usage barriers. Third, after several rounds of examination, seven sub-categories emerged under these two main categories. After careful familiarization with the interview data, we took the seven identified sub-categories from the survey data's open answers and coded the interview data with these barriers using the ATLAS.ti qualitative analysis software. Finally, seven-sub barriers with the deeper explanations were identified from the interview data.

4 Findings

In total, 101 valid survey responses were obtained. The demographics (gender, age, and socioeconomical status) of respondents (referred to as R1–R101) are reported in Table 1. Most of them were women (74.3%). Many were 30–39 years old (28.7%). The average age was 39.9 years and the standard deviation 14.6 years. The respondents presented varying socioeconomic statuses, but the most of them were employed (72.3%). The respondents were able to pick multiple socioeconomic status choices. All the respondents were from Finland. Almost all answered yes to having previous experience with QR code usage (93.1%).

Table 1: The survey respondents' demographics (n = 101)

	n	%		n	%
Gender			**Socioeconomic status**		
Male	26	25.7	Student	23	22.8
Female	75	74.3	Employed	73	72.3
			Self-employed	5	5.0
Age			Unemployed or unable to work	3	3.0
15–29 years	26	25.7	Stay-at-home parent	1	1.0
30–39 years	29	28.7	Pensioner	7	6.9
40–49 years	20	19.8	**Has used QR codes before**		
50–59 years	11	10.9	Yes	94	93.1
60+ years	15	14.9	No	6	5.9
			No response	1	1.0

Despite their previous experiences with QR codes, only 11 (10.9%) of the respondents reported using QR codes during their B&M store visit. In contrast, 83 of the respondents (82.2%) did not use the QR codes during the store visit, and seven (6.9%) did not respond to the question. For all respondents who answered that they did not use QR codes while visiting the B&M store, we asked the open question: "Why did you not use QR codes when visiting the B&M store?" Of the 83 non-users, 78 (93.98%) answered this question. The non-users' open answers were analyzed and divided into two main categories of usage barriers (company and customer related) with seven sub-barriers (see Table 2). These are presented in more detail in Table 2 and expanded upon using insights from the interviews.

Table 2: Themes and open answer counts from the survey

Theme	Count
Customer-related QR code usage barriers	**54**
Lack of interest in QR codes	32
User-related usage issues	12
Desire for a device-free B&M store	6
Dislike toward QR codes	4
Company-related QR code usage barriers	**36**
Unnoticeable QR codes in the B&M store	26
Service personnel in the B&M store	8
QR code-related technical problems	2

4.1 Customer-Related QR Code Usage Barriers

Lack of interest in QR codes. The lack of interest in QR codes could be seen through the open answer data, appearing as a passive resistance to QR codes. This passive resistance emerged in the form of ignoring QR codes but not directly resenting them. This topic was explained by the survey respondents as, for instance, too tired to use them (R12, R63), no need (R28, R55, R58, R72, R87, R91, R98, R99), or I wasn't buying products right now (R7, R17). The interview data revealed that QR codes were uninteresting for some interviewees because the codes did not seem rewarding or clear enough to be scanned. For example, some interviewees were too confused to get excited about scanning the QR code.

> "Well, maybe. I don't know what [value] these QR codes bring for me or why should I read them." (P3)

> "I don't know. Maybe those [QR codes] were nothing worth mentioning, so I just saw that there is one and maybe wondered what that was but haven't started to investigate or look into it any further." (P5)

Some interviewees found the design of the QR codes and tags unappealing, describing them as "just black-and-white" (P9) or "just some paper with that QR code" (P6). Also, the QR codes were associated with products that were irrelevant to the interviewees.

> "Maybe I wasn't interested enough because they were not included with products I would buy anyways. So, then, I didn't see it as relevant." (P2)

User-related usage issues. The data revealed that customers entering the B&M store had varying technical skills and devices, leading to some being unable to utilize the QR codes even if they wanted to, as indicated by the responses "I did not have the application to scan the QR codes" (R43), "lack of Internet" (R25), "lack of skill" (R73), "low battery" (R67), "I did not have a mobile phone with me" (R75), and "unfamiliar" (R92). Problems with the user's skills or their device's functionality created barriers to QR code use. In the interviews, however, many interviewees described QR code usage as an "easy thing to do" (P2) and an "everyday thing" (P13) in a technical sense. Most of the interviewees described their general IT skills as advanced. Despite this, some interviewees faced issues when figuring out how to use the QR code scanner.

> "I remember that it was like 'all fingers and thumbs' moment when you don't use them every day, like, how does this work." (P7)

The interviews also revealed that dysfunctional user devices created a barrier to QR code usage. For example, one interviewee's phone did not have a QR scanner directly in the camera application. Additionally, the QR code scanner application's flood of ads was distracting to another interviewee.

> "These QR code scanners that I have, those have so many ads in them, that there is such a great danger of hitting an ad and then going to the wrong page." (P9)

Desire for a device-free B&M store. The reluctance to adopt QR codes was further justified by the preference for a B&M store to be free of digital devices. One of the survey respondents indicated that "in a B&M store, I want to concentrate on looking and trying out physical products. In a B&M store, I don't surf on the Internet" (R47). Another survey respondent reported that they just "prefer trying clothes on me instead of looking for inspiration from the Internet" (R70). This did not encourage the use of QR codes since phones were viewed as a distraction and not part of a B&M shopping moment. These respondents wanted to experience, feel, and touch the products: "products in the B&M store were interesting and nicely on display" (R53). Thus, a barrier was created because some of the respondents did not want to experience products through the phone in the B&M store. This phenomenon of desire for a device-free B&M store was also reported in the interviews because "these products can be enjoyed without any digital aspects" (P12). Some interviewees even left their phone in the car to ensure their device-free shopping moment in the B&M store. They indicated that they would rather experience the store without digital encounters:

> "When I saw those [QR codes], I thought, "Is this necessary, when I come here to the B&M store?"…. I don't want to dig out my phone. Often my phone might be left in the car, and it isn't always accompanying me. Then you don't assume that you need it there, and then you hope that you can reach the information in the store without using digital devices. There is a webstore etc. when you can use technology." (P12)

Dislike toward QR codes. Disliking QR codes emerging as active resistance to QR codes, which means direct resentment towards QR codes in particular. In the open answers from the survey, certain respondents reported dislike and strong negative emotions rather than just a lack of interest, as exemplified by the responses "QR codes feel a little bit complicated and useless in general" (R14), "no additional value" (R32), and irrelevant for them right now (R44, R72). Some of the respondents indicated that they "haven't learned how to use them" (R57) or "not everyone is a " 'QR-code person' " (R77). This resistance toward QR codes created a barrier to their use and sometimes even to learning how to use them. Additionally, some interviewees felt that QR codes were unnatural because B&M store visits "do not require any phone" (P13) or they were not their "cup of tea" (P13) and, therefore, created a usage barrier. QR codes seemed to even represent an unwanted change or trend phenomenon.

> "They represent the new era, but I don't care for them or need them" (P13)

> "They are useless, or they are put up without purpose. They surely are useful for someone, but I feel that they seem out of place and bit "glued on." It's like they are put up because its trendy or new even though obviously they are no longer a new thing. Regardless, I think they are not as needed there [in the B&M Store] as in other places." (P4)

Some interviewees just wanted to "shop without scanning them" (P12) because the QR codes did not feel necessary or provide any additional value for them.

4.2 Company-Related QR Code Usage Barriers

Unnoticeable QR codes in the B&M store. Many survey respondents reported not noticing the QR codes during their B&M store visit (R8, R16, R18, R20, R27, R33, R34, R36, R39, R43, R48, R50, R51, R52, R55, R61, R64, R69, R70, R83, R84, R101). Almost all of the survey respondents had used QR codes before (see Table 1), and therefore, they understood what a QR code is and what it looks like, although some respondents reported noticing only the survey QR code (R16, R29, R31): "I thought all codes were the same; separating different codes could have helped" (R31). The interview data exposed issues with the QR codes, such as that they were too small (P2, P3, P4, P6, P9, P10, P16) or lacking color (P9) to be noticeable. Sometimes the QR codes were too well-camouflaged in the store. Additionally, the interviewees questioned themselves, wondering if perhaps they saw the QR codes, but their minds did not even register the codes, thus barring usage.

> "Either those were so well-integrated into the product description, or the eye is already so used to seeing QR codes around that they are not noted in that sense" (P11)
> "They blend in really well with the environment, maybe a little too well" (P6)

Service personnel in the B&M store. Some of the survey respondents described usually asking for customer service help when they needed information, such as, "I would rather ask a customer servicer" (R49) or that customer service personnel were "easy to approach" (R93). Customer service even outplayed the QR codes as a source of information: "I didn't need it. Great service and salespersons who know their business!" (R81). Thus, the customer service seemed to be of too high of a level to encourage survey respondents to use the QR codes. One interviewee clarified the matter: "one can ask a salesperson, at least in a B&M store" (P1). This created a QR code usage barrier because customer service as an information channel came to their minds before using QR codes. Some interviewees also trusted the information and answers from the store's salespeople more than trying to find information in other ways. This created a barrier to using the QR codes because customer service was the first choice to find answers:

> "If I wanted more information about those products, I'd rather ask the salesperson when I'm in the store. And I trust that the salesperson can best tell me about it and answer questions." (P12)

QR code-related technical problems emerged when positioning and visual design prevented their usage. It was noted in the survey, for example, that the QR codes did not work (R36, R65) when some of the survey respondents tried to scan the codes. One of the interviewees shed light on this technical problem by stating that the QR codes were placed too far away to be scanned with some devices, therefore creating a usage barrier:

> "I noticed the QR code related to this study, which was honestly a bit far behind the counter, so I had to type in the visible URL that was below it to get there." (P6)

Also, some participants experienced QR code dysfunction due to their small size (P2, P3, P4, P6, P9, P10, P16), which prevented them from being scanned.

5 Discussion

This study investigated customers' barriers to QR code usage in a B&M store in a real-life setting. The identified barriers are summarized in Figure 1.

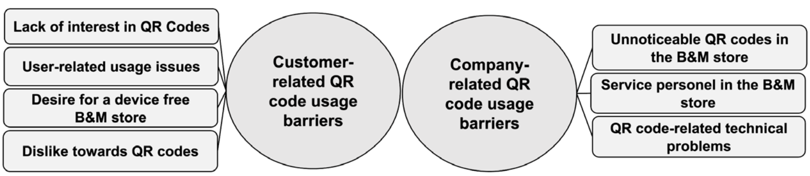


Figure 1: Summary of the findings

This study deepens the previous knowledge by identifying and describing QR code usage barriers relating to both customers and companies in the B&M store setting. The study responds to Lawry and Choi's (2013) call for experimental studies on real brands and QR codes. As in the study by Zhong and Moon (2022), participants in this study were familiar with QR codes but chose not to use them despite their previous experience.

This study suggests that QR code usage barriers in the B&M store setting can be customer related. Firstly, the finding of a lack of interest in QR codes is in line with Lau et al.'s (2022) finding of a 'hassle cost' when scanning QR codes and with Gao et al.'s (2015) criticism toward QR codes' appearance, which are perceived as unappealing and requiring too much effort to use. Also, as in the study by Shin et al. (2012), a lack of confirmation regarding what would happen upon scanning the QR code was also shown in this study; the QR codes were not clear enough despite information in the QR code tags. Because they did not signal to the customer what would happen after a successful scan, customers were not motivated to take action and scan the tags. Perhaps a promise of more exciting content from a customer's point of view (e.g., sustainability information, product manufacturing information, or product color options) could make the QR codes more attractive and thus worth of the 'hassle cost'.

Secondly, sometimes the customers did not expect to encounter QR codes in a B&M store. User-related usage issues revealed customers who were unprepared to scan the QR codes because they lacked the required usage skills, suitable devices, or Internet connection. These are novel findings because QR code usage barriers in terms of devices and skills have been scarcely reported in prior research. QR codes should not complicate the buying of products in the B&M setting but rather add extra confirmation to the purchase intent. Thirdly, as a novel finding, this study found that customers' desire for a device-free B&M store visit, without the need to use their digital devices, is a notable usage barrier. Some customers had even left their devices in their cars and did not expect digital encounters before stepping into the B&M store. This finding shows aspects of technostress (e.g., Salo et al., 2019; Pirkkalainen, et al., 2019) because annoyance toward using a phone in the B&M store was noticed in the study. The stressor could be, for example, a shattered expectation of only a physical encounter during the B&M store visit. This is an interesting finding because the study by Holkkola et al. (2022b) found that certain customers tend to showroom, meaning they actively search for more information about products and better deals via their phone while physically experiencing products in a B&M store.

Lastly, the findings of customer-related QR code usage problems suggest active resistance. This dislike toward QR codes could be due to a failure to meet the technology acceptance drivers, such as providing enjoyment, usability, or usefulness (Pucihar, 2020) or perceived value or trust (Lau et al., 2022). The QR codes were not accepted; these actively resisting QR code dislikers did not even have an intention of using QR codes and showed resistance toward the technology.

In turn, this study suggests that a company can involuntarily cause QR code usage barriers in the B&M setting. First, the findings of unnoticeable QR codes in the B&M store showed novel findings concerning QR codes may be too small, blend into the background, or be difficult to tell apart from each other. In line with Lau et al.'s (2022) finding's inattention, some customers did not register or notice the QR codes. It is possible that they did not expect QR codes in the B&M store. The visibility of QR codes and their tags should be improved to make them more noticeable. Visibility could be improved with conspicuous design choices to make a pop-out effect and not to camouflage them. Also, improving QR codes' visual appearance (Gao et al., 2015; Lin et al., 2013; Tsai and Peng, 2023; Xu et al., 2018) should be considered. In cases where multiple different QR codes are used, they should be clearly separated from each other.

Second, this study showed that the service personnel in the B&M store outplayed the QR codes because customer service was available and was too good. Thus, QR codes may be useful if customer service is not available or if additional content (e.g., videos) is provided via the QR codes. Lastly, non-working QR codes were reported. Singhal and Pavithr (2015) previously noted that QR codes should be of an optimal size and scanning distance. Thus, a usage barrier was created by the QR codes' small size and big distance. We suggest planning where QR codes will be located and their size.

6 Limitations and Future Research

This study considered the QR code usage barriers for customers in a real-life setting of a fashion retail store in Finland. This study provides an authentic in-depth understanding based on individual participants' experiences and thus is not to meant to be generalized. Notably, of participants, Finnish female B&M visitors were mostly represented in the findings. Future studies could research supporting factors of customers' QR code usage in a B&M store in different contexts. Retail markets should examine ways to ensure sustainable consumption following the barriers noted by Kemppainen et al. (2021). Last, QR code as an intermediary to a brand relationship could be investigated as stressed by Paananen et al. (2022b).

References

Brynjolfsson, E., Hu, Y. J., & Rahman, M. S. (2013). Competing in the age of omni-channel retailing. MIT Sloan Management Review, 54(4), 23–29.

Ertekin, S., & Pelton, L. E. (2014). An empirical study of consumer motivations to use QR codes on magazine ads. American International Journal of Contemporary Research, 4(5), 47-55.

Gao, Z., Zhai, G., & Hu, C. (2015). The invisible QR code. In Proceedings of the 23rd ACM International Conference on Multimedia (pp. 1047–1050). ACM.

Holkkola, M., Frank, L., Kemppainen, T., Paananen, T., & Luhtanen, V. (2022a). The role of sustainability in online customer experiences: a qualitative study on female fashion shoppers. In Proceedings of the 14th Mediterranean Conference on Information Systems (MCIS).

Holkkola, M., Nyrhinen, J., Makkonen, M., Frank, L., Karjaluoto, H., & Wilska, T.-A. (2022b). Who are the showroomers? Socio-demographic factors behind the showrooming be-havior on mobile devices. In A. Pucihar, M. Kljajić Borštnar, R. Bons, A. Sheombar, G. Ongena, & D. Vidmar (Eds.), Proceedings of the 35th Bled eConference: Digital restructur-ing and human (re)action (pp. 113–128). University of Maribor Press.

Hossain, M. S., Zhou, X., & Rahman, M. F. (2018). Examining the impact of QR codes on purchase intention and customer satisfaction on the basis of perceived flow. Interna-tional Journal of Engineering Business Management, 10, 1–10.

Kemppainen, T., Frank, L., Makkonen, M., & Hyvönen O.-I. (2021). Barriers to responsible consumption in e-commerce: Evidence from fashion shoppers. In A. Pucihar, M. Klja-jic Borstnar, R. Bons, H. Cripps, A. Sheombar, & D. Vidmar (Eds.), Proceedings of the 34th Bled eConference: Digital support from crisis to progressive change (pp. 327–340). Univer-sity of Maribor Press.

Kim, Y. G., & Woo, E. (2016). Consumer acceptance of a quick response (QR) code for the food traceability system: Application of an extended technology acceptance model (TAM). Food Research International, 85, 266–272.

Lau, S., Wiedmann, M., & Adalja, A. (2022). Consumer perceptions of QR code technology for enhanced fluid milk shelf-life information provision in a retail setting. JDS Communica-tions, 3(6), 393–397.

Lawry, C. A., & Choi, L. (2013). The omnichannel luxury retail experience: Building mobile trust and technology acceptance of quick response (QR) codes. Marketing ZFP, 35(2), 144–154.

Lemon, K., & Verhoef, P. (2016). Understanding customer experience throughout the customer journey. Journal of Marketing, 80, 69–96.

Liébana-Cabanillas, F., Ramos de Luna, I., & Montoro-Ríos, F. J. (2015). User behaviour in QR mobile payment system: The QR payment acceptance model. Technology Analysis & Strategic Management, 27(9), 1031–1049.

Lin, Y.-S., Luo, S.-J., & Chen, B.-Y. (2013). Artistic QR code embellishment. Computer Graphics Forum, 32(7), 137–146.

Mali, E., Paananen, T., Frank, L., & Makkonen, M. (2022). A Customer Perspective on Omni-channel Customer Journey and Channel Usage: A Qualitative Study. In P. Bednar, A. S. Islind, H. Vallo-Hult, A. Nolte, M. Rajanen, F. Zaghloul, A. Ravarini, & A. M. Braccini (Eds.), Proceedings of the 8th International Workshop on Socio-Technical Perspective in Information Systems Development (STPIS 2022) (pp. 299-310). RWTH Aachen. CEUR Workshop Proceedings, 3239.

Myers, M. D., & Newman, M. (2007). The qualitative interview in IS research: Examining the craft. Information and Organization, 17(1), 2–26.

Paananen, T., Kemppainen, T., Frank, L., Holkkola, M., & Mali, E. (2022a). Reinforcement of brand relationships in an omnichannel environment: A qualitative study on clothing shopping. In Proceedings of the 14th Mediterranean Conference on Information Systems (MCIS).

Paananen, T., Frank, L., & Kemppainen, T. (2022b). Customer-Brand Relationships in the Context of Digital Brands. In A. Pucihar, M. Kljajić Borštnar, R. Bons, A. Sheombar, G. Ongena, & D.

Vidmar (Eds.). Proceedings of the 35th Bled eConference: Digital Restructur-ing and Human (Re)action (pp. 495-510). University of Maribor.

Pirkkalainen, H., Salo, M., Tarafdar, M., & Makkonen, M. (2019). Deliberate or instinctive? Proactive and reactive coping for technostress. Journal of Management Information Sys-tems, 36(4), 1179–1212.

Pucihar, A. (2020). User acceptance of electronic commerce: Contributions from the Bled eConference. Electronic Markets, 30(1), 29–37.

Roggeveen, A. L., Nordfält, J., & Grewal, D. (2016). Do digital displays enhance sales? Role of retail format and message content. Journal of Retailing, 92(1), 122–131.

Rotsios, K., Konstantoglou, A., Folinas, D., Fotiadis, T., Hatzithomas, L., & Boutsouki, C. (2022). Evaluating the use of QR codes on food products. Sustainability, 14(8).

Salo, M., Pirkkalainen, H., and Koskelainen, T. (2019). Technostress and social networking services: Explaining users' concentration, sleep, identity, and social relation problems. Information Systems Journal, 29(2), 408–435.

Shin, D.-H., Jung, J., & Chang, B.-H. (2012). The psychology behind QR codes: User experience perspective. Computers in Human Behavior, 28(4), 1417–1426.

Singhal, A., & Pavithr, R. (2015). Degree certificate authentication using QR code and smartphone. International Journal of Computer Applications, 120(16), 38–43.

Thomas, D. R. (2003). A general inductive approach for qualitative data analysis. School of Population Health, University of Auckland.

Tiwari, S. (2016). An introduction to QR code technology. In Proceedings of the 2016 International Conference on Information Technology (ICIT) (pp. 39–44). IEEE.

Trivedi, R., Teichert, T., & Hardeck, D. (2019). Effectiveness of pull-based print advertising with QR codes: Role of consumer involvement and advertisement appeal. European Journal of Marketing, 54(1), 145–167.

Tsai, M.-J., & Peng, S.-L. (2023). QR code beautification by instance segmentation (IS-QR). Digital Signal Processing, 133.

Xu, M., Hao, S., Yafei, L., Xi, L., Jing, L., Jianwei, N., Pei, L., & Bing, Z. (2019). Stylized aes-thetic QR code. IEEE Transactions on Multimedia, 21(8), 1960–1970.

Zhong, Y., & Moon, H.-C. (2022). Investigating customer behavior of using contactless pay-ment in China: A comparative study of facial recognition payment and mobile QR-code payment. Sustainability, 14(12).

Zimmermann, H. D. (2016). Digital transformation—The emerging digital economy. In Proceed-ings of International Conference: Liberec Informatics Forum: ICT in the Role of Services: State of the art and perspectives (pp. 138–146). Tech University Liberec.

Appendix A: Examples of QR code tags

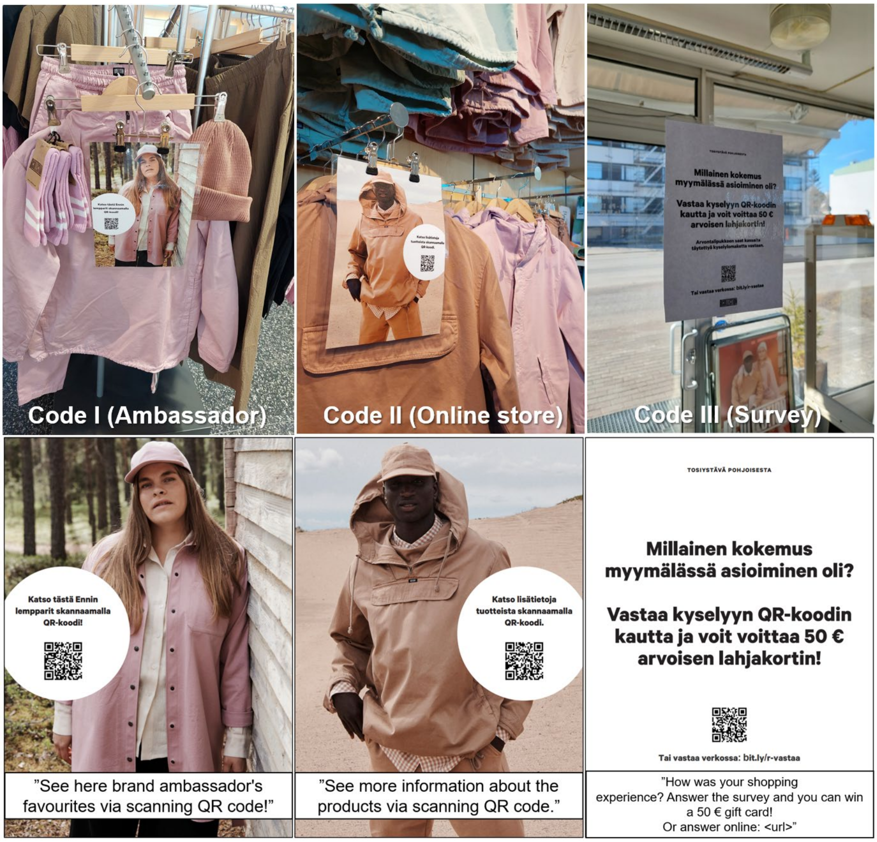
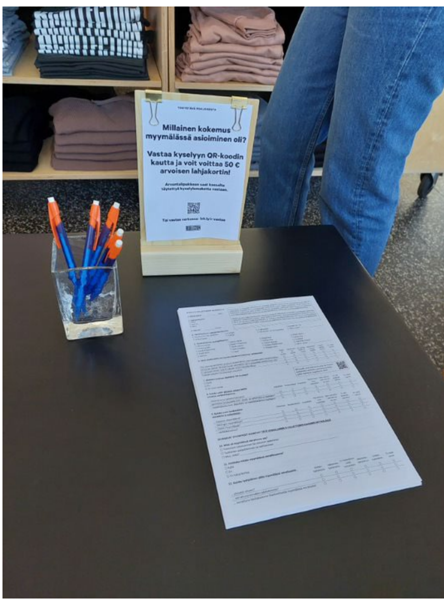


Figure 2: Promo material of R-Collection brand (https://www.r-collection.fi/)

Appendix B: Details about the study's interview participants

	Gender	Age	Employment Status	Interview Duration (Min)
P1	Female	37	Employed	43
P2	Female	30	Student, employed	53
P3	Female	23	Student	64
P4	Female	40	Employed	84
P5	Female	29	Employed	47
P6	Male	29	Student, employed	65
P7	Male	24	Student, employed	52
P8	Female	33	Employed	58
P9	Female	42	Employed	49
P10	Female	25	Student	40
P11	Male	38	Employed	69
P12	Female	33	Employed	70
P13	Female	59	Employed	69
P14	Female	24	Student	51
P15	Female	32	Employed	65
P16	Female	29	Employed	64

Appendix C: Setting of the experiment in the brick-and-mortar store



Using the Apple Watch to Teach and Learn About Heart Rate Variability While Vacationing

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Vacations are known to contribute to well-being. Wearable sensing technologies associated with 'the quantified self' hold promise for designing experiences such as vacations based on evidence to optimize their well-being outcomes. Tourism organizations may also ask to collect data from customers to help with experience management. The present project shows the potential of heart rate variability data, measured using an Apple Watch, during vacation to produce such insights, and to do so in cooperation with students for the purpose of inspiring them to state-of-the-art research ideas in the context of tourism. Findings show that heart rate variability during vacation appears to follow a conversation-of-resources pattern, whereby days with low life satisfaction on vacation feature significant increases in heart rate variability. While students gained insights from providing these data and becoming familiar with the Apple Watch, future iterations of this project may feature students learning to work with their data themselves.

Keywords:
tourism,
emotions,
experience,
quantified self,
heart rate variability

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1 Introduction

The term *the quantified self* has been used to refer to the use of personal technologies to digitize and analyze the workings of one's own body and mind (Lupton, 2016; Swan, 2013). The original impetus for exploring the quantified self was development of biosensing technologies such as smartwatches with photoplethysmogram sensors to measure heart rate and sensors which recorded temperature, location, and movement. There was hope that such data would positively inform individuals wishing to improve their own health and well-being. A part of life important to well-being is vacationing (Mitas & Kroesen, 2019). The present contribution applies this logic the use of the Apple Watch to measure six students' autumn vacation experiences, with two aims: 1) to assess the role of heart rate variability in vacation well-being outcomes, and 2) to reflect on this project as a way of teaching students about the quantified self.

Vacations, defined here as travel away from one's usual place of residence for leisure purposes of between one night and one year in duration, have demonstrable positive effects for well-being. We use a *subjective well-being* conceptualization in this paper, which means that we define well-being as a judgment an individual makes about *their own* life, and that this judgment comprises an affective dimension, operationalized as positive and negative emotions and moods, as well as a cognitive dimension, operationalized as life satisfaction (Diener & Oishi, 2005). In the short term, vacations produce boosts in positive emotions (de Bloom et al., 2010; Mitas et al., 2012); over a period of several years, vacation frequency is associated with higher life satisfaction as well (Mitas & Kroesen, 2019).

The theoretical foundation we use to examine this association comprises the broaden-and-build theory, which holds that brief experiences of positive emotion (which often occur on vacation) accumulate to personal resources, eventually contributing to well-being as a whole (Fredrickson, 2001); and conservation of resources, which alleges that workaday life drains individuals' personal resources in a way that only a respite from work—often a vacation—can allow to naturally regenerate (Hobfoll, 2011). Both theories would suggest that vacations contribute to well-being via increased positive emotions and/or decreased negative emotions. However, while broaden-and-build theory suggests this process would be running across all emotional experiences, conservation of resources theory suggests that vacation experiences would be at their most powerful when personal resources had been diminished.

Vacation experiences have occasionally been studied using the kind of mobile sensing technology that brings to mind the quantified self. For example, wristbands which measure skin conductance have been used to measure peaks of emotional arousal during city walks (Kim & Fesenmaier, 2015; Shoval et al., 2018) and theme park visits (Strijbosch et al., 2021). These measurements can demonstrate, for example, which emotional content of a tour improves an experience, and which degrades it (Mitas, Mitasova, et al., 2020). Skin conductance is an indicator of emotional arousal independent of valence, however, so it cannot indicate whether an experienced emotion peak is positive or negative (Braithwaite et al., 2015). For this purpose, heart rate variability is a more promising metric, though it is not well understood (Levenson, 2014; Ragot et al., 2017). Unlike skin conductance, which indicates sympathetic arousal in response to emotional stimuli, heart rate variability is associated with the parasympathetic down-regulation of this response. In other words, heart rate variability increases when the mind judges an emotional situation to be non-threatening and begins to return physiological responses to emotion back to baseline levels. Therefore, heart rate variability is associated with well-being over a course of days to weeks (Kok & Fredrickson, 2010).

Very few examples of heart rate variability measurement in the context of vacationing exist. Heart rate variability, alongside heart rate and skin conductance, was assessed in a sample of museum visitors in the Netherlands (Mitas, Cuenen, et al., 2020) as well as in a Spanish city walk (i Agustí et al., 2019). The assumption of these studies is that heart rate variability is associated minute-to-minute with emotional valence or, at least, negatively associated with unpleasant emotional stress. While that assumption remains untested, the validity of heart rate variability as a metric of favorable well-being on a scale of days or weeks is somewhat more widely accepted. It is unknown whether it is associated with the subjective well-being changes that occur during vacationing.

Therefore, in the present study, we used daily measurements of heart rate variability and self-reported subjective well-being before, during, and after six students' vacations during the autumn of 2022 to determine if 1) subjective well-being self-reports changed during vacation; 2) heart rate variability changed during vacation, and 3) these changes interacted.

The choice to work with students as participants was made not only based on convenience, but also served an important educational goal. After providing their data, students were debriefed on study variables and hypotheses, and challenged to generate research proposals based on wearable sensing technologies such as the Apple Watch as tools answer applied research questions in tourism experience management. Thus, by reflecting on being research participants, students were triggered to design new project ideas with practical implications based on technology that had just been used to measure their experiences.

2 Methods

In the present study, we invited six students to borrow an Apple Watch paired with an iPhone using the Apple Health application to monitor heart rate variability at three to five random, recurring 60 second daily intervals. This approach is native within the Apple Health software environment. We asked participants to use the device over a period of three weeks. The second of these weeks was the annual 'October break' during which students are free from classes and exams, and many take vacations, including camping or visiting family. Besides recording their heart rate variability, we asked the student-participants to respond to daily questionnaires measuring their positive and negative emotions, life satisfaction, and whether or not they were on vacation. To record emotions using the SPANE instrument (Diener et al., 2010), we asked participants to indicate how strongly they felt each of 8 different emotions (*happy, joyful, content, positive, positively surprised, negative, sad, angry, and afraid*) on a 5-point scale from *Not at all* to *Extremely*. This emotion list represents a slight adjustment from the original SPANE, in that general and redundant items are omitted, and positive surprise, which is important to tourism experiences, was added. Positive emotion items were averaged together into a positive emotion index, while negative emotion items were averaged together into a negative emotion index. We measured life satisfaction using the almost universal Satisfaction With Life Scale (SWLS; Diener et al., 1985), which comprises five statements such as *I am most satisfied with my life* and a 7-point Likert-type scale from *Strongly disagree* to *Strongly agree*. Instead of using the raw heart rate variability data, we asked the students to report the daily average generated by Apple Health, in order to keep the data structured at a daily level.

In line with our three research questions, we conducted three analyses in a within-persons random intercept framework. It was necessary to use random intercept models as much variation in longitudinal well-being data can be explained by within-participant autocorrelation. Thus, each data point had to be analyzed with respect to the baseline of the participant it came from. With this in mind, we first created a boxcar regressor which was coded 1 for days on vacation and otherwise 0. This was used to predict subjective well-being and heart rate variability measures. Then, we entered subjective well-being variables as predictors to the model of heart rate variability as a function of vacation. Finally, we allowed the boxcar regressor for vacationing to interact with subjective well-being variables.

3 Findings

Participants reported being slightly happy on average during the data collection period. Means of positive emotions (3.24) and life satisfaction (4.69) were just over the scale midpoints of each respective variable, while negative emotions were just below (2.26). Average daily heart rate was 71.12 beats per minute, while inter-beat intervals varied by a daily average of 59.53 miliseconds, which is how the Apple Watch measures heart rate variability (Table 1).

Table 1: Descriptive statistics

	Response scale	Mean	Proportion	Standard deviation
Positive emotions	1 - 5	3.24		0.71
Negative emotions	1 - 5	2.26		0.58
Life satisfaction	1 - 7	4.69		1.13
Heart rate		71.12		35.41
Heart rate variability		59.53		36.48
Days on vacation	0 – 100%		20%	

As expected, being on vacation improved participants' positive emotions (difference = 0.32 (0.19); p = 0.099) at a marginally significant level, while life satisfaction remained unchanged (difference = 0.04 (0.15); p = 0.781). Their negative emotions were also marginally higher (difference = 0.28 (0.16); p = 0.0743). Heart rate variability was higher on vacation, but the difference was not significant (difference = 6.025 (5.026); p = 0.2344). Day-to-day variation in heart rate variability was also unrelated to all subjective well-being variables (all p's > 0.3).

Table 2: Random intercept model coefficients

Outcome variable	Predictor(s)	Coefficient (Standard error)	Model AIC; BIC
Positive emotions	Being on vacation	**3.19 (0.19) ***	170.5; 180.1
Negative emotions	Being on vacation	**0.28 (0.16) ***	138.9; 148.4
Life satisfaction	Being on vacation	0.042 (0.153)	139.1; 148.5
Heart rate variability	Being on vacation	6.025 (5.026)	707.3; 716.8
Heart rate variability	Positive emotions	-2.687 (2.939)	707.8; 717.4
Heart rate variability	Negative emotions	2.638 (3.595)	708.1; 717.7
Heart rate variability	Life satisfaction	-3.375 (3.933)	692.8; 702.2
Heart rate variability	Positive emotions	-2.587 (3.031)	709.2; 723.5
	Being on vacation	38.806 (35.176)	
	Positive emotions X Being on vacation	-9.180 (10.031)	
Heart rate variability	Negative emotions	3.378 (3.696)	709.0; 723.3
	Being on vacation	44.243 (28.029)	
	Negative emotions X Being on vacation	-13.634 (9.723)	
Heart rate variability	Life satisfaction	-2.299 (3.842)	691.4; 705.5
	Being on vacation	**51.506 (22.686)****	
	Life satisfaction X Being on vacation	**-8.915 (4.335)****	

Note: * = p < 0.1; ** p < 0.05

Heart rate variability was also unrelated to positive and negative emotions when these were allowed to interact with the boxcar regressor representing vacation days (all p's > 0.1). However, the interaction between being on vacation and life satisfaction significantly predicted heart rate variability (coefficient = -8.915 (4.335); p = 0.0433), over and above a significant positive effect of vacation (difference = 51.505 (22.686); p = 0.0262). In other words, heart rate variability was significantly higher on vacation on days with low life satisfaction. As life satisfaction increased, the positive effect of vacation on heart rate variability decreased, and above a life satisfaction of 5.78—approximately a point higher than the mean in our sample—the sign of the vacation effect on heart rate variability is modeled to become negative (Figure 1).

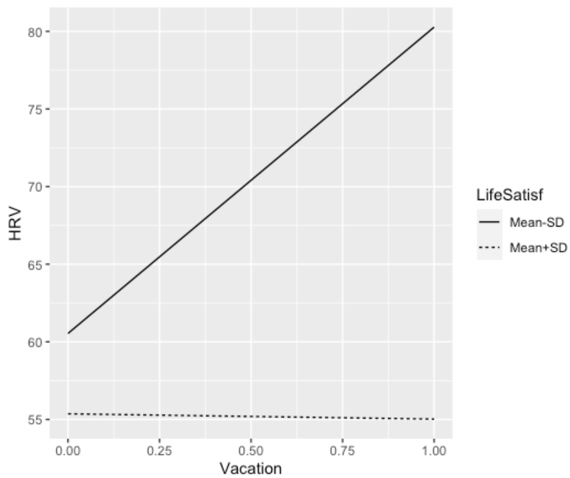

Figure 1: Simple slopes plot of relationship of vacationing (1 = vacation; 0 = at home), life satisfaction, and heart rate variability

4 Discussion

We used Apple Watches to measure six students' heart rate variability before, during, and after the autumn holiday week. We aimed to examine the effects of vacationing on heart rate variability and subjective well-being. Within-individual, between-day analyses showed that vacationing during the holiday week featured slightly improved emotions and, for days with low life satisfaction, improved heart rate variability as well. These findings have theoretical implications for understanding the effects of vacationing on well-being, as well as for teaching about the quantified self in the context of tourism.

4.1 Theoretical implications

It has been posited that vacations contribute to well-being by creating positive emotions (Mitas et al., 2012), thus building up life satisfaction over time by 'broadening and building' resources (Fredrickson, 2001; Mitas & Kroesen, 2019). The present data do not represent a time span which can demonstrate effects of positive emotion on life satisfaction, as that normally takes a number of years, but did show improvement in positive emotions. Thus, our findings are not confirmatory but consistent with this account. Other scholars have demonstrated that vacations improve occupational well-being outcomes by restoring or conserving attentional and physical resources (Fritz & Sonnentag, 2006). Our finding that life satisfaction negatively moderates the effect of vacationing on heart rate variability are accordingly consistent with conservation of resources theory (Hobfoll, 2011). On days with high life satisfaction, participants did not experience elevated heart rate variability if they were on vacation. Vacationing did raise their heart rate variability on days with low life satisfaction, however. In sum, it is possible that days with low life satisfaction were marked by physical, attentional, or emotional exhaustion. To be on vacation those days, without the demands of school, facilitated a restoration of those resources reflected by elevated heart rate variability.

4.2 Reflections on teaching

Students collected data in six groups of four students. We instructed them to consider various ways to record experiences using quantified self approaches which tourism companies can, in turn, ask their customers to share as a source of feedback and quality monitoring. Thus, within each group, only one student had the Apple Watch and reported their heart rate variability. Others recorded their location or considered their photos or social media posts as a source of potential data. As a result of working in groups, with a breadth of data sources in each group, students had a more diverse view on possibilities than if they merely heard about these research methods secondhand. While they were nominally studying tourism, wherein they considered possible implications for »marketing and advertising efforts,« »offsites or workations for employees,« or »determine how travel packages perform,«

students were also able to consider applications to universities to »give better insights of work/study lifestyle« or »insights in person's life satisfaction…for people that have a lot of pressure at work.«

Nevertheless, from a teaching point of view, the present methods could be improved, namely in three ways. First, the sample size could be larger if more devices were available. This would obviously improve the sensitivity of the analyses, but would also give the students the choice to use multiple data streams, for example combining their physiological data together with their photos. Second, some of the students found the process rather unappealing, having to keep devices charged, and wearing during potentially dangerous or appearance-sensitive activities. For example, they asked if we had any other watch bands available so the watches would look better. Also, students emphasized that security of the data, and decoupling location tracking from the physioloigcal and self-response data collection, would be important for the confidentiality of the data. Third, rather than proposing research based on the data they had collected, students could be taught to inspect and visualize their own data, which would empower them to not only propose but also conduct research based on such devices once working in the travel industry.

It is widely appreciated that excellent vacation experiences contribute to well-being (Mitas et al., 2017) and that wearable sensing technologies hold promise for designing such experiences based on evidence (Bastiaansen et al., 2019). We acknowledge that the sample size of six students x 21 days is too small for a robust analysis of the examined phenomena of vacation experiences and well-being. This study should be seen as a test of data collection and modeling methodology on the way to a larger and more diverse sample which would address these questions more substantially. Despite the small sample size, the present project shows the potential of heart rate variability measurement during vacation to produce such evidence, and to do so in cooperation with students for the purpose of inspiring them to state-of-the-art research ideas in the context of tourism.

References

Bastiaansen, M., Lub, X., Mitas, O., Jung, T. H., Passos Acenção, M., Han, D., Moilanen, T., Smit, B., & Strijbosch, W. (2019). Emotions as core building blocks of an experience. International Journal of Contemporary Hospitality Management, 31.

Braithwaite, J. J., Watson, D. G., Jones, R., & Rowe, M. (2015). A Guide for Analysing Electrodermal Activity (EDA) & Skin Conductance Responses (SCRs) for Psychological Experiments.

de Bloom, J., Geurts, S. A., Taris, T. W., Sonnentag, S., de Weerth, C., & Kompier, M. A. (2010). Effects of vacation from work on health and well-being: Lots of fun, quickly gone. Work & Stress, 24(2), 196-216.

Diener, E., Emmons, R. A., Larsen, R. J., & Griffin, S. (1985). The satisfaction with life scale. Journal of personality assessment, 49(1), 71-75.

Diener, E., & Oishi, S. (2005). The nonobvious social psychology of happiness. Psychological Inquiry, 16(4), 162-167.

Diener, E., Wirtz, D., Tov, W., Kim-Prieto, C., Choi, D.-w., Oishi, S., & Biswas-Diener, R. (2010). New well-being measures: Short scales to assess flourishing and positive and negative feelings. Social Indicators Research, 97(2), 143-156.

Fredrickson, B. L. (2001). The role of positive emotions in positive psychology: The broaden-and-build theory of positive emotions. American psychologist, 56(3), 218.

Fritz, C., & Sonnentag, S. (2006). Recovery, well-being, and performance-related outcomes: The role of workload and vacation experiences. Journal of Applied Psychology, 91(4), 936.

Hobfoll, S. E. (2011). Conservation of resources theory: Its implication for stress, health, and resilience.

i Agustí, D. P., Rutllant, J., & Fortea, J. L. (2019). Differences in the perception of urban space via mental maps and Heart Rate Variation (HRV). Applied Geography, 112, 102084.

Kim, J., & Fesenmaier, D. R. (2015). Measuring emotions in real time: Implications for tourism experience design. Journal of Travel Research, 54(4), 419-429.

Kok, B. E., & Fredrickson, B. L. (2010). Upward spirals of the heart: Autonomic flexibility, as indexed by vagal tone, reciprocally and prospectively predicts positive emotions and social connectedness. Biological psychology, 85(3), 432-436.

Levenson, R. W. (2014). The autonomic nervous system and emotion. Emotion review, 6(2), 100-112.

Lupton, D. (2016). The quantified self. John Wiley & Sons.

Mitas, O., Cuenen, R., Bastiaansen, M., Chick, G., & van den Dungen, E. (2020). The War from both Sides: how Dutch and German Visitors Experience an Exhibit of Second World War Stories. International Journal of the Sociology of Leisure, 3(3), 277-303.

Mitas, O., & Kroesen, M. (2019). Vacations Over the Years: A Cross-Lagged Panel Analysis of Tourism Experiences and Subjective Well-Being in the Netherlands. Journal of Happiness Studies, 1-20.

Mitas, O., Mitasova, H., Millar, G., Boode, W., Neveu, V., Hover, M., van den Eijnden, F., & Bastiaansen, M. (2020). More is not better: The emotional dynamics of an excellent experience. Journal of hospitality & tourism research, 1096348020957075.

Mitas, O., Nawijn, J., & Jongsma, B. (2017). Between Tourists: Tourism and Happiness. In M. K. Smith & L. Puczko (Eds.), The Routledge Handbook of Health Tourism (pp. 47-64). Routledge.

Mitas, O., Yarnal, C., Adams, R., & Ram, N. (2012). Taking a "peak" at leisure travelers' positive emotions. Leisure Sciences, 34(2), 115-135.

Ragot, M., Martin, N., Em, S., Pallamin, N., & Diverrez, J.-M. (2017). Emotion recognition using physiological signals: laboratory vs. wearable sensors. International Conference on Applied Human Factors and Ergonomics,

Shoval, N., Schvimer, Y., & Tamir, M. (2018). Real-time measurement of tourists' objective and subjective emotions in time and space. Journal of Travel Research, 57(1), 3-16.

Strijbosch, W., Mitas, O., van Blaricum, T., Vugts, O., Govers, C., Hover, M., Gelissen, J., & Bastiaansen, M. (2021). Evaluating the Temporal Dynamics of a Structured Experience: Real-Time Skin Conductance and Experience Reconstruction Measures. Leisure Sciences, 1-25.

Swan, M. (2013). The quantified self: Fundamental disruption in big data science and biological discovery. Big data, 1(2), 85-99.

A Virtual Companion for Lifelong Learning – Design Principles for Motivation, Social Learning, and Exam Preparation

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Lifelong vocational learning in a digital context frequently falters due to a lack of motivation, structure, time management, and attention to adult students' work-life balance. In remote settings, students have further little contact with peers and feel disconnected. This paper answers how a Virtual Learning Companion (VLC) can be designed to address these challenges and fulfill the specific needs of vocational students. Following a Design Science Research (DSR) approach, a meta-requirement mapping process combines insights from a literature review and ten semi-structured interviews with vocational students. A focus group with experts from the field of vocational training, online learning, chatbot design, and DSR evaluated the results. As a result, five Design Principles are presented: (1) Motivational Goal Setting, (2) Context and Learner Adaptation, (3) Focus and Control, (4) Promoting Resilience, and (5) Enabling Social Interactions and Feedback. Exemplary Design Features further illustrate the VLC development.

Keywords:
virtual companionship, education, design science research, virtual collaboration, Bled eConference

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1 Introduction

Lifelong learning is the pursuit of continuous learning and skill development beyond formal education (Cropley & Knapper, 1983). Advanced technologies in distance and hybrid learning environments have opened up new opportunities for lifelong learning. Pedagogical Conversational Agents (PCA) present such a novel technology (Khosrawi-Rad et al., 2022; Wollny et al., 2021) and refer to intelligent dialog systems, e.g., chatbots, which interact with learners using natural language (Gnewuch et al., 2017; Hobert & von Wolff, 2019). A specific form of PCA are Virtual Learning Companions (VLC), designed to facilitate learning and establish a close bond with their users (Greenwald et al., 2016; Strohmann et al., 2022). They are available regardless of time or location and can motivate learners, assist in time management, and foster self-reflection (Gubareva and Lopes, 2020; Khosrawi-Rad, et al., 2022; Wollny et al., 2021). They differ from PCAs by acting relationship-oriented and being designed for long-term use, often inspired by artificial intelligence techniques (Khosrawi-Rad, et al., 2022b).

Vocational training in lifelong learning differs from formal education as it involves adults with diverse backgrounds studying alongside their work commitments (Cropley & Knapper, 1983), covering a wider age range, having limited contact with fellow students, and requiring effective time management between work, family, and studies (Rinn et al., 2022). In vocational training, students must develop self-regulation and acquire structures, skills, habits, knowledge, and attitudes (Cropley & Knapper, 1983; Rinn et al., 2022). To design and develop VLCs for this specific learning context, it is necessary to understand and prioritize the needs and values of learners in vocational training (Rinn et al., 2022). In recent years, research on PCAs has increased (Khosrawi-Rad et al., 2022) and authors proposed design knowledge for various specific application contexts such as argumentative writing support (Wambsganss et al., 2020), avoiding procrastination (Rodriguez et al., 2019), or designing a PCA as a tutor (Winkler & Roos, 2019). However, existing design principles are inadequate for the novel VLC approach and fail to cater to learners in vocational training, highlighting a research gap in VLC design knowledge and facilitating the practical implementation of long-term learning support (Khosrawi-Rad et al., 2022). This study refers to this research gap by answering the research question of how to design VLCs, which address the needs of students in lifelong learning in terms of (1) learning behavior, exam preparation, and time management,

(2) motivation, and (3) social learning. To gather design knowledge, we utilize Design Science Research (DSR) as a practical and scientifically rigorous approach (Hevner et al., 2004). Design principles are derived by integrating kernel theories, VLC design features, and user requirements from ten interviews.

2 Theoretical Grounding

This paper aims to highlight and address three specific challenges related to self-regulated learning in vocational education, which encompasses cognitive, metacognitive, behavioral, motivational, and emotional aspects of learning (Panadero, 2017; Rinn et al., 2022): (1) learning strategy, including exam preparation and time management, (2) motivation and goal setting, and (3) social learning. Table 1 represents a theoretical framework derived from a literature review of kernel theories from psychology which form the theoretical basis of the DP formulation (Kuechler and Vaishnavi, 2008; Möller et al., 2022). Design Features (DF) highlight applicable learning techniques and approaches for implementing and applying kernel theories in a VLC (Möller et al., 2020).

Table 1: Conceptualization and References to Theoretical Foundations

	Learning Strategy, Exam Preparation & Time Management
Kernel Theory	Cognitivism: Long-, Short-term, and Working Memory (Cowan, 2008); Cognitive Bottleneck Theory (Saxe et al., 2019); Multitasking (Rosen, 2008); Shallow & Deep Knowledge (Bennet & Bennet, 2008; Jackson & Graesser, 2007); Chunking (Miller, 1956; Rosenbloom et al., 1989); Bloom's Taxonomy (Bloom, 1956); Selective Attention (Johnston & Dark, 1986); Expertise (Gobet, 2019); Transfer and Situated Learning (Greeno et al., 1993); Deliberate Practice (Anders Ericsson, 2008);
DF	Flipped Classroom (Bergmann & Sams, 2014); Pomodoro Technique (Cirillo, 2018); Micro-learning (Hug, 2006; Javorcik & Polasek, 2019);
	Motivation
Kernel Theory	Intrinsic and Extrinsic Motivation (Reiss, 2012; Serin, 2017) Flow (Nakamura & Csikszentmihalyi, 2014); Self-Determination (Deci & Ryan, 1980); The Model of Goal Directed Behaviour (Ajzen & Madden, 1986); Goal-setting (Locke & Latham, 2012); Exam-Anxiety (Stöber, 2004); Attribution (Kelley, 1967); Self-directed learning (Merriam & Baumgartner, 2020; Tekkol & Demirel, 2018); Social Identity perspective on motivation (Ellemers et al., 2002; Mirbabaie et al., 2021)
DF	SMART Goal Setting (Doran, 1981); Rubicon Model of Action Phases (Achtziger & Gollwitzer, 2009);
	Social Learning
KernelT heory	Vygotsky's Sociocultural Learning Theory (Hall, 2007; Vygotsky, 1978); Social Facilitation (Bond & Titus, 1983; Zajonc, 1965); Social Learning (Bandura & Walters, 1977); Theory of Social Comparison (Festinger, 1954; Michinov, 2012); Media Synchronicity Theory (Dennis & Valacich, 1999);
DF	Three Types of Feedback (Jackson & Graesser, 2007)

2.1 Learning Strategy, Exam Preparation, and Time Management

Cognitivism theories inform the selection of efficient learning strategies and effective learning materials by revealing how humans process information. Effective learning strategies align workloads with an individual's cognitive abilities, facilitating exam preparation and time management. The working memory's limited capacity can suffer from cognitive overload by processing excessive information and reduced accuracy and increased errors, known as "choking" (Saxe et al., 2019; Slonim, 2002; Welford, 1952), as the brain rapidly switches between tasks (Rosen, 2008). Similar performance losses occur in multitasking (Welford, 1952). Breaking down content into small, focused learning units (Rosenbloom et al., 1989) as applied in microlearning (Yin et al., 2021) and learning in short, sequenced intervals, as applied in the pomodoro technique (Cirillo, 2018), foster more sustainable learning outcomes. The depth of processing affects information retention (Graesser et al., 2017). Learning by heart is easier but less sustainable than profound understanding (Bloom, 1956). Content that has been studied briefly and superficially is stored in short-term memory and quickly forgotten (Cowan, 2008). Deep learning includes mechanisms like repetition and deliberate practice (Anders Ericsson, 2008; Cowan, 2008). Transferring existing knowledge to new situations through associations and integration expands knowledge networks (Greeno et al., 1993). Interactive teaching concepts, like the flipped classroom, promote deep learning as, students act as teachers (Bergmann & Sams, 2014; Huang et al., 2019). Vocational training benefits from connecting new information to existing knowledge, expertise, and experience (Greeno et al., 1993). In summary, a VLC should assist learners in optimizing efficiency, deep learning, and exam performance by aiding in workload planning, organization, and prioritization based on individual capacities and timelines. Incorporating existing learning strategies like micro-learning, the pomodoro technique, or flipped classroom as design features in a VLC can provide advantages such as moderation, feedback, personalization, and active learning.

2.2 Motivation

Motivation is gradual and can involve varying levels of extrinsic or intrinsic motivation, although the distinction between the two polarities is fluid and there is a continuum between intrinsic and extrinsic motivation (Reiss, 2012). Extrinsic motivation is determined by external factors such as rewards or punishments, while intrinsic motivation is driven by personal interest and passion for an activity (Serin, 2017). Working on an intrinsically motivating task is the prerequisite for the experience of flow and the complete immersion and absorption in an activity (Nakamura & Csikszentmihalyi, 2014), often seen as the ideal state of learning. Further, a task or activity that elicits a flow experience must be slightly demanding and extend existing capacities (Nakamura and Csikszentmihalyi, 2014). Learners need clear proximal stretching goals and immediate feedback about the progress that is being made (Nakamura and Csikszentmihalyi, 2014). The goal-setting theory confirms that high and specific goals can motivate increased performance (Locke & Latham, 2012). In this context, the SMART Method (Doran, 1981) helps formulate specific, measurable, attainable, realistic, and time-related goals. However, setting adequate goals might not be enough for long-term motivation (Locke & Latham, 2012). The theories of planned behavior (Ajzen, 2011) and goal-directed behavior (Aarts & Elliot, 2011; Ajzen & Madden, 1986) state how beliefs shape intentions and behavior. Doubts, fears, and lack of control are the biggest obstacles to goal achievement (Ajzen & Madden, 1986). Exam anxiety is caused by self-doubts or negative self-efficacy beliefs and increases with pressure, excitement, or stress before the exam (Morris & Liebert, 1970; Stöber, 2004). To counteract negative beliefs, the Self-Determination Theory (Deci & Ryan, 1980) suggests that effective learning fulfills three fundamental psychological needs: competence, autonomy, and relatedness. The feeling of competence can be enhanced by adopting a favorable attribution style that enhances a positive self-image (Kelley, 1967): Attributing positive outcomes and achievements to internal capacities, efforts, and progress, while considering negative results as situational and changeable (e.g. caused by lack of time), can enhance self-confidence. Autonomy can be increased by setting motivational goals that are in line with one's capacities. Learning should further be self-directed (Tekkol & Demirel, 2018), and learners should be in control of planning, continuing, and evaluating their learning experiences (Merriam & Baumgartner, 2020). Didactic models such as the Rubicon model of action phases (Achtziger & Gollwitzer, 2009), guide the learner through different phases of task accomplishment, i.e. goal setting, planning, realization, and evaluation of goal achievement. To conclude, a VLC should aid learners in enhancing their motivation through the utilization of strategies that promote goal-setting (Locke & Latham, 2012), autonomy, confidence (Deci & Ryan, 1980), and self-efficacy beliefs (Tärning & Silvervarg, 2019). Incorporating established didactical methods such as the SMART-Method for goal setting (Doran, 1981) and the Rubicon model of action phases (Achtziger & Gollwitzer, 2009) can be beneficial features to foster motivation and flow. The use of a VLC allows for more meaningful and self-directed learning, enabling learners to apply these strategies independently.

2.3 Social Learning

As seen before, learning is highly context-dependent and influenced by the social environment, culture, and task (Hall, 2007; Lave & Wenger, 1991; Vygotsky, 1978). Socio-constructivism suggests learning is best as a shared social rather than an individual experience (Allport, 1920; Rosenberg, 2009). The groups, peers, or social cycles people belong to strongly define their social identity and how they see themselves (Ellemers et al., 2002; Mirbabaie et al., 2021). People learn through observing, modeling, and imitating the behaviors, attitudes, and emotional reactions of others (Bandura & Walters, 1977). Learners form an image of their self and competencies through social comparison with relevant others, for example, fellow students, teachers, or role models (Festinger, 1954). Yet, in remote learning, receiving adequate feedback is often an unmet need (Rinn et al., 2022). It is difficult to foster natural social exchange (Kock, 2005). Even rich media cannot ensure optimal collaboration, as the communication channel must be adapted to the task (Dennis et al., 2008; Dennis & Valacich, 1999). Thereby three types of feedback can be distinguished (Jackson & Graesser, 2007): First, task-based feedback gives practical and domain-specific advice on how to complete an activity and avoid mistakes; second, progress-based feedback evaluates the overall learning progress; and third empathic feedback offers emotional support. In digital settings, task-based feedback can be provided in a fast, synchronous way, helping learners to identify errors and proceed (Jung et al., 2010). Students further benefit from recoding common questions of other students (Dennis et al., 2008). Concerning emotional or procedural feedback, findings suggest a positive effect of exchanges on social media in knowledge sharing and building trust among peers (Cao et al., 2012). Yet not all learners are comfortable sharing their emotions and data online (Atske, 2021). To conclude, a VLC should provide feedback to support a positive self-image and competence. While automated scoring and task-based feedback are common practices, the provision of emotional support is still in its nascent stages.

3 Method

Design Principles (DPs) contribute to design knowledge and guide effective and innovative conceptual design at a meta-level, (Gregor et al., 2020; Möller et al., 2020). Following the DSR approach, the research plan follows six steps for formulating DPs (Möller et al., 2020): (1) Definition of a practically relevant problem, formulated as a research question (see introduction section). (2) Identification of kernel theories as a justificatory knowledge base (see theory section). (3) Development of User Stories (US) from a thematic analysis of semi-structured interviews with students from three vocational learning institutions in Germany, promoting a user-centered approach to artifact development (Abras et al., 2004). (4) Meta-requirement mapping, clustering similar US into distinct meta-requirements. (5) Formulation of preliminary DPs, based on the meta-requirements and kernel theories, following a predefined framework from Gregor et al. (2020). Suggestions for DP implementation through exemplary design features (DFs) are derived from both the interviewees' suggestions and the literature. (6) Evaluation of the DPs in an expert focus group.

Ten semi-structured interviews were conducted with vocational education students from three German institutes offering hybrid or online courses, selected through a systematic stratified sampling approach to representing various demographic backgrounds (Gläser & Laudel, 2010). Six men and four women aged 22 to 50 were interviewed. The structured interview guideline provided deeper insights into seven themes identified in a prior quantitative survey (Rinn et al., 2022): (1) respondent's life and (2) learning situation, (3) methods and techniques used, (4) learner's motivation, (5) social learning, (6) time management, and (7) learning success and learning challenges. Open-ended questions were used to generate creative, original, and atypical answers. Finally, the interviewees were asked to draw conclusions based on their answers about the design of a VLC. The interviews were conducted by two independent researchers (Dec 2021-Mar 2022) and lasted from 33 to 84 minutes. Interviews were voice recorded and transcribed using the software Happy Scribe. Personal data was anonymized. A qualitative thematic content analysis (Mayring, 2015) of the ten transcribed interviews was carried out with the software MAXQDA 2020. The coding scheme was deductively generated and refined based on the interview guideline and participants' statements. The analysis yielded 844 codes, highlighting the top three codes for each theme. The findings were synthesized in

36 user stories (US), illustrating a specific user's needs and preliminary requirements for VLC-supported learning. US were formulated as follows: "As <role>, I want <requirement>, so <need>." Throughout a meta-requirement mapping process, four researchers used an adapted 1-2-4-all method (Lipmanowicz & McCandless, 2014) to link user stories and kernel theories and create a consolidated set of meta-requirements. Researchers independently clustered a subset of meta-requirements, which were then peer-reviewed and finally discussed and consolidated by all researchers.

Based on these meta-requirements and prescriptive knowledge derived from the literature, a set of preliminary DPs was formulated following a predefined framework from Gregor et al. (2020), specifying the aim, implementor and user, context, underlying mechanisms and rationale for each DP (see the digital appendix: https://bit.ly/eBled23). The DPs were evaluated by a focus group of five experts from different domains (online- and remote teaching and learning, chatbot design, DSR). The DPs and prototypical examples of DF were presented to the experts using the online collaboration platform Miro. Following the presentation of each DP, participants individually completed an online survey based on the light reusability framework (Iivari et al., 2018), assessing five factors: accessibility, importance, novelty and insightfulness, actability and guidance, and effectiveness. The effectiveness of each DP in addressing the targeted construct was measured using a reflective self-assessment. (e.g., “Compared to my current situation, I believe that a VLC that incorporates this DP would improve motivation.”). After the survey completion, each DP was openly discussed in the focus group and qualitative feedback was recorded.

4 Artifact Description

The meta-requirement mapping of the kernel theories and interview results were summarized in five DPs for VLCs in digital teaching, which are explained below.

4.1 Motivational Goal Setting (DP1)

The goal of DP1 is to design a VLC which promotes motivational goal setting for the learner in the planning stage of the learning process (Achtziger & Gollwitzer, 2009) to build up competence awareness, autonomy (Deci & Ryan, 1980), self-efficacy (Ajzen & Madden, 1986), and motivation (Locke & Latham, 2012; Nakamura & Csikszentmihalyi, 2014). Boundary conditions are addressed in DP5, namely the need for adaptation to the learner's individual needs and a realistic self-assessment. To manage time and tasks appropriately constraints and workload need to be anticipated (see DP3). The following mechanisms ensure motivational goal setting: (1) Set long-term goals **that inspire the learner and** that reflect personal development, skill acquisition, and career opportunities (Hall, 2007; Vygotsky, 1978). (2) Breaking down tasks into short-term learning goals that are specific, challenging, and attainable (Doran, 1981; Locke & Latham, 2012). (3) Constantly evaluate the progress towards a learning goal to increase the learners' autonomy (Achtziger & Gollwitzer, 2009; Deci & Ryan, 1980). (4) Increase the perception of competence, and self-efficacy by celebrating success, goal achievement, and challenges (Deci & Ryan, 1980; Kim, 2001). The following DFs support these mechanisms: The SMART concept (Doran, 1981) helps to formulate motivational goals. The Rubicon model (Achtziger & Gollwitzer, 2009) is a framework for planning, tracking, and evaluating goal achievement and milestones. Goals and progress can be visibly displayed, e.g., in the form of a personal mission statement, progress bar, or success record.

4.2 Enabling Social Interactions and Feedback (DP2)

The goal of DP2 is to provide valuable feedback and social support to the learner while performing a task, especially during the progress evaluation phase (Hall, 2007; Vygotsky, 1978). Feedback should be provided by peers and instructors on three levels to promote the perception of competence and social relatedness (Jackson & Graesser, 2007): (1) Task-related feedback, (2) empathic feedback for social connection, and (3) procedural feedback on long-term goals. Further, feedback-givers must be matched according to the needs and experience of the learner to foster a motivational, upward comparison (Festinger, 1954). Task-related feedback should be provided by knowledgeable colleagues or instructors through a rich, low-threshold, and highly synchronized communication channel (Dennis & Valacich, 1999). Procedural feedback should be given by experts in the field who have more expertise and experience than the learner. Different channels should be used: Personal networks, such as Instagram, are better for reaching out to friends and family and getting empathetic feedback. Professional networks, such as LinkedIn, allow networking with experts for procedural feedback. Task-based feedback and the ability to interact and discuss with instructors and peers should be available via a direct, built-in chat feature.

4.3 Focus and Control (DP3)

DP3 aims to foster focus, concentration and perceived control while limiting disruption to allow an experience of flow (Nakamura & Csikszentmihalyi, 2014), throughout different work phases (Achtziger & Gollwitzer, 2009). The following mechanisms are suggested help to avoid cognitive overload and enhance concentration (Saxe et al., 2019): The VLC should help divide content into smaller work packages aligned with the learning goal (Aarts & Elliot, 2011), and individual circumstances (Miller, 1956; Rosenbloom et al., 1989), e.g., through time-boxing or micro-learning (Hug, 2006). The VLC can further instruct learners on coping strategies for managing external factors, such as deadlines and unforeseen events, to improve their sense of control and competence.

4.4 Fostering Resilience (DP4)

The goal of DP4 is to equip the learner with coping strategies for stress and exam anxiety (Stöber, 2004). The aim is to foster the learner's sense of competence, autonomy, and resilience (Deci & Ryan, 1980; Stöber, 2004). Since learning difficulties are a personal matter, it is necessary that the user accepts the VLC as a mentor and strives for long-term interaction. The following underlying mechanisms can help foster resilience: (1) Recording the learner's mental state and stress level through the collection of personal and behavioral data, (2) Providing an initial assessment and suggesting professional contacts if needed. A VLC cannot replace specialist intervention for severe psychological symptoms, (3) Suggestion of personalized interventions based on learner's perceived competence, agency, and self-efficacy beliefs. (4) The VLC supports planning by estimating the required time for preparation based on historical data.

4.5 Context- and Learner Adaptation (DP5)

DP5 aims to provide individualized support to the learner throughout the entire learning process. The VLC should collect information about individual needs, preferences, and circumstances. Further, the VLC should have an extensive knowledge base about the learning content to determine the right level for examination protocols and learning time (see also DP3). The VLC should provide a transparent communication of results and provision of feedback about learning behavior (see also DP4), and should suggest learning materials and methods based on learners' preferences and learning progress. However, such an approach needs the user's consent before implementing any adaptations.

5 Evaluation

A focus group of five experts assessed the DPs. All DPs were deemed understandable and accessible, indicating no misinterpretation due to non-comprehension. The experts further differentiated between "must-have" and "nice-to-haves" DPs, which would be useful but less urgent. The focus group unanimously chose Motivational Goal Setting (DP1) as the most relevant DP. The experts found that the SMART-goal-setting method, including the visualization of goals, was an effective feature. However, limitations were noted in the actability and responsiveness of the VLC to the learner. DP2, "focus and flow", was rated as the second priority. There were controversial opinions about the exemplary design feature, the pomodoro technique. A pedagogical expert noted that time restrictions may disrupt the flow. Developers suggested improving the user experience of VLC by pooling different methods to enhance flow and focus into a single, multi-device interface. Context- and learner adaptation (DP3) was rated as "relatively" important. One participant said that this DP is highly relevant because it best expresses what makes the VLC a true "companion". Yet, the complex, individualized design may be overwhelming for inexperienced learners, who may need time to learn how to use it effectively. Therefore, a "basic" and a "pro" version are proposed to provide suitable guidance and actability. Overall, the focus group viewed the ability to facilitate social interaction and feedback (DP4) as beneficial but not essential. The VLC should inquire if learners are willing and able to connect and provide support to their peers. Most experts valued feedback and comparisons to other students. Controversy surrounds the involvement of external feedback givers for emotional and procedural feedback. The option to disable social media usage is crucial to address privacy concerns related to sharing information about learners' progress. The importance of stress reduction and the promotion of resilience and well-being through a VLC (DP5) was discussed, with some controversy over the provision of in-depth psychological care. Experts agreed on the relevance of stress reduction, but some argued that in-depth psychological care might be beyond the competence and objectives of a VLC. The experts suggested that it may be more feasible for a VLC to focus on preventive measures, such as improving time management skills and promoting breaks, physical activity, and social contact. The VLC could track and analyze behavioral data to assess workload and support healthy habits, as long as data protection is ensured.

6 Discussion

In recent years, research on PCA has increased (Khosrawi-Rad et al., 2022) and researchers contributed design knowledge on PCAs in different application contexts (Rodriguez et al., 2019; Wambsganss et al., 2020; Winkler & Roos, 2019). We extend this knowledge to vocational training by user-centered DPs for VLCs. The DPs were derived from user interviews and expert evaluations, highlighting its relevance and validity to the target group. However, the missing instantiation is a limitation that future studies should further evaluate. Based on the evaluation of the DPs, a VLC should address the diverse needs of individual learners, such as their learning strategies, exam preparation, time management, motivation, and social learning. Each identified kernel theory (see Table 1) contributes to the understanding and description of selected learners' requirements. However, our research indicates a need for more transdisciplinary research as developing complex information systems like VLCs incorporates insights from diverse fields like cognitive and social psychology and pedagogy. Further, we identified 23 scientific concepts (see Table 1), which help to extract concrete applications, such as methods or guidelines, and are identified as design features (DF). The results of the evaluation of the DPs show that some of the identified concepts are very helpful, such as the formulation and visualization of SMART goals (Doran, 1981) and the provision of feedback on three levels (Jackson & Graesser, 2007). However, some aspects are controversially discussed, e.g., the pomodoro technique (Cirillo, 2018), and privacy issues.

7 Conclusion

The transformative power of technology in lifelong vocational education cannot be denied. As distance and hybrid learning become more prevalent, the need for personalized support increases. This paper presents a set of design principles for Virtual Learning Companions (VLCs) that can promote resilience, goal setting, content focus, and control over the learning process while providing tasked-based feedback to address the lack of structure, time management, and work-life balance support. Additionally, a VLC can address the issues of disconnection, lack of peer contact, and motivation commonly experienced by adult students, by facilitating social interaction and emotional feedback. The results contribute to the research stream on digital lifelong vocational education and offer practical insights for developers and providers of learning platforms, ultimately leading to better learning outcomes and success for adult learners.

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References

Aarts, H., & Elliot, A. (Eds.). (2011). *Goal-Directed Behavior*. Psychology Press. https://doi.org/10.4324/9780203869666

Abras, C., Maloney-Krichmar, D., & Preece, J. (2004). User-centered design. *Bainbridge, W. Encyclopedia of Human-Computer Interaction. Thousand Oaks: Sage Publications*, *37*(4), 445–456.

Achtziger, A., & Gollwitzer, P. (2009). Rubikonmodell der Handlungsphasen. In V. Brandstätter (Ed.), *Handbuch der Allgemeien Psychologie: Motivation und Emotion*. https://kops.uni-konstanz.de/handle/123456789/17176

Ajzen, I. (2011). The theory of planned behaviour: Reactions and reflections. *Psychology & Health*, *26*(9), 1113–1127. https://doi.org/10.1080/08870446.2011.613995

Ajzen, I., & Madden, T. J. (1986). Prediction of goal-directed behavior: Attitudes, intentions, and perceived behavioral control. *Journal of Experimental Social Psychology*, *22*(5), 453–474. https://doi.org/10.1016/0022-1031(86)90045-4

Allport, F. H. (1920). The influence of the group upon association and thought. *Journal of Experimental Psychology*, *3*, 159–182. https://doi.org/10.1037/h0067891

Anders Ericsson, K. (2008). Deliberate Practice and Acquisition of Expert Performance: A General Overview. *Academic Emergency Medicine*, *15*(11), 988–994. https://doi.org/10.1111/j.1553-2712.2008.00227.x

Atske, S. (2021, April 7). Social Media Use in 2021. *Pew Research Center: Internet, Science & Tech.* https://www.pewresearch.org/internet/2021/04/07/social-media-use-in-2021/

Bandura, A., & Walters, R. H. (1977). *Social learning theory* (Vol. 1). Englewood Cliffs Prentice Hall.

Bennet, D., & Bennet, A. (2008). The depth of knowledge: Surface, shallow or deep? *VINE*, *38*(4), 405–420. https://doi.org/10.1108/03055720810917679

Bergmann, J., & Sams, A. (2014). *Flipped learning: Gateway to student engagement*. International Society for Technology in Education.

Bloom, B. S. (1956). Learning domains or Bloom's taxonomy. In *Handbook: The Cognitive Domain*. David McKay.

Bond, C. F., & Titus, L. J. (1983). Social facilitation: A meta-analysis of 241 studies. *Psychological Bulletin*, *94*(2), 265–292. https://doi.org/10.1037/0033-2909.94.2.265

Cao, X., Vogel, D. R., Guo, X., Liu, H., & Gu, J. (2012). Understanding the Influence of Social Media in the Workplace: An Integration of Media Synchronicity and Social Capital Theories. *45th Hawaii International Conference on System Sciences*, 3938–3947. https://doi.org/10.1109/HICSS.2012.618

Cirillo, F. (2018). *The Pomodoro Technique: The Life-Changing Time-Management System*. Random House.

Cowan, N. (2008). What are the differences between long-term, short-term, and working memory? *Progress in Brain Research*, *169*, 323–338. https://doi.org/10.1016/S0079-6123(07)00020-9

Cropley, A. J., & Knapper, C. K. (1983). Higher education and the promotion of lifelong learning. *Studies in Higher Education*, *8*(1), 15–21. https://doi.org/10.1080/03075078312331379081

Deci, E. L., & Ryan, R. M. (1980). Self-determination Theory: When Mind Mediates Behavior. *The Journal of Mind and Behavior*, *1*(1), 33–43.

Dennis, A. R., Fuller, R. M., & Valacich, J. S. (2008). Media, Tasks, and Communication Processes: A Theory of Media Synchronicity. *MIS Quarterly*, *32*(3), 575–600. https://doi.org/10.2307/25148857

Dennis, A. R., & Valacich, J. S. (1999). Rethinking media richness: Towards a theory of media synchronicity. *Proceedings of the 32nd Annual Hawaii International Conference on Systems Sciences*, 10-pp.

Doran, G. T. (1981). There's a SMART way to write management's goals and objectives. *Management Review*, 35–36.

Ellemers, N., Spears, R., & Doosje, B. (2002). Self and social identity. *Annual Review of Psychology*, *53*(1), 161–186.

Festinger, L. (1954). A theory of social comparison processes. *Human Relations*, *7*(2), 117–140.

Gläser, J., & Laudel, G. (2010). *Experteninterviews und qualitative Inhaltsanalyse als Instrumente rekonstruierender Untersuchungen* (4. Auflage). VS Verlag für Sozialwissenschaften.

Gnewuch, U., Morana, S., & Maedche, A. (2017). Towards Designing Cooperative and Social Conversational Agents for Customer Service. *Proceedings of the 38th International Conference on Information Systems*. Proceedings of the 8th International Conference on Information Systems (ICIS).

Gobet, F. (2019). The Classic Expertise Approach and Its Evolution. In P. Ward, J. Maarten Schraagen, J. Gore, & E. M. Roth (Eds.), *The Oxford Handbook of Expertise* (pp. 35–55). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780198795872.013.2

Graesser, A.C., Lippert, A.M., Hampton, A.J. (2017). Successes and Failures in Building Learning Environments to Promote Deep Learning: The Value of Conversational Agents. In: Buder, J., Hesse, F. (eds) Informational Environments. Springer, Cham. https://doi.org/10.1007/978-3-319-64274-1_12

Greeno, J. G., Moore, J. L., & Smith, D. R. (1993). *Transfer of situated learning.*

Greenwald, S. W., Funk, M., Loreti, L., Mayo, D., & Maes, P. (2016). EVA: Exploratory Learning with Virtual Companions Sharing Attention and Context. *2016 IEEE 16th International Conference on Advanced Learning Technologies (ICALT)*, 26–30. https://doi.org/10.1109/ICALT.2016.56

Gregor, S., Chandra Kruse, L., & Seidel, S. (2020). The Anatomy of a Design Principle. *Journal of the Association for Information Systems*, *21*, 1622–1652. https://doi.org/10.17705/1jais.00649

Gubareva, R., & Lopes, R. P. (2020). Virtual assistants for learning: A systematic literature review. *CSEDU 2020 - Proceedings of the 12th International Conference on Computer Supported Education*, *1*, 97–103. Scopus.

Hall, A. (2007). Vygotsky goes online: Learning design from a socio-cultural perspective. In *Learning and socio-cultural Theory: Exploring Modern Vygotskian Perspectives international workshop 2007* (Vol. 1, No. 1, p. 6).

Hevner, A. R. (2021). The Duality of Science: Knowledge in Information Systems Research. *Journal of Information Technology*, *36*(1), 72–76. https://doi.org/10.1177/0268396220945714

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design Science in Information Systems Research. *MIS Quarterly*, *28*(1), 75–105. https://doi.org/10.2307/25148625

Hobert, S., & von Wolff, R. M. von. (2019). Say Hello to Your New Automated Tutor – A Structured Literature Review on Pedagogical Conversational Agents. *Wirtschaftsinformatik 2019 Proceedings*.

Huang, W., Hew, K. F., & Gonda, D. E. (2019). Designing and evaluating three chatbot-enhanced activities for a flipped graduate course. *International Journal of Mechanical Engineering and Robotics Research*, *8*(5), 813–818. Scopus. https://doi.org/10.18178/ijmerr.8.5.813-818

Hug, T. (2006). Microlearning: A New Pedagogical Challenge (Introductory Note). In T. Hug, M. Lindner, & P. A. Bruck, (Eds.), Microlearning: Emerging Concepts, Practices, and Technologies After E-Learning: Proceedings of Microlearning Conference 2005: Learning & Working in New Media (pp. 8-11). Innsbruck, áustria: Innsbruck University Press.

Iivari, J., Hansen, M. R. P., & Haj-Bolouri, A. (2018). A Framework for Light Reusability Evaluation of Design Principles in Design Science Research. *Proceedings of the 13th International Conference on DESRIST*. International Conference on Design Science Research and Information Systems and Technology.

Jackson, G. T., & Graesser, A. C. (2007). Content matters: An investigation of feedback categories within an ITS. *Frontiers in Artificial Intelligence and Applications*, *158*, 127.

Javorcik, T., & Polasek, R. (2019). Transformation of e-learning into microlearning: New approach to course design. *AIP Conference Proceedings*, *2116*(1), 060016.

Johnston, W. A., & Dark, V. J. (1986). Selective Attention. *Annual Review of Psychology*, *37*(1), 43–75. https://doi.org/10.1146/annurev.ps.37.020186.000355

Jung, J. H., Schneider, C., & Valacich, J. (2010). Enhancing the motivational affordance of information systems: The effects of real-time performance feedback and goal setting in group collaboration environments. *Management Science*, *56*(4), 724–742.

Kelley, H. H. (1967). Attribution theory in social psychology. *Nebraska Symposium on Motivation*, *15*, 192–238.

Khosrawi-Rad, B., Rinn, H., Schlimbach, R., Gebbing, P., Yang, X., Lattemann, C., Markgraf, D., & Robra-Bissantz, S. (2022). Conversational Agents in Education – A Systematic Literature Review. *ECIS 2022 Conference Proceedings*.

Khosrawi-Rad, B., Schlimbach, R., Strohmann, T., & Robra-Bissantz, S. (2022). Design Knowledge for Virtual Learning Companions. *Proceedings on the International Conference on Information Systems Education and Research*.

Kim, B. (2001). Social constructivism. *Emerging Perspectives on Learning, Teaching, and Technology*, *1*(1), 16.

Kock, N. (2005). Media richness or media naturalness? The evolution of our biological communication apparatus and its influence on our behavior toward E-communication tools. *IEEE Transactions on Professional Communication*, *48*(2), 117–130. https://doi.org/10.1109/TPC.2005.849649

Kuechler, B., & Vaishnavi, V. (2008). On theory development in design science research: Anatomy of a research project. *European Journal of Information Systems*, *17*(5), 489–504.

Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation*. Cambridge University Press.

Lipmanowicz, H., & McCandless, K. (2014). *The Surprising Power of Liberating Structures: Simple Rules to Unleash A Culture of Innovation* (1st edition). Liberating Structures Press.

Locke, E. A., & Latham, G. P. (2012). Goal Setting Theory: The Current State. In *New Developments in Goal Setting and Task Performance*. Routledge.

Mayring, P. (2015). *Qualitative Inhaltsanalyse: Grundlagen und Techniken* (12., überarbeitete Auflage). Beltz Verlag.

Merriam, S. B., & Baumgartner, L. M. (2020). *Learning in Adulthood: A Comprehensive Guide*. John Wiley & Sons.

Michinov, N. (2012). Is electronic brainstorming or brainwriting the best way to improve creative performance in groups? An overlooked comparison of two idea-generation techniques. *Journal of Applied Social Psychology*, *42*, E222–E243.

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, *63*(2), 81.

Mirbabaie, M., Stieglitz, S., Brünker, F., Hofeditz, L., Ross, B., & Frick, N. (2021). Understanding Collaboration with Virtual Assistants – The Role of Social Identity and the Extended Self. *Business & Information Systems Engineering*, *63*(1), 21–37.

Möller, F., Guggenberger, T. M., & Otto, B. (2020). Towards a Method for Design Principle Development in Information Systems. In S. Hofmann, O. Müller, & M. Rossi (Eds.), *Designing for Digital Transformation. Co-Creating Services with Citizens and Industry* (pp. 208–220). Springer International Publishing. https://doi.org/10.1007/978-3-030-64823-7_20

Möller, F., Schoormann, T., Strobel, G., & Hansen, M. (2022, December 1). Unveiling the Cloak: Kernel Theory Use in Design Science Research. *ICIS 2022 Proceedings*. https://aisel.aisnet.org/icis2022/adv_methods/adv_methods/2

Morris, L. W., & Liebert, R. M. (1970). Relationship of cognitive and emotional components of test anxiety to physiological arousal and academic performance. *Journal of Consulting and Clinical Psychology*, *35*, 332–337. https://doi.org/10.1037/h0030132

Nakamura, J., & Csikszentmihalyi, M. (2014). The Concept of Flow. In M. Csikszentmihalyi (Ed.), *Flow and the Foundations of Positive Psychology: The Collected Works of Mihaly Csikszentmihalyi* (pp. 239–263). Springer Netherlands. https://doi.org/10.1007/978-94-017-9088-8_16

Panadero, E. (2017). A Review of Self-regulated Learning: Six Models and Four Directions for Research. *Frontiers in Psychology*, 8:422. doi: 10.3389/fpsyg.2017.00422

Reiss, S. (2012). Intrinsic and Extrinsic Motivation. *Teaching of Psychology*, *39*(2), 152–156. https://doi.org/10.1177/0098628312437704

Rinn, H., Khosrawi-Rad, B., Schlimbach, R., Masurek, M., Robra-Bissantz, S., & Markgraf, D. (2022). *Needs of Students in Further Education -A Mixed Methods Study*. Gemeinschaft Neuer Medien (GeNeMe) 2022.

Rodriguez, J., Piccoli, G., & Bartosiak, M. (2019). *Nudging the Classroom: Designing a Socio-Technical Artifact to Reduce Academic Procrastination*. Hawaii International Conference on System Sciences. https://doi.org/10.24251/HICSS.2019.533

Rosen, C. (2008). The myth of multitasking. *The New Atlantis*, *20*, 105–110.

Rosenberg, M. J. (2009). The Conditions and Consequences of Evaluation Apprehension. In R. Rosenthal, R. L. Rosnow, & Alan E. Kazdin (Eds.), *Artifacts in Behavioral Research* (pp. 211–263). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195385540.003.0007

Rosenbloom, P. S., Laird, J. E., & Newell, A. (1989). The chunking of skill and knowledge. *Working Models of Human Perception*, 391–410.

Saxe, A. M., Bansal, Y., Dapello, J., Advani, M., Kolchinsky, A., Tracey, B. D., & Cox, D. D. (2019). On the information bottleneck theory of deep learning. *Journal of Statistical Mechanics: Theory and Experiment*, *2019*(12), 124020.

Serin, H. (2017). The Role of Passion in Learning and Teaching. *International Journal of Social Sciences & Educational Studies*, *4*(1), Article 1.

Slonim, N. (2002). *The information bottleneck: Theory and applications* [Ph.D. Thesis]. Hebrew University of Jerusalem, Israel.

Stöber, J. (2004). Dimensions of test anxiety: Relations to ways of coping with pre-exam anxiety and uncertainty. *Anxiety, Stress & Coping*, *17*(3), 213–226.

Strohmann, T., Siemon, D., Khosrawi-Rad, B., & Robra-Bissantz, S. (2022). Toward a design theory for virtual companionship. *Human–Computer Interaction*, 1–41. https://doi.org/10.1080/07370024.2022.2084620

Tärning, B., & Silvervarg, A. (2019). "I Didn't Understand, I´m Really Not Very Smart"—How Design of a Digital Tutee's Self-Efficacy Affects Conversation and Student Behavior in a Digital Math Game. *Education Sciences*, *9*(3), Article 3. https://doi.org/10.3390/educsci9030197

Tekkol, İ. A., & Demirel, M. (2018). An Investigation of Self-Directed Learning Skills of Undergraduate Students. *Frontiers in Psychology*, *0*. https://doi.org/10.3389/fpsyg.2018.02324

Vygotsky, L. S. (1978). *Mind in Society: Development of Higher Psychological Processes*. Harvard University Press. https://doi.org/10.2307/j.ctvjf9vz4

Wambsganss, T., Söllner, M., & Leimeister, J. M. (2020, December 13). Design and Evaluation of an Adaptive Dialog-Based Tutoring System for Argumentation Skills. *International Conference on Information Systems (ICIS)*. International Conference on Information Systems (ICIS), Hyderabad, India. https://www.alexandria.unisg.ch/261297/

Welford, A. T. (1952). The "psychological refractory period" and the timing of high-speed performance—A review and a theory. *British Journal of Psychology*, *43*, 2–19.

Winkler, R., & Roos, J. (2019). Bringing AI into the Classroom: Designing Smart Personal Assistants as Learning Tutors. *ICIS 2019 Proceedings*. https://aisel.aisnet.org/icis2019/learning_environ/learning_environ/10

Wollny, S., Schneider, J., Di Mitri, D., Weidlich, J., Rittberger, M., & Drachsler, H. (2021). Are We There Yet? - A Systematic Literature Review on Chatbots in Education. *Frontiers in Artificial Intelligence*, *4*, 654924. https://doi.org/10.3389/frai.2021.654924

Yin, J., Goh, T.-T., Yang, B., & Xiaobin, Y. (2021). Conversation Technology With Micro-Learning: The Impact of Chatbot-Based Learning on Students' Learning Motivation and Performance. *Journal of Educational Computing Research*, *59*(1), 154–177. https://doi.org/10.1177/0735633120952067

Zajonc, R. B. (1965). Social Facilitation: A solution is suggested for an old unresolved social psychological problem. *Science*, *149*(3681), 269-274.

EMPIRICAL VERIFICATION OF DIFFERENT RANK DYNAMIC ROLES IN INFORMAL HIERARCHIES

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Organizations today face a more volatile, uncertain, complex and ambiguous market environment, referred to by the term »VUCA world«. To this, they commonly respond with management approaches that comprise flat hierarchies and a decentralization of decision-making structures. But while some companies are very successful with such approaches, others struggle significantly. One reason is that conflicts about ranks in the informal hierarchy arise as the formal hierarchy diminishes. Hence, understanding group dynamics and the different strategies of team members in the social competition becomes increasingly important. In previous works, a theoretical model containing five different roles was presented. These roles result from specific psychological capabilities, values, and needs of each individual and include specific contributions to the social functioning of the group. In this paper, participants of an online survey have been asked about their contribution to team success. A subsequent factor analysis of n = 421 datasets proofed the existence of five different roles and, thus, the validity of the model.

Keywords:
new work, working culture, group dynamics, informal hierarchy, rank dynamics, leadership, status

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1 The History of Leadership and Group Dynamics Research

After World War II, research on sociology and psychology was highly motivated by recent experiences and focused on explaining the phenomena of the war. Against this background, Milgram published his works on obedience which were broadly discussed not only in the scientific community (1963). At the same time, Schindler worked on the »bifocal group therapy« for schizophrenic patients (Schindler 2016, Spaller 2018). An important component were his observations of the »rank order positions« within the group, which was how he found the negative influence of authority on the psychological well-being of the patients. As a byproduct he developed the rank dynamic model, becoming the epitome of group dynamic research. Nevertheless, it took half a century until empirical verification took place (Bachmann 2022).

In general, the idea that aggression and authority should be accepted as intrinsic parts of human nature has been a difficult strand in academic debates. It is to the credit of behavioral psychologists like Lorenz that the reason and the benefits of aggression did not vanish completely from scientific attention. In his studies of animal behavior, he considered aggression to be »an element within the concert of drives« (Lorenz 1963), meaning that it fulfills certain functions that a species cannot do without. However, the more social a species is, the more aggression is expressed through a complex set of signals. This allows conflicts to escalate in a controlled manner, and the individuals involved can surrender before suffering serious injury. In consequence, the knowledge about the opponents' strengths leads to a rank order within a pack that additionally prevents perpetual conflicts.

In later decades, evolutionary psychologists identified many similarities between animals and humans, and legitimately challenged the view that humans could be outstandingly more rational and civilized than animals in social groups (Buss 2015). However, publications in this field have focused mainly on mating and only little on the importance of rank dynamics for human behavior in the context of work and leadership.

In business practice, the attitudes were ambivalent. In 1960, McGregor defined Theory X and Theory Y (1960), suggesting that managers would just have to trust their employees to create a better and more productive work environment. In 1978, Bergmann first wrote about New Work (2019). But for a long time, management thinking was still dominated by a Tayloristic stance. Command-and-control was widely seen as the only way to coordinate large undertakings. It was in the nineties, when the New Economy and the IT skill shortage led to a revolution in project management and leadership (Duhigg 2016). Creativity, flexibility, and employer attractiveness gained higher importance. Liberal approaches, such as Design Thinking and agile project management, began to replace the overly excessive bureaucracy and rigidity of previous approaches, slowly shifting responsibility to the employee level. At the same time, formal hierarchy was being reduced, the informal hierarchy kicked in and became more important for successful project implementation (Diefenbach & Sillince 2011). This aspect has been widely neglected and might be one of the possible reasons why numerous companies have been struggling a lot with New Work formats (Busch & Link 2021).

2 Rank Dynamic Mechanisms and Strategies in Recent Works

For a deeper understanding of the influence and the mechanisms of informal hierarchies, the characteristic behavior of individuals in gaining a best-possible rank must be known. Schindler's model may be a clue but seems not yet specific enough. The applicability of Schindler's role definitions, derived from psychiatric patients to business teams may suffer from certain weaknesses – especially since the patients had no reason to compete for salary or promotion. It is therefore unclear whether the role definitions accurately reflect the roles that occur in the business context, or whether there are more roles that should be considered.

In previous work, the author presented a model describing how ranks are negotiated within groups (Vatter & Kugler 2022). According to this, the root of rank dynamics is the competition for resources, like food, influence on group decisions, mating partners, and the psychological pleasantness of attention or admiration. As they are limited, group members compete for them against each other. Simultaneously, they must cooperate with each other to gain resources and ensure the continued existence of the group. This balancing between competition and cooperation is an ongoing decision each individual has to make.

An individual´s decision is based on the factors (Fig. 1):

1. the individual's psychological *capabilities*, like the ability to endure conflicts or act in a socially valued manner,
2. the individual's *values*, expressed in the behavior regarded as acceptable or socially appropriate.
3. the individual's psychological *needs*, like the need for admiration or being admitted to a group in a harmonious manner, and

Depending on these factors, a group member forms a strategy on how to compete in the rank dynamic within a team. This strategy manifests itself in certain patterns of behavior that can be interpreted as signals about what kind of contributions others can expect.

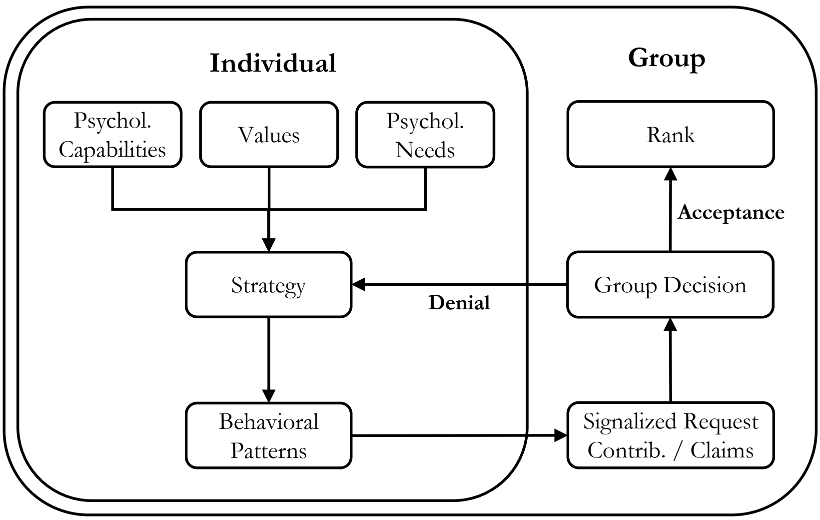

Figure 1: Rank Dynamic Negotiation Model
Source: According to Vatter & Kugler 2022

The group then decides on behalf of three questions if it trusts the signals given:

1. Is the individual *able* to make the promised contribution?
2. Is the individual *willing* to make the promised contribution?

3. Is the *need* for the promised contribution higher than the resources claimed (or are other team members providing this kind of contribution sufficiently)?

The first two questions are highly based on uncertainty. Therefore, any signal associated with costs, such as the risk of punishment, is valued more than the plain verbal statement (McAndrew 2002, 2018). If all three questions are answered with yes, the individual is granted the desired rank in the informal hierarchy. If not, challenged role owners receive the support of the group and the challenger typically must resign to a lower rank. Therefore, not all individuals thrive for the highest rank, as they may lack the needed abilities or rather avoid the associated costs and risks. Some individuals prefer a lower rank which still provides enough resources to survive.

On this behalf, Vatter & Kugler reviewed Schindler's role definitions and compared them to observations in business environment (2022). Hence, the roles have been revised as following:

- The *Alpha role* was kept unchanged the leader of the group. Its contribution is to coordinate the activities of the group and allocate resources. Moreover, it defines the rules within the group and takes uncomfortable but necessary decisions, e.g., the expulsion of a member from the group (see below). By assuming responsibility, it lowers the psychological stress of the other team members.
- The *Beta role* was defined as Alpha's assistant.[8] Therefore, it is assumed to have good social skills and the ability to be subordinate and loyal. In addition, it contributes by providing positive emotions and by carrying out Alpha's orders. The contribution to the group is to provide order and maintain social cohesion.
- A new *Delta role* forms the middle class of a group, preferring a secure and stable rank without prospect of a leadership position.[9] Its contribution lies in its labor, both manual and intellectual. It is characterized by a preference for structure and therefore advocates authority.

[8] In contrast to Schindler's definition, Beta is not primarily providing workforce (see Delta).

[9] Best comparable to Schindler's Beta

- The *Gamma role* represents the opposition to Alpha and embodies the alternative perspective of various matters.[10] In its rebellious attitude it is convinced it was the better leader but lacks the followership of the other members. By providing an additional point of few, Gamma limits Alpha's scope of action and prevents arbitrary decisions. Thus, Gammas most important contribution is to hold up a regulatory mechanism.
- The *Omega role* is on the last rank of the informal hierarchy. The group does not recognize any useful contribution from its side. It is unable to defend against the group's aggression and is therefore at risk of being excluded from the group.

3 Hypothesis and Objective of This Work

Even though social behavior is complex and may vary significantly in different situations and over time, there are arguments that make it seem plausible that the number of roles is limited. This is, because a group's social needs for psychological contributions may be manifold, but still finite. Additionally, roles should be easy to detect, so other group members can easily understand what kind of contribution an individual is promising. Moreover, pretending a certain behavior consistently is very difficult. So, coherent behavior makes the signaled proposal more reliable. For these reasons, roles should be Nash equilibria and corresponding strategies most successful if consistently adhered to (Holt & Roth 2004). If these assumptions are true, a specific set of roles should be detectable.

Hence, the aim of this paper is to verify the existence of the mentioned roles in the informal hierarchy.

4 Data Collection and Analysis

Based on the given role definitions, a self-assessment questionnaire has been designed. Each of the five scales was represented by six items (Alpha: A1 – A6, Beta: B1 – B6, …). To increase participant acceptance of the questionnaire and the

[10] We agree with Bachmann that Schindler's Omega role should be divided into an »active Omega« and a »passive Omega«. The switch in names seems appropriate, as they are loacted on different rank levels and »Omega« should be used for the lowest rank in the group.

discrimination, a seven-point Likert scale was used for the response category, ranging from "totally agree" to "totally disagree". A seven-point Likert scale is easy to understand, reduces the "middle effect", and positively contributes to the discriminative power of the items. The items were constructed targeting an individual's contribution to the group. This was considered meaningful as asking for the contribution is positively connotated and truthful answers can be expected. Additionally, the contributions seemed to be a good distinguishing feature of a role. When finding questions for contributions was found impossible, especially for the Omega role, other significant characteristics of the role are determined.

A pretest was carried out with five test persons which led to some adjustments in the wording of the final items (Tab. 1). The survey was implemented as online questionnaire and was distributed among students and on various social media platforms. The author's university is mainly aimed at working students. It can therefore be assumed that the participants have several years of professional experience. In total, 457 subjects, mainly German citizens, completed the test.

The resulting datasets had been undergone several plausibility checks, such as the relative speed index RSI < 2. So, dubious entries were excluded beforehand the analysis and no further statistical outlier handling was pursued. This resulted in n = 421 usable datasets in total.

4.1 Descriptive Analysis and Assessment of Model Quality

In the resulting data 53 % of the test persons were male and 47 % female. 54 % of all test persons were between 20 and 29 years old, 19 % between 30 and 39, 11 % between 40 and 49 and 14 % over 50 years old. 5 % had a secondary school diploma (ger.: Qualifizierter Hauptschulabschluss), 19 % medium maturity (ger.: Mittlere Reife), 28 % a high-school diploma (ger.: Abitur) and 48 % a university degree. PhD and no diploma both ranked below 1 %. 65 % of all participants reported to be working, while 34 % were studying. This may be inaccurate as most students at that university work regularly and study part-time.

In the first step of the analysis, the model validity was determined. Cronbach's Alpha showed values between 0.45 and 0.90, the discriminatory power was between 0.06 and 0.80. In particular, some items of the Delta and Gamma scales showed weak values. To correct this, the analysis was continued with an exploratory factor analysis (EFA).

4.2 Exploratory Factor Analysis (EFA)

The applicability of the EFA was tested using the Kaiser-Meyer-Olkin test, which showed values between 0.72 and 0.96 (Bühner 2021). Hence, the EFA could be applied. The EFA was performed in form of a parallel analysis with resampling and 2,000 repetitions, applying the Weighted Least Square method (WLS). The resulting eigenvalues showed a value within the confidence interval for a five-factor model (Fig. 2). So, the presence of five factors has been proven.

Then, the EFA was proceeded to determine the factor loadings (Tab. 2). The Promax rotation and the WLS estimation have been used. The item complexity turned out to be 1.5. According to the results, three items (B5, D4 and D5) have been removed from the list of items. Two further items have been assigned to different scales as the cross-loadings were significantly higher than the loadings on the initially intended scale (B6 to Alpha, G1 to Omega). By this, the quality characteristics improved significantly. None of the discriminatory powers were below 0.20. By this, the Cronbach's Alpha of the Delta scale increased to 0.51.

Table 1: Rank dynamic self-assessment questionnaire

	Items[11]
A1	In the team, I have the final say in decisions.
A2	I am more responsible for the team's results than the other team members.
A3	I set the goals in the team and take over the organization.
A4	I take charge of the team in critical situations.
A5	I act as a spokesperson between my team and external stakeholders.
A6	I see my contribution to the team as taking on leadership responsibilities.
B1	I mediate in interpersonal conflicts within the team.
B2	I exert a positive influence on the team leadership.
B3	I promote social cohesion in the team.
B4	I maintain a good relationship with the team leader.
B5	I contribute my professional expertise to the team.
B6	I enforce the team's rules when someone steps out of line.
D1	My actions in the team represent the team's labor power.
D2	As a team member, I primarily increase the team's labor power.
D3	I perform the intellectual or manual work tasks in the team.
D4	My contribution to the team is mainly the completion of work.
D5	It’s ok if I do not have to participate in decisions and only do the tasks.
D6	I prefer direct task accomplishment rather than discussion about it.
G1	The team does not have clear goals and structures for me.
G2	I criticize the coordinated approach in the team.
G3	I exhibit unconventional working methods compared to colleagues.
G4	In the team, I critically question the current approach.
G5	I constantly think about the improvement of the team.
G6	I question the status quo of the team.
O1	The team does not let me participate in decision-making processes.
O2	My views are ignored by the team.
O3	The team does not cooperate with me.
O4	I am the scapegoat of the team.
O5	I am not a full team member.
O6	I cannot speak freely and openly in the team.

[11] For the items’ original German wording, see Weisbeck 2023

Table 2: Factor loadings of rank dynamic self-assessment survey*

Item	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
A1	0.80				
A2	0.75				
A3	0.81				
A4	0.78				
A5	0.59				
A6	0.87				
B1	0.40	0.56			
B2		0.34			
B3		0.80			
B4		0.43			-0.36
B5					-0.31
B6	0.61				
D1			0.42		
D2			0.52		
D3			0.43		
D4	-0.32		0.36		
D5	-0.36				0.31
D6			0.43		
G1					0.43
G2				0.49	
G3				0.46	
G4				0.87	
G5				0.42	
G6				0.64	
O1					0.40
O2					0.71
O3					0.67
O4	0.40				0.60
O5					0.51
O6					0.65
	Alpha	Beta	Delta	Gamma	Omega

* Factor loadings < 0.3 have been removed.

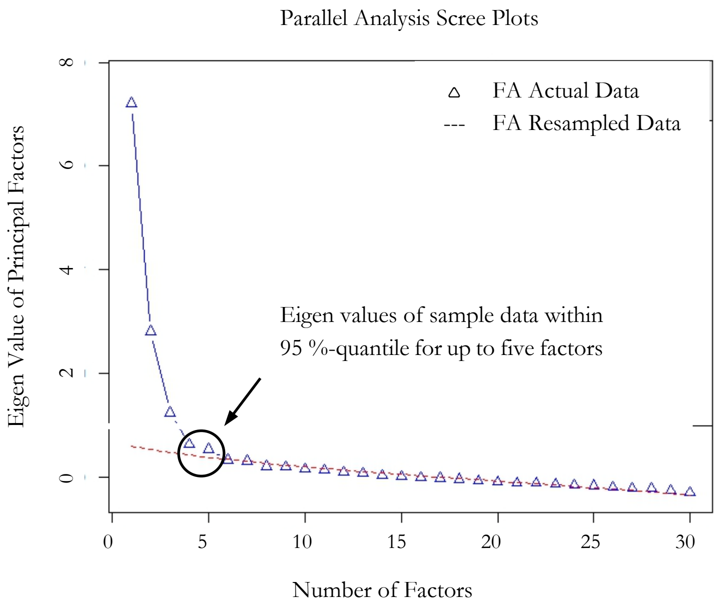

Figure 2: Parallel Analysis Scree Plots

4.3 Calculation of Higher Order EFA

After this, the correlations between the five factors were calculated and showed significant values between -0.43 and 0.62. Therefore, a general factor g was considered and a higher order EFA was calculated. The results showed the following loadings onto the general factor: Alpha: 0.7, Beta: 0.7, Delta: 0.4, Gamma: 0.8, Omega: -0.3. These correlations can be interpreted as similarities in the characteristics of the five roles.

The loadings can—with all due caution—be interpreted as amount of contribution a role makes to the group. This seems plausible as all roles do contribute to the group except the Omega role. Thus, it is prone to being excluded from the group, as the theory suggests.

4.4 Confirmatory Factor Analysis (CFA)

Lastly, a confirmatory factor analysis (CFA) has been performed to confirm the validity of the model. There, the higher order model (with general factor g) and the regular model (without general factor g) were compared. Their quality characteristics were calculated as shown in table 3.

Table 3: Quality characteristics of CFA

	CFI	TLI	RMSEA	SRMR	χ^2-Test
Good Fit	≥ 0.97	≥ 0.97	≤ 0.05	≤ 0.05	≤ 2
Acceptable Fit	≥ 0.95	≥ 0.95	≤ 0.08	≤ 0.10	≤ 3
Regular Model (without general factor)	0.973	0.970	0.042	0.065	1,75
Higher Order Model (with general factor)	0.961	0.957	0.050	0.072	2.06

The regular model performed well on behalf of almost all quality criteria (Gäde 2020, p. 649). Only the SRMR value was 0.065 and, thus, can be considered as acceptable only. The higher order model performed acceptable on almost all quality criteria. Only the RMSEA value was 0.050 and, thus, is regarded as good fit. This means the higher order model did slightly worse than the regular model without the general factor g. This is traced back on the fact that the higher order equation must fulfill more conditions as the regular model.

5 Relevance for business teams

To establish a good working culture, it first must be clarified what this really means. It is a common misunderstanding that the best working culture would be as cooperative as possible and totally free of conflicts. On closer inspection, this turns out to be untrue. Conflicts, in general, occur for the purpose to find the right decision about group related issues. For this can be done efficiently, an intact informal hierarchy is needed. Rank dynamic conflicts are necessary to constantly adjust the informal hierarchy and create a rank dynamic structure every member of group can live with. Avoiding these conflicts means stalling the process and preventing the group from reaching a productive state. This means, conflicts must be managed, so they can take an appropriate share in a balanced mix of a team's social interactions. For a long-term success, leaders need to ask:

1. Is the *informal hierarchy* of the team balanced? Is there an adequate mixture of informal roles?
2. Is the *relation of competition and cooperation* balanced? Can group members have the conflicts they need to have and are those resolved quickly and do not consume unnecessary energy?
3. Am I accepted as the *instance that sets the norms* according to which conflicts are fought out?

If the last point is given, the team leader steer the team by cultural norms. This means, that there is a common understanding, which kind of behavior is accepted and what will not be tolerated. This has many advantageous over the directives as they are commonly applied. Those are circumvented by competitive or unsatisfied employees where possible. In the first case, cooperative employees are protected by cultural norms and can freely live out their creativity and compete in terms of the individual strengths.

6 Summary and Outlook

The success of project teams, particularly when new liberal leadership approaches are applied, highly depend on a functioning group dynamic. Team members make specific contributions to the team, depending on their psychological capabilities, needs and values, competing for a specific rank in the group. In the present paper, Schindler's set of roles has been slightly adjusted, so the match better to the circumstances of work environments. A self-assessment questionnaire has been designed and a survey was carried out. A factor analysis showed that the five factors could be determined which is a strong indication for the existence of the roles.

Though this may be considered as a major step ahead, there are three main limitations to this work. First, the results are solely based on self-assessment and do not proof that other team members share the appraisal of the test subjects. Therefore, an alignment with a third person assessment will be subject of subsequent work. Second, it is not clear if the assumed rank order can really withstand in real conflict situations and group resources are assigned accordingly. There might be more influence factors which determine, who wins a confrontation in a real-world environment. This intensifies as a large proportion of test-persons were students with an unknown amount of work experience. Thus, the model needs more validation on behalf of the outcome of competitive experiments or field observations.

The third limitation refers to the definition of the roles. Even though their existence seems without doubt there is a lack of detailed description and a full understanding of their motives, behavioral patterns, and interaction. Thus, a deeper qualitative investigation and further adjustment seem to be justified. Moreover, it is not excluded that there are further important roles which occur less frequently, and so they could not be detected with the given item set.

References

Bachmann, T. (2022). Functional Group Positions and Contact Behavior in Problem-Solving Groups. Gr Interakt Org, 53(1), 131–144. https://doi.org/10.1007/s11612-021-00613-6

Bergmann, F. (2019). New Work New Culture. Zero Books, Winchester, UK.

Bühner, M. (2021). Einführung in die Test- und Fragebogenkonstruktion. 4th ed., Pearson Education, Halbergmoos, Germany.

Busch, M. W. & Link, K. (2021). Was macht Agilität mit Macht? Eine Analyse des Machtphänomens und agilen Organisationen. Journal für Psychologie 29 (1): 9–38. https://doi.org/10.30820/0942-2285-2021-1-9.

Buss, D. (2015). Evolutionary psychology: The new science of the mind. 5. ed., Psychology Press, New York, USA.

Diefenbach, T. & Sillince, J. A. A. (2011). Formal and Informal Hierarchy in Different Types of Organization. Organization Studies, 32(11), 1515–1537. https://doi.org/10.1177/0170840611421254

Duhigg, C. (2016). What Google Learned From Its Quest to Build the Perfect Team. In: The New York Times Magazine, 25.02.2016

Gäde, J. C., Schermelleh-Engel, K. & Brandt, H. (2020). Konfirmatorische Faktorenanalyse (CFA). In: Moosbrugger, H. & Kelava A. (Edts.): Testtheorie und Fragebogenkonstruktion, 3. ed., Springer, Berlin, Heidelberg, Germany, 615–660.

Holt, C. A., & Roth, A. E. (2004). The Nash equilibrium: A perspective. Proc. National Academy of Sciences, 101(12), 3999-4002. https://doi.org/10.1073/pnas.0308738101

Lorenz, K. (1980). Das sogenannte Böse: Zur Naturgeschichte der Aggression, 7. ed., dtv, München, Germany.

McAndrew, F. T. (2002). New Evolutionary Perspectives on Altruism: Multilevel-Selection and Costly-Signaling Theories. Current Directions in Psychological Science, 11(2), 79–82. https://doi.org/10.1111/1467-8721.00173

McAndrew, F. T. (2018). Costly Signaling Theory. In T. Shackelford (Ed.), Encyclopedia of Evolutionary Psychological Science, 1–8. Springer, Cham, Germany. https://doi.org/10.1007/978-3-319-16999-6_3483-1

McGregor, D. (1960). Theory X and theory Y. Organization Theory, 358(374), 5.

Milgram, S. (1963). Behavioral Study of Obedience. Journal of Abnormal and Social Psychology. 67(4), 371-378

Ouchi, W. G. & Price, R. L. (1978). Hierarchies, clans, and theory Z: A new perspective on organization development. Organizational Dynamics, 7(2), 25-44.

Schindler, R. (2016). Das lebendige Gefüge der Gruppe: Ausgewählte Schriften. Psychosozial-Verlag, Gießen, Germany, First publication: 1957

Schwaber, K. & Sutherland, J. (2020). The Scrum Guide. Scrum Alliance. Available online: https://scrumguides.org/docs/scrumguide/v2020/2020-Scrum-Guide-US.pdf. Last Access: 02/03/2023

Spaller, C. (2018). Das lebendige Gefüge der Gruppe: Plädoyer für eine kritische Relektüre der Rangdynamik nach Raoul Schindler. Gr Interakt Org, 49(4), 405–412. https://doi.org/10.1007/s11612-018-0436-4

Vatter, P. & Kugler, M. (2022). Rangdynamische Konflikte – Dysfunktionales Verhalten in infor-mellen Hierarchien. zfo – Zeitschrift Führung + Organisation, 6, 359-363.

Weisbeck, A. (2023). Informelle Hierarchie - Untersuchung des Zusammenhangs zwischen Persönlich-keitsstruktur und rangdynamischer Position, Master Thesis, FOM University of Applied Sciences, Nuremberg, Germany.

ENHANCING THE UNDERSTANDING OF E-COMMERCE REVIEWS THROUGH ASPECT EXTRACTION TECHNIQUES: A BERT-BASED APPROACH

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The growth of online customer reviews on e-commerce platforms has led to an overwhelming volume and variety of data, making manual analysis impractical for both consumers and managers. Consequently, machine learning techniques, such as Aspect-Based Sentiment Analysis (ABSA), have gained prominence for their ability to determine sentiment at the aspect level. This study aims to fine-tune natural language processing models for aspect extraction in e-commerce customer reviews. We manually annotated 2781 online user review sentences in English and employed different extensions of the BERT model to identify implicit and explicit aspects. This approach diverges from prior studies, as our dataset comprises real user reviews from five prominent e-commerce platforms. The findings demonstrate the models' effectiveness in extracting aspects from diverse e-commerce user reviews, yielding a deeper understanding of user-generated content and customer satisfaction trends, and providing valuable insights for managerial decision-making. This study contributes to the ABSA literature and offers practical implications for e-commerce platforms aiming to improve their products and services based on customer feedback.

Keywords: customer reviews, e-commerce, aspect extraction, BERT, machine learning

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1 Introduction

Currently, customers heavily rely on review content posted by other users on various e-commerce sites prior to making a purchase decision. However, with the ever-increasing volume and variety of online content, it has become challenging for customers to manually sift through the vast amounts of information available (Ansari et al., 2020). Moreover, managerial decision-making requires a constant flow of up-to-date information to provide insight into the trends and dynamics of customer satisfaction and manual classification of reviews has become increasingly difficult. Therefore, the popularity of machine learning techniques, such as opinion mining and aspect term detection, has increased in recent years due to the rise in online data volume and diversity. Aspect-Based Sentiment Analysis (ABSA) is a subfield of Sentiment Analysis (SA) that primarily focuses on determining the sentiment of products or services at the aspect level. To gain a deeper understanding of user-generated content, an essential task in ABSA is to extract both implicit and explicit aspects from various online reviews.

This paper aims to fine-tune the Bidirectional Encoder Representations from Transformers (BERT) and two of its extensions for aspect extraction in user-generated content in the form of customer reviews of e-commerce platforms. The research question we set forth to answer is the following:

How can aspect extraction techniques from manually annotated customer reviews be used to enhance the understanding of customer opinions in e-commerce?

This was accomplished by manually annotating 2781 online user review sentences in English. Unlike the majority of literature that assesses aspect extraction tasks using only the Laptops and Restaurants datasets from the SemEval 2014, 2015, and 2016 ABSA aspect extraction context (Xu et al., 2019, Pereget al., 2019; Chauhan et al., 2022; Venugopalan et al, 2022), this study employed BERT to categorize implicit and explicit aspects of our manually annotated dataset into 14 distinct groups. The data used for this analysis was obtained from real user reviews of five prominent e-commerce platforms that are available online. The present study demonstrates the effectiveness of using BERT for aspect extraction from a diverse range of user reviews in the e-commerce domain. By utilizing the manually annotated dataset and categorizing implicit and explicit aspects into 14 distinct groups, this study has provided a deeper understanding of user-generated content and customer satisfaction trends offering novel academic insights. Furthermore, the findings of this study can inform managerial decision-making and help e-commerce platforms to improve their products and services to meet the needs and expectations of their customers.

The rest of the paper is structured as follows. Section 2 presents a literature review on academic contributions focusing on aspect detection in customer reviews. The methodology and data preparation are discussed in Section 3, with the main results presented and discussed in Section 4. Finally, some conclusions, limitations and future research directions are provided in Section 5.

2 Aspect detection and extraction

Sentiment analysis (SA), also referred to as opinion mining, is the process that involves identifying, recognizing, and categorizing users' emotions or opinions on various services such as movies, products, events, or any attributes as positive, negative, or neutral. The data used in the analysis can be gathered from diverse sources such as review websites, forum discussions, blogs, Twitter, etc. SA is a powerful tool as it provides valuable information about people's preferences and can help companies gain a clear perspective regarding their product or service features (Mehta et al., 2020). By analyzing customer sentiments, companies can identify areas of improvement, determine customer satisfaction levels, and gauge market trends. SA has been widely applied in various industries, including hospitality, healthcare, and e-commerce, among others.

Previous studies have generally categorized SA into document-level, sentence-level, and aspect-level SA. These levels aim to classify whether a whole document, a sentence (subjective or objective), and an aspect express a sentiment (Nazir et al., 2020). Target-based sentiment analysis (TBSA) or Aspect-based Sentiment Analysis (ABSA) is a sub-task of SA that provides a better understanding of the problem of SA at a fine-grained level (Liu 2012; Pontiki 2014) because it focuses directly on sentiments rather than on language structure. ABSA analyzes specific aspects or entities of a product, service, or topic and determines the sentiment associated with them. This technique provides a more in-depth and nuanced understanding of public opinion, making it useful for companies to develop marketing strategies, improve product features, and enhance customer satisfaction. ABSA includes subtasks such as aspect/target term extraction (ATE), opinion term extraction (OTE), aspect/target term sentiment classification (ATC), and others (Peng et al, 2020).

The objective of ATE is to identify and extract terms that represent aspects of a given sentence. For instance, in the sentence "Excellent customer service and delivery", the aspect terms are “customer service” and “delivery”. ATE typically involves two sub-tasks: (1) extracting all aspect terms (such as "delivery") from the text, and (2) grouping aspect terms with similar meanings into categories, where each category represents a single aspect (e.g., “delivery”, “shipping”, and “track number” will be clustered into the shipping aspect). It should be noted that ABSA categorizes aspects into two types: explicit and implicit aspects. Explicit aspects are directly mentioned in a text. In contrast, implicit aspects are not explicitly indicated by any specific word or term (Alqaryouti et al., 2020). For instance, in the sentence “If you need something tomorrow go somewhere else”, “shipping” is an implicit aspect.

Prior research on aspect extraction can be classified into four approaches: rule-based (Poria et al., 2014; Liu et al., 2015), supervised (Maitama et al., 2021; Poria et al., 2016), unsupervised (Chauhan et al., 2020; Luo et al., 2019), and semi-supervised (Ansari et al., 2020; Anand et al., 2016). According to He et al., (2017), rule-based methods typically do not group extracted aspect terms into categories, while supervised learning requires annotated data and may face domain adaptation issues. Unsupervised methods are utilized to avoid reliance on labeled data. In addition to the methods such as statistical analysis, topic modeling, and dependency parsing used in prior unsupervised aspect extraction studies, supervised aspect extraction techniques such as Conditional Random Field (CRF) and long short-term memory have also been employed (Maitama et al, 2021).

In recent years, deep learning has become one of the most effective approaches for natural language processing tasks, due to its supervised training process with large amounts of training data. However, acquiring a large amount of supervised data can be a difficult and time-consuming process, particularly for NLP tasks in low-resource languages. In these cases, transfer learning can offer a solution by allowing a model to be pre-trained on a large amount of unsupervised data before being fine-tuned for a specific task under supervised conditions. BERT is one of the latest popular algorithms that employ this transfer learning approach (Yanuar et al., 2021).

3 Methodology

This section will present the NLP-based aspect extraction and classification methodology. Our main goal is to construct a model that is able to detect the aspects of customer feedback automatically. As presented in Figure 1, we have applied five steps to achieve our research objective. In this section, we discuss data collection, annotation, and preprocessing, and present the machine-learning models used for aspect extraction and classification.

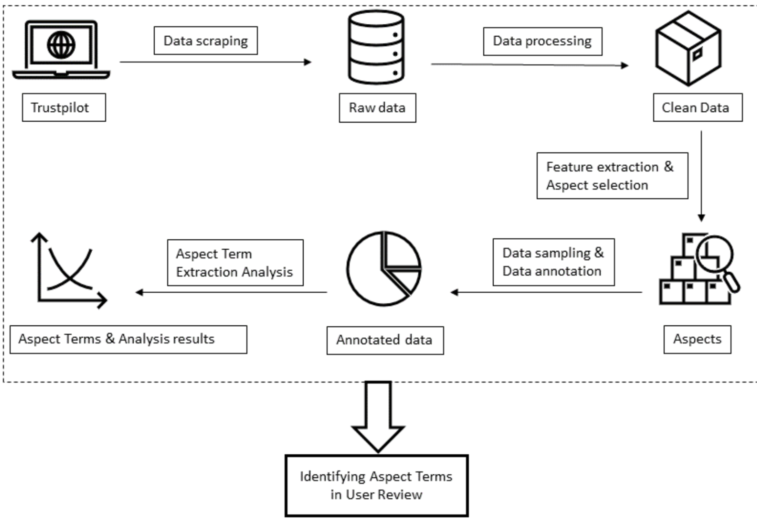

Figure 1: The stages of the research process

3.1 Data collection and processing

In order to study the user-generated content in e-commerce and evaluate their potential insights with ABSA, we collected 12,000 English reviews from Trustpilot, one of the biggest platforms in hosting online reviews, between 2013 and 2021. Next, we randomly selected 3,500 messages for aspect extraction and manual data annotation, excluding messages that did not meet certain criteria, such as not being written in English or not discussing any of the considered aspects. The final dataset consists of 2,782 data points consisting of the reviews from five online stores, namely Zalando, Wish, Sheinside, Boozt, and Nelly. Reviewers from 73 different countries contributed to the reviews, with the UK (1166 reviews) and the US (778 reviews) having the highest number of reviews among all 73 countries.

Prior to extracting our probable candidate aspects, we executed a series of seven text-cleaning steps: converting the text to lowercase, eliminating any non-English text, discarding all non-alphabetic characters, stripping out HTML tags and URLs, expanding contractions in the reviews, eliminating stop words, and performing lemmatization. Following text processing, the total count of distinct words was determined to be 4580. In preparation for manual data annotation, it was necessary to specify the aspects relevant to the domain. The final set of aspects, as presented in Table 1, is extracted from the literature and analysis of the reviews. Some further details can be found in Davoodi et al. (2022).

Table 1: Final aspects

1	Shipping	The quality of the delivery can refer to various factors, such as the cost and timeline.
2	Trust	The customers' overall sentiment towards the store.
3	Item quality	The level of quality of the products.
4	Customer service	The quality of customers' direct interactions with the store's representatives, such as their helpfulness, professionalism, and effectiveness
5	Pricing	The prices offered by the store, as well as the availability of discounts and promotional campaigns.
6	Product features	The quality of the product images and size guides provided on the website and implicit aspects such as described or expected
7	Refund process	The speed and quality of the refund process, as well as the effectiveness and efficiency of the store's handling of refund-related issues.
8	Return process	The speed, convenience, and cost associated with the return process for customers.
9	App experience	The experience that a user has while interacting with the website of the store.
10	Delivered product status	The state of the products that have been delivered, such as if they are broken or have an odor
11	Information	The presence and accuracy of the information, including the quality of advertisements and whether they may be deceptive.
12	Packaging	The visual appeal and quality of the product’s packaging.
13	Payment	The level of quality in the financial transaction process, including accuracy, security, efficiency, and different payment options.
14	Product availability	The range of products or brands that are being offered.

3.2 Data annotation

Prior to annotating the data, we utilize Python libraries such as contextualSpellCheck and Caribe to conduct spell and grammar checks on the reviews, thereby converting them into standard English text. Subsequently, we established a set of rules to convert implicit aspects into explicit ones while endeavoring to maintain the original text as closely as possible.

Following the text-cleaning process, two annotators manually annotated the data separately. The sentences were divided into individual words, and labels were assigned to the nouns or noun phrases only if they conveyed a sentiment related to at least one of the aspects, subsequently disregarding aspects with a neutral sentiment. Previous studies have revealed that aspects are often represented by nouns or noun phrases, while opinions are typically conveyed through adjectives or adjective phrases (Samah et al., 2014). Research on sentiment analysis has also demonstrated that certain tag combinations are instrumental in identifying aspects and opinions. In contrast to these prior investigations, the present study relied heavily on sentence parsing by considering a broader range of sentence components as potential aspects and/or opinions (Hu et al., 2004; Hu et al., 2004; Subrahmanian et al., 2008; Samha et al., 2014). It is important to note that the aspect terms were extracted solely based on their positive or negative sentiment in the given sentence without considering the preceding or subsequent sentence, i.e., the review as a whole.

The ATE task is typically approached as a sequence labeling problem, where each input word is assigned one of three labels: "B" for the beginning of an aspect term, "I" for the continuation of an aspect term, or "O" for non-aspect terms. The "I" label is necessary because some aspect terms can consist of multiple words, and the system must identify and extract all of them as aspects (Karimi et al., 2020). However, in this study, we provided 29 labels as follows: *O, App_experience_B, App_experience_I, Trust_B, Trust_I, Customer_service_B, Customer_service_I, Delivered_product_status_B, Delivered_product_status_I, Information_B, Information_I, Item_quality_B, Item_quality_I, Packaging_B, Packaging_I, Payment_B, Payment_I, Pricing_B, Pricing_I, Product_availability_B, 'Product_availability_I, Product_features_B, Product_features_I, Refund_process_B, Refund_process_I, Return_process_B, Return_process_I, Shipping_B, and Shipping_I.*

In the given example, "*Love this site fantastic saving for quality stuff.*", the text is first transformed into a set of words, and then the annotators assign corresponding labels to each word. The label sequence for this example is as follows: ['O', 'O', 'Trust_B', 'O', 'Pricing_B', 'O', 'Item_quality_B', 'Item_quality_I', 'O']. Once the individual annotations were completed, disagreements were identified and discussed to arrive at a final agreement between the annotators.

3.3 Machine learning models for aspect extraction

To evaluate our annotated model, we selected three recent transformer-based machine-learning models: BERT, RoBERTa, and BERT_Review.

BERT (Devlin et al., 2018) is a language model that can evaluate the context of a word from both the left and right sides simultaneously, unlike traditional language models that process sentences from one direction. This is achieved using the masked language modeling (MLM) technique, which randomly masks a word in a sentence and replaces it with a [MASK] token. The model then attempts to predict the masked word based on the context from both sides of the masked word. In addition to MLM, BERT also includes a next-sentence prediction (NSP) task, which involves predicting whether a given sentence follows another sentence or not. This helps BERT to capture the relationship between sentences and improve its ability to perform tasks such as question answering and text classification. Overall, BERT's bidirectional feature and MLM technique make it a powerful language model that can provide more contextual features from a sentence compared to other models such as ELMO.

RoBERTa (Liu et al., 2019) and BERT_Review (Xu et al., 2019) are variants of the BERT model, with the former showing promising results in various natural language processing (NLP) tasks. These variants are designed to enhance BERT's performance by incorporating different modifications. RoBERTa, for example, utilizes a transformer architecture like BERT but is trained differently and for a longer duration. Additionally, RoBERTa employs the entire sentence as input and eliminates the following sentence prediction objective.

BERT_Review is designed to address Review Reading Comprehension (RRC). For this purpose, Xu et al. (2019) created a dataset, which is based on a well-known benchmark used for aspect-based sentiment analysis. However, due to the limited training examples available for RRC and aspect-based sentiment analysis in their data, they subsequently explored a post-training method using BERT to improve the fine-tuning process for RRC. Additionally, they applied the proposed post-training approach to other review-based tasks, such as aspect extraction and aspect sentiment classification in aspect-based sentiment analysis, to demonstrate its universality. The results indicated that the proposed post-training approach is highly efficient (Xu et al., 2019).

3.4 Model building

To evaluate our annotated model, we selected three recent transformer-based machine-learning models: BERT, RoBERTa, and BERT_Review. Given the limited size of our dataset, we opted to employ cross-validation as a means of achieving a more reliable estimation of our models' performance. Specifically, we partitioned our manually annotated dataset into distinct training and validation sets by means of a five-fold cross-validation methodology, involving ten steps of iteration per fold. Subsequently, to obtain an aggregate summary of model performance, we calculated the mean value across all folds for each performance metric. To transform the input text to numeric features, we utilized a transformer tokenizer for all models. We utilized loss and accuracy as the performance metric for all models, with the main model serving as the baseline. For training BERT, RoBERTa, and BERT_Review our network model includes the main model with 12 layers and 768 hidden dimensions as well as the initial learning rate of 1e-4. Moreover, the training batch size was defined as 8. The programming language used for model building and data analysis is Python 3.10.11. We evaluated the models' performance using two commonly used measures: accuracy and F1 score.

4 Results

In this section, we will present the outcomes of our experiments and demonstrate the efficacy of different machine-learning models in the domain of aspect extraction and classification. We will also compare our findings to prior academic research in this area. Additionally, we will discuss several noteworthy observations that are relevant to managing expectations regarding performance.

4.1 Performance analysis

As detailed in the preceding section, a total of three distinct models were built and trained. The outcomes of these models are presented in Table 2. The table displays the mean loss, accuracy, and F1 value of the validation set after performing 5-fold cross-validation. Additionally, the execution time required to build the models is reported.

Table 2: Aspect extraction performance

Method	Loss. validation set	Accuracy-validation set	F1-validation set	Execution time (in seconds)
BERT_Review	**0.104**	**0.972**	**0.841**	**3,077**
BERT	0.113	0.969	0.829	3,075
RoBERTa	0.109	0.969	0.828	2,905

After conducting 5-fold cross-validation for three transformer-based models, we calculated the mean validation accuracy for each model. To test for statistical significance between the models, we performed a one-way ANOVA with post-hoc Tukey HSD tests. The results showed that BERT_Review had a significantly higher mean accuracy compared to the other two models. However, there was no significant difference in mean accuracy between BERT and RoBERTa. As demonstrated in Table 2, the BERT_Review model displayed marginally superior performance when compared to two other models, achieving an F1 score of 84%. Given the fact that the study involved 29 distinct categories, this level of performance can be considered promising. After running the cross-validation, to analyze the performance of the best model we partitioned the dataset into the fixed train (70%), validation (15%), and test (15%) sets. We used the test set for the error analysis. The analysis results are presented in Table 3.

Table 3: Aspect extraction performance of the best model

Method	Accuracy-validation	F1-validation	Accuracy-test	F1-test	Number of misclassifications (test)
BERT_Review	0.975	0.86	0.972	0.85	169

In regard to the specific misclassifications generated by the BERT_Review model, a portion of the errors can be attributed to the identification of neutral aspects in the messages. For instance, the following review was misclassified by the model as a return process. However, there should not be any aspect marked in this message, as the sentiment expressed towards the return process in this message is neutral: *"I ordered around 300 dollars worth of clothes for my kids and I need to return 100 dollars worth of clothes."*

Secondly, there are certain aspects in the dataset that occur less frequently, such as payment. Consequently, the model did not have sufficient samples to accurately identify these aspects.

Thirdly, in the majority of the misclassification cases, the model was able to extract the correct aspects. However, there were slight differences in the position of the true and predicted aspects, which we believe can be easily addressed by increasing the training sample. For instance, in the following example: *"No more purchase from Wish, no support after delivery of a product."* The true aspects are *Company, Customer Service, and Shipping*, and the model was able to correctly identify them. However, for the *Shipping* aspect, the model should have identified *"delivery of a product"* as the *shipping* aspect but instead marked each "*delivery*" and "*product*" word separately as *shipping*.

Finally, consider the following example: *"Order arrived really fast and was well wrapped."* In this case, the aspects being referred to are *shipping* and *packaging*. However, the model used in the study only predicted the aspect of *shipping*, whereas the true label encompasses both *shipping* and *packaging*. As a result, both predicted aspects are technically true, but the issue of accurately identifying multiple aspects needs to be addressed further in future research. Moreover, it is important to acknowledge that human annotation errors may occur during the manual annotation process, and such errors have the potential to negatively impact the performance of the machine learning models trained in this research.

4.2 Discussion

The input for classification models and data annotation, which involves extracting relevant aspect terms from reviews, is crucial in natural language processing. Previous research in this area has predominantly utilized datasets from SemEval 2014, SemEval 2015, and SemEval 2016 (Wang et al, 2021; Dai et al., 2019) for their experimental studies. However, our study focused on e-commerce businesses that do not have physical shops when collecting data, aiming to identify and understand the most prevalent sources of satisfaction and dissatisfaction in this context. For this purpose, data were collected from five distinguished and widely used e-commerce platforms that cater to a diverse range of customers. The comprehensiveness and broadness of this data make it applicable to research endeavors aimed at analyzing smaller online retailers and comparable enterprises.

While automated annotations are less time-consuming and costly than manual annotations, they are generally less accurate. In this study, we opted for manual annotation to gain a comprehensive understanding of the review content and its relevance to the target companies. By presenting a manually annotated dataset that includes extracted aspect terms with negative and positive sentiments, companies can ensure that they concentrate on the correct elements by obtaining precise aspect detection results. Additionally, the combination of sentiment classification of the extracted aspects can enable automated and accurate identification of the sources of dissatisfaction.

From our review of the literature, we have found that BERT and RoBERTa are among the most frequently employed models for aspect extraction in user reviews (Chauhan et al., 2020; Tian et al., 2020; Yanuar et al., 2020; Lopes et al., 2021) and the F1 score is achievable in the range of 0.738-0.85 depending on the domain and the language of the reviews. Our experimental results revealed that the BERT_Review model outperformed the other two models under consideration. Among all categories, the Trust_B aspect attained the highest F1 score of 0.92, while Payment_I had the lowest score of 0.4. This finding indicates that the inclusion of infrequent aspects may negatively impact the model's performance. One potential solution to address this issue is to automatically generate labeled data for infrequent aspects.

5 Conclusions

This study involved the development of a novel manually annotated dataset for the aspect extraction task, which was evaluated by using three state-of-the-art transformer-based models. The evaluation results demonstrate that the models performed well, but further improvements could be achieved by adding more samples to the dataset, particularly for infrequent aspects such as payment and packaging. A possible direction for future research could involve the use of this manually annotated dataset to generate automated labeled data, thereby enhancing the performance of the models. For example, this could entail fine-tuning Large Language Models like GPT-2 (Radford et al., 2019) and GPT-3 (Brown et al., 2022), as explored by Veyseh et al. (2022) and Ding et al. (2022). Moreover, this approach could help to address the key challenges associated with aspect extraction tasks, which is the scarcity of training data that limits the training of large neural networks. Large Language Models have proven remarkable few-shot capabilities in various NLP tasks (Min et al., 2021). Given this, a logical use case would be utilizing it for data annotation purposes.

References

Alqaryouti, O., Siyam, N., Abdel Monem, A., & Shaalan, K. (2020). Aspect-based sentiment analysis using smart government review data. Applied Computing and Informatics. Vol. ahead-of-print, 20 pages.

Anand, D., & Naorem, D. (2016). Semi-supervised aspect-based sentiment analysis for movies using review filtering. Procedia Computer Science, 84, 86-93.

Ansari, G., Saxena, C., Ahmad, T., & Doja, M. N. (2020). Aspect term extraction using graph-based semi-supervised learning. Procedia Computer Science, 167, 2080-2090.

Brown, T., Mann, B., Ryder, N., Subbiah, M., Kaplan, J. D., Dhariwal, P., ... & Amodei, D. (2020). Language models are few-shot learners. Advances in neural information processing systems, 33, 1877-1901.

Chauhan, G. S., Meena, Y. K., Gopalani, D., & Nahta, R. (2020). A two-step hybrid unsupervised model with attention mechanism for aspect extraction. Expert systems with applications, 161, 113673.

Chauhan, G. S., Meena, Y. K., Gopalani, D., & Nahta, R. (2022). A mixed unsupervised method for aspect extraction using BERT. Multimedia Tools and Applications, 81, 31881-31906.

Dai, H., & Song, Y. (2019). Neural aspect and opinion term extraction with mined rules as weak supervision. arXiv preprint arXiv:1907.03750.

Davoodi, L., & Mezei, J. (2022). A comparative study of machine learning models for sentiment analysis: Customer reviews of e-commerce platforms. In Proceedings of the 35th Bled eConference Digital Restructuring and Human {Re} (pp. 217-230).

Devlin, J., Chang, M. W., Lee, K., & Toutanova, K. (2018). Bert: Pre-training of deep bidirectional transformers for language understanding. arXiv preprint arXiv:1810.04805.

Ding, B., Qin, C., Liu, L., Bing, L., Joty, S., & Li, B. (2022). Is GPT-3 a Good Data Annotator? arXiv preprint arXiv:2212.10450.

He, R., Lee, W. S., Ng, H. T., & Dahlmeier, D. (2017, July). An unsupervised neural attention model for aspect extraction. In Proceedings of the 55th Annual Meeting of the Association for Computational Linguistics (pp. 388-397).

Hu, M., & Liu, B. (2004, August). Mining and summarizing customer reviews. In Proceedings of the tenth ACM SIGKDD international conference on Knowledge discovery and data mining (pp. 168-177).

Hu, M., & Liu, B. (2004, July). Mining opinion features in customer reviews. In Proceedings of the 19th national conference on American Association for Artificial Intelligence (pp. 755-760).

Im, J., Song, T., Lee, Y., & Kim, J. (2019). Confirmatory aspect-based opinion mining processes. arXiv preprint arXiv:1907.12850.

Karimi, A., Rossi, L., & Prati, A. (2021, January). Adversarial training for aspect-based sentiment analysis with bert. In Proceedings of 2020 25th International Conference on Pattern Recognition (ICPR) (pp. 8797-8803).

Liu, B. (2012). Sentiment Analysis and Opinion Mining. Synthesis Lectures on Human Language Technologies, 5, 1-167.

Liu, Q., Gao, Z., Liu, B., & Zhang, Y. (2015, June). Automated rule selection for aspect extraction in opinion mining. In the Proceedings of the Twenty-Fourth international joint conference on artificial intelligence (pp. 1291-1297).

Liu, Y., Ott, M., Goyal, N., Du, J., Joshi, M., Chen, D., ... & Stoyanov, V. (2019). Roberta: A robustly optimized bert pretraining approach. arXiv preprint arXiv:1907.11692.

Liu, Y., Ott, M., Goyal, N., Du, J., Joshi, M., Chen, D., ... & Stoyanov, V. (2019). Roberta: A robustly optimized bert pretraining approach. arXiv preprint arXiv:1907.11692.

Luo, L., Ao, X., Song, Y., Li, J., Yang, X., He, Q., & Yu, D. (2019, August). Unsupervised Neural Aspect Extraction with Sememes. In Proceedings of The Twenty-Eighth International Joint Conference on Artificial Intelligence {IJCAI-19} (pp. 5123-5129).

Lopes, É., Correa, U., & Freitas, L. (2021, April). Exploring Bert for aspect extraction in Portuguese language. In Proceedings of The International FLAIRS Conference (pp. 1-4).

Maitama, J. Z., Idris, N., Abdi, A., & Bimba, A. T. (2021, May). Aspect extraction in sentiment analysis based on emotional affect using supervised approach. In Proceedings of the 4th International Conference on Artificial Intelligence and Big Data (ICAIBD) (pp. 372-376).

Mehta, P., & Pandya, S. (2020). A review on sentiment analysis methodologies, practices, and applications. International Journal of Scientific and Technology Research, 9, 601-609.

Min, B., Ross, H., Sulem, E., Veyseh, A. P. B., Nguyen, T. H., Sainz, O., ... & Roth, D. (2021). Recent advances in natural language processing via large pre-trained language models: A survey. arXiv preprint arXiv:2111.01243.

Nazir, A., Rao, Y., Wu, L., & Sun, L. (2020). Issues and challenges of aspect-based sentiment analysis: A comprehensive survey. IEEE Transactions on Affective Computing, 13, 845-863.

Peng, H., Xu, L., Bing, L., Huang, F., Lu, W., & Si, L. (2020, April). Knowing what, how and why: A near complete solution for aspect-based sentiment analysis. In Proceedings of the AAAI Conference on Artificial Intelligence (pp. 8600-8607).

Pereg, O., Korat, D., Wasserblat, M., Mamou, J., & Dagan, I. (2019). ABSApp: a portable weakly-supervised aspect-based sentiment extraction system. arXiv preprint arXiv:1909.05608.

Pontiki, M., Galanis, D., Papageorgiou, H., Androutsopoulos, I., Manandhar, S., AL-Smadi, M., ... & Eryiğit, G. (2016). Semeval-2016 task 5: Aspect-based sentiment analysis. In Proceedings of the ProWorkshop on Semantic Evaluation (SemEval-2016) (pp. 19-30).

Poria, S., Cambria, E., & Gelbukh, A. (2016). Aspect extraction for opinion mining with a deep convolutional neural network. Knowledge-Based Systems, 108, 42-49.

Poria, S., Cambria, E., Ku, L. W., Gui, C., & Gelbukh, A. (2014, August). A rule-based approach to aspect extraction from product reviews. In Proceedings of the second workshop on natural language processing for social media (SocialNLP) (pp. 28-37).

Radford, A., Wu, J., Child, R., Luan, D., Amodei, D., & Sutskever, I. (2019). Language models are unsupervised multi task learners. OpenAI blog, 1, 9.

Samha, A. K., Li, Y., & Zhang, J. (2014). Aspect-based opinion extraction from customer reviews. arXiv preprint arXiv:1404.1982.

Subrahmanian, V. S., & Reforgiato, D. (2008). AVA: Adjective-verb-adverb combinations for sentiment analysis. IEEE Intelligent Systems, 23, 43-50.

Tian, H., & White, M. (2020, July). A pipeline of aspect detection and sentiment analysis for E-commerce customer reviews. In Proceedings of the 43rd International ACM SIGIR Conference on Research and Development in Information Retrieval {SIGIR} (pp. 1-9).

Venugopalan, M., & Gupta, D. (2022). An enhanced guided LDA model augmented with BERT based semantic strength for aspect term extraction in sentiment analysis. Knowledge-based systems, 246, 108668.

Veyseh, A. P. B., Dernoncourt, F., Min, B., & Nguyen, T. H. (2022, July). Generating Complement Data for Aspect Term Extraction with GPT-2. In Proceedings of the Third Workshop on Deep Learning for Low-Resource Natural Language Processing (pp. 203-213).

Wang, Q., Wen, Z., Zhao, Q., Yang, M., & Xu, R. (2021, November). Progressive self-training with discriminator for aspect term extraction. In Proceedings of the 2021 conference on empirical methods in natural language processing (pp. 257-268).

Xu, H., Liu, B., Shu, L., & Yu, P. S. (2019). BERT post-training for review reading comprehension and aspect-based sentiment analysis. arXiv preprint arXiv:1904.02232.

Yanuar, M. R., & Shiramatsu, S. (2020, February). Aspect extraction for tourist spot review in Indonesian language using BERT. In Proceedings of the 2020 International Conference on Artificial Intelligence in Information and Communication (ICAIIC) (pp. 298-302).

The Role of the Service Desk for eHealth Solutions in the Digital Transformation of Slovenian Healthcare

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The Service Desk carries out three basic tasks: general support for all users of the eHealth system, support in connecting to the secure healthcare network (zNET), and making electronic appointments for medical services. This article analyses the operation of the Service Desk through time dynamics, the content of requests dealt with and services provided during the COVID-19 pandemic. The article is based on the case study research methodology. The data showed accelerated growth in the use of the Service Desk, with a more than seven-fold increase recorded in 2021 relative to 2020. The biggest proportion of the Service Desk requests in 2021 related to the zVEM Patient Portal and zNET. The Service Desk is one of the most important mechanisms for the successful development and use of the eHealth system in Slovenia, and the pandemic only made this even more evident and distinct.

Keywords:
eHealth, user help, eHealth Service Desk, digital transformation of healthcare

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1 Introduction

The effective and comprehensive digital transformation of the Slovenian healthcare system is one of the fundamental changes that should contribute to greater success in dealing with numerous challenges facing Slovenia's healthcare sector. Experiences in developed countries indicate (Bokolo, 2021; Arcury et al., 2020) that successfully implemented projects for healthcare digitalisation have exceptional strategic importance for further development of the healthcare system and considerable implications for increased social well-being and economic growth (European Commission, 2018). The project of Slovenian healthcare digitalisation (eZdravje or eHealth), which follows the national and European guidelines, was one of the key long-term goals of the public sector in Slovenia. The management of the digital solutions that were created as part of the eHealth project was taken over in 2015 by the National Institute of Public Health (NIJZ). Up until then, the eHealth project was managed by the Ministry of Health, and a large proportion of the start-up funds was provided from the European Social Fund.

An exhaustive review of the field indicates that the difficulties encountered right from the outset in the eHealth project stem on the one hand from the technological characteristics of the existing and rather fragmented healthcare information systems (HIS), which are a consequence of the uncoordinated development in the area of health informatics in recent decades. On the other hand, the responsibility for the existing state of affairs can be attributed principally to the decision-making entities that left the development of health informatics in this period up to individual or institutional initiatives, needs and interests, without unified strategic guidelines. Moreover, decision-makers in this period have not been able to effectively promote the eHealth initiative or ensure stronger political (financial, HR, organisational) support through the formulation of a modern and consistent strategy in this area.

The consequences of these factors are reflected in specific challenges identified by the NIJZ in its activities for the successful implementation and management of the eHealth system:

- the unpreparedness (administrative, technological, organisational, procedural, and so forth) of certain healthcare providers for appropriate use of the eHealth solutions;

- procedural, organisational, security, and user problems at healthcare providers;
- the lack of professional consensus regarding the substantive issues (e.g. the healthcare service code (VZS), authorizations for accessing the Central Registry of Patient Data (CRPD));
- the narrow focus of individual stakeholders on their own professional field without being aware of the interdependency of all stakeholders in the healthcare ecosystem;
- a lack of competent IT experts at healthcare providers who could ensure adequate maintenance and operation of the eHealth system;
- inadequate funds for digitalisation projects at healthcare providers and the NIJZ, which works to ensure the development and maintenance of central national eHealth system components.

Despite these challenges, the lack of unified strategic documents and inadequate investment in the area, great progress has been made in the development and implementation of eHealth solutions in the past four years. The national importance of some eHealth solutions was widely acknowledged, such as the zVEM Patient Portal, which received the two biggest IT prizes in Slovenia: the prize for current achievements in the information society for 2022, and the 2022 "eReward" for the zVEM mobile application. The zVEM+ portal is a version of the zVEM portal and is only intended for use by healthcare professionals.

As expected, and as it actually turned out during the management of the eHealth system, a large number of users often need help or advice for various reasons. Accordingly, a special organisational unit called the Service Desk was established and is managed by an external provider. The Service Desk is intended for all eHealth system users who wish to report disruptions in operation, who need assistance or require information regarding the functioning of the eHealth system. In the meantime, the Service Desk has proven to be one of the most important components of eHealth, as it has directly or indirectly helped thousands of users and significantly contributed to the successful development of eHealth solutions, their implementation and increasing use. In line with the points set out above, this article focuses on the research question of how the COVID-19 pandemic impacted the functionality and use of the Service Desk. Accordingly, the article analyses the operation of the eHealth Service Desk during the COVID-19 pandemic through the dynamic and content of requests dealt with and services provided.

2 Methods

The article presents an analysis of the functionality and use of the eHealth Service Desk during the COVID-19 pandemic. Our research sought to answer the question of how the COVID-19 pandemic impacted the development and use of the Service Desk. During the pandemic, new circumstances appeared that required rapid adaptation, so the Service Desk underwent an accelerated evolution. This is an example of the digital service that experienced fast-track expansion process during COVID-19, which indicates that in this respect the pandemic was a special opportunity for development. Our research was based on the case study research methodology (Yin, 2018; Kljajić, 2021), which included an in-depth analysis of the field and its critical review. We used statistics from the administrative and business intelligence modules in the analysis to compare the number of events, calls received and time taken in minutes in 2020 and 2021. We also compared data on the support provided for various eHealth solutions.

The analysis was conducted on the one hand based on a review of the literature in this field (Lee, 2022), as well as on the examination of project documentation and the technical specifications for the Service Desk. On the other hand the study was carried out on the basis of observations, experiences and the expert opinion of professionals at the NIJZ who are in charge of the eHealth system and the Service Desk. In addition we used the actual statistical data to support the findings obtained (NIJZ, 2021). The selection of research methods was based on the particular features of the research field and the fact that the entire area of healthcare digitalisation in Slovenia is still in a relatively early stage, so there is just a narrow circle of experts with appropriate knowledge and experience in this field. This methodological approach enabled not just an insight into the current theoretical and technological basis for these kinds of digital solution, but also an empirical overview of the use of the Service Desk in the Slovenian healthcare system. The participation of experts from the NIJZ in the research provided an insight into the technological and statistical aspects of the operation, and also enabled a critical and thorough insight into the user aspects of the Service Desk, since the participating experts from the NIJZ are very familiar with the user experiences of patients and health workers in the field, and with their satisfaction with the eHealth solutions. The analysis of the functionality and use of the Service Desk was conducted in the first half of 2023. Structured interviews with the NIJZ experts and the acquisition of statistical data from business and administrator modules were carried out between January and April 2023.

The article focuses on the Service Desk principally due to its importance both for patients and healthcare workers. The synthesis of findings from the literature, user functionalities, statistical reports and the views of experts from the NIJZ enables us to formulate credible conclusions based on verifiable data regarding the highlighted research aims (Lindgren et al., 2020). The use of the above-defined methodological framework, including a combination of various approaches and techniques for data gathering, was vitally important for the credibility of the analysis (Sim & Waterfield, 2019). The comprehensive analysis of data obtained from a diverse array of sources and from interviews with experts from the NIJZ ensured an appropriate platform for interpreting the data and formulating consistent conclusions regarding the research objectives (Thomas, 2021), which address the functionality and use of the eHealth Service Desk.

3 Results

The Service Desk for eHealth users was considered in the very first strategic documents relating to eHealth. Since the transfer of eHealth to the NIJZ at the end of 2015, its role has become increasingly significant. This was especially evident during the COVID-19 pandemic, when the usual methods of training users and dealing with requests were not possible, and the development and usage of the eHealth solutions took a major leap forward.

The Service Desk provides assistance for nearly 30 eHealth features and has three basic tasks:

- general support for all users of the eHealth system;
- support in connecting to the zNET;
- making electronic appointments for medical services.

General support for all users of the eHealth system is intended for patients, healthcare workers, administrative staff, IT specialists, software providers and all other users of the eHealth system who wish to report disruptions in operation, who need help or require information relating to the functioning of the eHealth system. Support in connecting to the zNET offers assistance to healthcare providers who wish to connect to the national eHealth infrastructure and become a part of the secure healthcare network. The eAppointments system for medical services helps patients to make appointments electronically. Users can access help by means of the online form at the web page, via email messages or by telephone for all eHealth features, for assistance with eAppointments, and for connection to the zNET. The website also provides answers to frequently asked questions.

During the COVID-19 pandemic the Service Desk responsibilities were expanded to provide support for a range of new eHealth solutions. New solutions for healthcare providers concerned assistance in screening tests for COVID-19, entering test results for COVID-19 in zVEM+, the zVEM+ feature for COVID-19 entry points and support for patient information. The zVEM+ portal enables the capture of data, its processing, and the issuing of various reports that healthcare providers must send out. It is intended for providers, which do not use their own information system for this kind of operation (Rant, Stanimirović & Janet, 2022a; Rant, Stanimirović & Janet, 2022b). New eHealth solutions for patients included the EU Digital COVID certificate (EU DCP) and registration for vaccination against COVID-19. In addition to these features, special support was provided to patients in making eAppointments, since the operation of the entire healthcare system was extremely restricted.

Support is provided by a permanent, experienced team of advisers specialised in various fields and features of eHealth. The advisers undergo constant training – both general and for specific features – and attend lectures, trainings and workshops. Videos are available for review and training of new co-workers. The Service Desk has built a massive knowledge base, keeping documentation and working to provide answers to frequently asked questions. The Service Desk website publishes notices related to the operation of the eHealth system and promptly publishes information about detected malfunctions and problems on the national level.

In the course of this research we used the statistical data from the administrative and business intelligence modules and compared the number of events, calls received and time taken in minutes in 2020 and 2021 by the Service Desk. Data reveals that the number of Service Desk requests grew considerably during the COVID-19 pandemic (Figure 1).

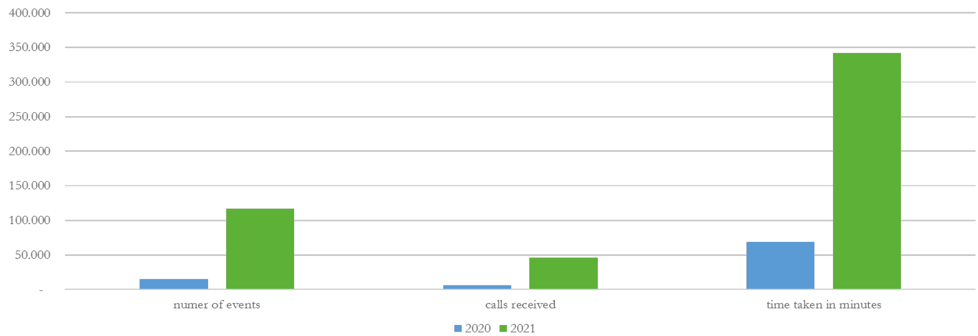

Figure 1: Ratio of Service Desk requests in 2020 and 2021

Additionally we compared the number of Service Desk requests in 2021 concerning the different eHealth solutions (Table 1).

Table 1: Percentage of Service Desk requests for different eHealth solutions in 2021

eHealth solution	Percentage of requests %
zVEM Patient Portal	69.06
ePrescription	0.32
eAppointment	4.80
CRPD	5.08
Vaccination registry	1.27
zNET	12.50
Security scheme	1.06
Application for preventive treatment	0.15
Teleradiology	0.12
Telestroke	0.05
eTriage	0.07
Other information	5.49

The biggest proportion of the Service Desk requests in 2021 related to the zVEM Patient Portal (Figure 2).

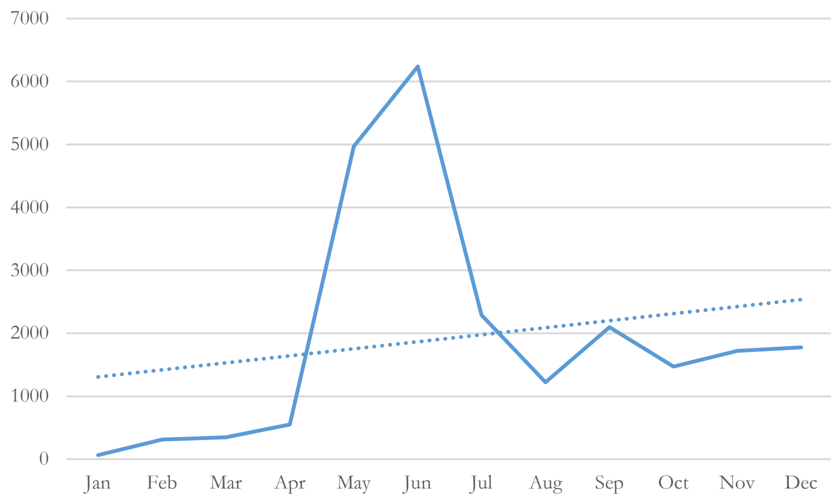

Figure 2: Number of Service Desk requests related to the zVEM Patient Portal in 2021

The data also show that the Service Desk requests for help with eAppointments followed the epidemiological situation, as the numbers grew the most in May 2021, after the first wave of the COVID-19 pandemic (Figure 3).

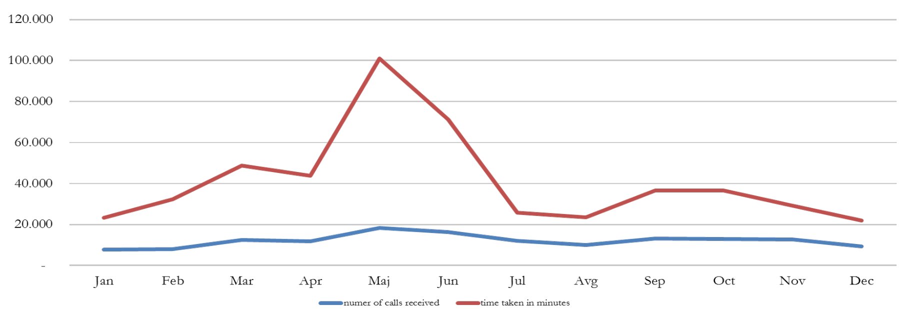

Figure 3: Service Desk requests for help with eAppointments

Since January 2021, the number of calls for eAppointments has been increasing, with a significant jump in May of that year, as a result of the introduction of the new digital solution for vaccination against COVID-19, which citizens mistakenly expected from the eHealth Service Desk. The increased volume of immaterial and irrelevant calls, which continued in June, was causing problems and preventing the Service Desk from reaching those patients who really needed help with eAppointments. In an attempt to free up the phone lines, we removed the eAppointment phone number from the entry page of the zVEM Patient Portal, as it was seen by many as the entry point for booking vaccinations. We also added congestion alerts to the website and additional instructions for patients looking for answers to other questions.

A significant increase in the number of calls to the Service Desk was detected after the introduction of eHealth solutions designed to monitor rapid tests for COVID-19, the introduction of vaccinations against COVID-19 and the issuance of EU digital COVID certificates. The existing team in the Service Desk was burdened more than usual, which affected the resolution of other eHealth requests.

The provider of the Service Desk points out a really large number of requests for connecting to the zNET, with which they are burdened on a daily basis. The rush to join was especially intense in April, because it was decided that from May 2021 eHealth solutions can only be accessed through the zNET. It was pointed out that it is necessary to provide the contact information of IT specialists for many new users of the zNET.

It is also evident that a greater proportion of requests are resolved at the Service Desk. However, due to the heavy load on the agents, there are occasional errors such as request redirection and missing data. In order to reduce the workload and stress of the Service Desk agents, we redesigned the informational website and supplemented it with updated contents. To connect to the zNET, a special phone number and email address were introduced. We analysed the increased volume of requests related to COVID-19 and prepared strategies to improve response times in resolving requests. A workshop for resolving requests related to IT issues and the zNET was held in April. Discussions are still taking place regarding Service Desk agents' access to the zVEM+ portal for user support purposes.

4 Discussion

The research findings showed that the COVID-19 pandemic had a profound and extensive impact on the functionality and use of the Service Desk. The COVID-19 pandemic showed how important the digitalisation of healthcare is (Stanimirović & Matetić, 2020), and in particular how the existence of a national infrastructure and central systems is vital for digitalisation. This was the case in developing the eHealth solutions in Slovenia. The COVID-19 pandemic circumstances and the inaccessibility of health services has accelerated the use of digital solutions, including eHealth solutions. This demanded the upgrades of numerous eHealth solutions, which needed to be developed and implemented in the shortest time possible. Some digitalisation objectives were achieved through existing solutions with some adaptations, while certain solutions needed to be reworked, and some needed to be developed completely from scratch.

In the 2020-2021 period two solutions in particular made great progress – the zVEM Patient Portal and the CRPD (Rant et al., 2022a). On the zVEM Patient Portal the number of registered users grew nine-fold (925%) in 2021 relative to 2020, and the number of visits grew 12 times (1,273%). The number of documents in the CRPD grew eight-fold in 2021 relative to 2019 (849%) (Rant et al., 2022b).

The rapid development of digital solutions and the exceptionally short time for implementation, which did not allow for the usual training of users and dealing with requests, generated unexpected pressure at the Service Desk. To a large extent, the pressure came from the users' and general public's lack of information and high expectations of eHealth solutions created by the media and politics, as well as the general public. Data on the number of requests received by the Service Desk reveal the exceptional growth in activity in the last two years. The number of events in 2021 grew more than seven times (766%), as did the number of calls received (742%), and the time taken in minutes grew five-fold (493%) (Figure 1). The highest growth is visible in May and June 2021 (Figure 2), which is also related to the acquisition of the EU Digital COVID certificates via the zVEM Patient Portal and the introduction of vaccinations and testing at healthcare providers. In May 2021 for instance, 80% to 90% of requests related to the zVEM Patient Portal or to questions regarding the EU DCP (Figure 2). This proportion declined later on.

One of the reasons for such demand for assistance with the zVEM Patient Portal is certainly help from the Service Desk agents in obtaining the EU DCP, which was required by the strict rules on movement in Slovenia during the COVID-19 pandemic. A significant advantage is that on the part of the agents, a real human answered the calls and not an automated system. The agents could adapt to users, their knowledge, experience and level of digital literacy. In this way, users obtained assistance firstly in accessing the zVEM Patient Portal, and following this, the agents would walk users step by step to finally obtaining the EU DCP. User satisfaction can be seen in the numerous expressions of gratitude they offered.

In providing support, the agents encountered many challenges and difficulties. Without a doubt, the greatest difficulty was the unpredictability of the daily and monthly workload, for which it was hard to prepare. There was a major increase in the number of calls and requests during the COVID-19 pandemic, and the Service Desk workload increased radically with the introduction of new features (e.g. the zVEM Patient Portal and the COVID certificate).

Users needed help with a variety of digital solutions, including eAppointments for vaccination, aAppointments for examinations, obtaining referrals and prescriptions, access to results and discharge letters. All this was available to them on the zVEM Patient Portal, for which it was mandatory to obtain a qualified digital certificate, and later the SI-PASS. The Service Desk agents led users through what are at times the truly complex and time-consuming procedures of registration for various online services.

One of the difficulties encountered by the Service Desk is the large number of calls that are not related to the eHealth systems, but are principally related to the COVID-19 pandemic. Such calls cause a notable burden at the Service Desk and the unavailability of the phone lines, which in turn causes dissatisfaction among those users who really need help and who must frequently wait longer for assistance. During the pandemic the Service Desk received general questions about health, questions about COVID-19 treatment and medications, and about vaccinations, vaccines and side effects. Moreover, patients contacted the Service Desk with questions about the measures in place and restrictions on movement. All these questions, requests and claims undermined the activities and main purpose of the Service Desk, which is to support users of the eHealth system, and not to provide the public with answers to general questions about COVID-19 and related epidemiological measures.

4 Conclusion

Since the completion of the project in 2015 the national eHealth system in Slovenia has undergone unimagined development. The whole national eHealth architecture underwent particularly accelerated development during the COVID-19 pandemic. In this period of such extensive development of new eHealth solutions and rapid growth in use (more than ten-fold), the Service Desk played a key role. Its proficient and unstinting assistance to users, be it citizens or health professionals, facilitated the effective use of the new and already existing eHealth solutions. The latter findings revealed the important role of the Service Desk in the field of healthcare digitalisation, especially in crisis situations and when introducing new digital solutions. On the other hand, the huge increase in requests received by the Service Desk during this period revealed that eHealth solutions were not well promoted and that a large number of citizens and health professionals do not have the skills to use digital solutions. These findings obligate managers of the national eHealth system to invest more in eHealth infrastructure, especially in such important components as the Service Desk. At the same time, the findings imply that the efforts and resources allocated to the promotion of eHealth solutions, education and training of citizens and professionals so far, have been decidedly insufficient and that the results of these activities have not yielded the desired results. It seems that the COVID-19 pandemic has done more to raise awareness and usage of eHealth solutions in a very short period of time than any other initiative before, be it of a political, legislative, administrative or financial character. Given this alarming fact, there should be a thorough examination and discussion of what activities are needed to address the exposed issues, otherwise we might largely undermine all efforts and achievements so far and significantly compromise the further development of healthcare digitalisation projects.

References

Arcury, T. A., Sandberg, J. C., Melius, K. P., Quandt, S. A., Leng, X., Latulipe, C., ... & Bertoni, A. G. (2020). Older adult internet use and eHealth literacy. Journal of Applied Gerontology, 39(2), 141-150.

Bokolo, A. J. (2021). Application of telemedicine and eHealth technology for clinical services in response to COVID-19 pandemic. Health and Technology, 11(2), 359-366.

European Commission. (2018). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions on enabling the digital transformation of health and care in the Digital Single Market; empowering citizens and building a healthier society. SWD (2018) 126 final. Brussels.

Kljajić Borštnar, M. (2021). Raziskovanje informacijskih sistemov. . Fakulteta za organizacijske vede. https://estudij.um.si/pluginfile.php/676575/mod_resource/content/2/U%C4%8Dbenik%20raziskovalna%20metodologija%20Kljaji%C4%87%20Bor%C5%A1tnar%20Mirjana%202021.pdf

Lee, W. L., Lim, Z. J., Tang, L. Y., Yahya, N. A., Varathan, K. D., & Ludin, S. M. (2022). Patients' technology readiness and eHealth literacy: implications for adoption and deployment of eHealth in the COVID-19 era and beyond. CIN: Computers, Informatics, Nursing, 40(4), 244-250.

Lindgren, B. M, Lundman, B., Graneheim, U. H. (2020). Abstraction and interpretation during the qualitative content analysis process. Int J Nurs Stud, 108: 103632. https://doi.org/10.1016/j.ijnurstu.2020.103632.

Nacionalni inštitut za javno zdravje (2021). Statistika zahtevkov na Prvem nivoju podpore uporabnikom eZdravja. Nacionalni inštitut za javno zdravje, Ljubljana.

Rant, Ž., Stanimirović, D., & Janet, J. (2022a). Functionalities and use of the zVEM patient portal and the central registry of patient data. In A. Pucihar, M. Kljajić Borštnar, R. Bons, A. Sheombar, G. Ongena, & D. Vidmar (Eds.), 35th Bled eConference Digital Restructuring and Human (Re)action: June 26 – 29, 2022, Bled, Slovenia (pp. 65–79). University of Maribor, University Press. doi:10.18690/um.fov.4.2022.4

Rant, Ž., Stanimirović, D., & Janet, J. (2022b). Razvoj portala zVEM in Centralnega registra podatkov o pacientu. In P. Šprajc, D. Maletič, N. Pavlović, I. Podbregar, A. Škraba, D. Tomić, U. Vincenzo, & A. Žnidaršič (Eds.), 41th International Conference on Organizational Science Development: society′s challenges for organizational opportunities (pp. 873–884). University of Maribor, University Press. doi:10.18690/um.fov.3.2022.63

Sim, J, Waterfield, J. (2019). Focus group methodology: some ethical challenges. Quality & Quantity. 2019 Jul;53(6):3003-3022.

Stanimirovic, D, Matetic, V. (2020). Can the COVID-19 pandemic boost the global adoption and usage of eHealth solutions?. J Glob Health, 10(2): 0203101. https://doi.org/10.7189/jogh.10.0203101.

Thomas G. (2021). How to do your case study. Thousand Oaks, CA: Sage Publications.

Yin, R. K. (2018). Case study research and applications: design and methods (6th ed.). Sage.

Adaptive Learning Technologies In Blended Learning Design: How Do Students and Teachers Use This Technology in Practice?

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Blended learning is adopted as the teaching method in an increasing number of higher education institutes worldwide. Adaptive learning technology (ALT) can be incorporated in such learning designs, especially to support students' a-synchronous, individual learning activities. In this empirical, mixed-method study, we investigated in what way teachers and students use the provided functionalities of a specific ALT to realise a blended course design. We interviewed four teachers delivering the same course using the ALT and we quantitatively analysed student trace data from the ALT log system. Our results show that teachers do recognize the added value of employing an ALT, but they do not realise its full potential by lack of usage of the dashboard, knowledge sharing among teachers and too little attention for (meta)cognitive and social support of students. The trace data analysis shows that students display cramming behaviour (no repetition and/or spaced practice), they are selective in which learning objectives they study and a majority chooses a suboptimal learning path. Based on our results, we conclude that, in the case we studied, the full potential that the ALT offers is not realised to the benefit of students, since both teachers and students show suboptimal behavior. We give recommendations for practice and future research based on our conclusions.

Keywords:
blended learning, active learning, adaptive learning technologies, case study, Bled eConference

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1 Introduction

Blended education is high on the agendas of educational institutions, especially after the Covid pandemic (Bruggeman et al., 2022; Dziuban et al., 2018). By combining the strengths of different learning environments, students can have a richer learning experience. In order to provide students with a rich learning environment in which they actively learn independent of time and/or place, a-synchronous learning activities are often part of students' learning arrangements.

The deployment of adaptive learning technologies for these a-synchronous learning activities has grown rapidly and these technologies are increasingly used in educational settings. Real-time interaction is not needed in those learning activities, as students interact when they want and at their own pace with course content through, among others, screencasts, exercises, and discussion boards. As a consequence, in theory there is more time at school for students to interact about course contents with peers and teachers synchronously. In practice, we often see that students and teachers do not take enough advantage of the used adaptive technologies. Students do not always prepare enough to effectively use the time in the classroom for further understanding of all learning content. And teachers do not always (know how to) use all provided information in the dashboards about students' progress to actively (change the) focus of the live interactions to the topics that students consider difficult.

A main goal of adaptive technologies is supporting active learning. Therefore, the current study focuses on teachers' possibilities to reach this goal by using adaptive learning technologies in a course design and aims to answer the question: *"How do teachers and students use adaptive technologies in practice and what can they do to contribute to active learning by students?"*

2 Theoretical framework

2.1 Blended and Active Learning

Hrastinski analysed the many definitions of blended learning and came to the conclusion that blended learning has become "an umbrella term" (Hrastinski, 2019). Therefore, he recommends explicitly stating what is understood by blended learning in the context of specific research. In addition, research at the higher education institute in the Netherlands where this study took place has concluded that many of the definitions of blended learning (Kat-De Jong, 2021): (1) place too much emphasis on the distinction between physical and online education; and/or (2) place too much emphasis on the ICT aspect; and/or (3) insufficiently reason from the student's perspective. Subsequently, within this institute blended learning has been defined as: "Providing a rich learning experience as a result of a deliberate, integrated, and harmonious combination of synchronous and a-synchronous learning activities in which students participate remotely, on campus, and in the workplace.".

Bernard et al. (2014) conclude from various comparative studies that a blended learning arrangement leads to better results for students (e.g., regarding motivation, engagement, and grades) than a fully offline or a fully online setup. In addition, Van der Stappen (2022) concludes that the added value of blended learning can be achieved precisely then when effectively combining the strengths of different learning environments, i.e., on campus, in the online learning environment, and in the workplace.

Various international meta-studies have studied the added value of blended learning, which can be summarized as follows (Last & Prinsen, 2021): (1) Blended learning can increase students' *engagement and learning efficiency*; (2) Blended learning offers *flexibility* in place and (partly) time of learning, e.g. for (the growing group of) international and working students; (3) Blended learning can potentially *maximize the benefits of several places while reducing their weaknesses* by combining online and face-to-face learning activities; and (4) Blended learning can increase students' *confidence* in their own abilities (self-efficacy) and *intrinsic motivation.*

Active learning is the central concept within the active (blended) learning ecosystem (Hedgepath, 2014; Last & Jongen, 2023).. If well-designed, blended learning motivates and activates students. This implies that students need to take ownership of their own learning process and, thus, need to engage in self-regulated learning (Jansen, 2021). However, self-regulated learning skills do not develop naturally, and research shows that the vast majority of students struggle to actually self-regulate their learning properly (Bol & Garner, 2011). In order for students to actually achieve a state of active learning, all three aspects of the aforementioned ecosystem (i.e.

pedagogy, physical and virtual space, and technology) are to be considered integrally by teachers when designing and evaluating blended learning arrangements that support active learning.

2.2 Community of Inquiry

Although not developed specifically for blended learning, the Community of Inquiry framework is one of the most influential blended learning models (Hrastinski, 2019). It has been argued that it is useful for understanding and designing blended learning due to the generic nature of the framework, and the resonance with both face-to-face and online learning (Garrison & Vaughan, 2008). The Community of Inquiry framework represents a process of creating a deep and meaningful (collaborative-constructivist) learning experience through the development of three interdependent elements (Garrison et al., 2001):

- *Social presence*: the ability of learners to project their personal characteristics into the Community of Inquiry, thereby presenting themselves as "real people". Intervention categories (Arbaugh et al., 2008): affective expression, open communication, and group cohesion;
- *Cognitive presence*: the extent to which the participants in any particular configuration of a Community of Inquiry are able to construct meaning through sustained communication. Intervention categories (Arbaugh et al., 2008): activating activities, exploration, integration, and completion;
- *Teaching presence*: the design, facilitation, and direction of cognitive and social processes for the purpose of realizing personally meaningful and educational worthwhile learning outcomes. Intervention categories (Arbaugh et al., 2008): design & organization, facilitating discourse, and direct instruction.

The idea behind this framework is that teachers create a blended learning environment encompassing a strong (interaction between) social, cognitive and teaching presence.

2.3 Adaptive Learning Technologies

With Covid and home-schooling as major accelerators, the deployment of adaptive learning technologies has increased significantly. A learning environment is adaptive *"…to the degree that (a) its design is based on data about common learner challenges in the target subject matter, (b) its pedagogical decision-making changes based on psychological measures of individual learners, and (c) it interactively responds to learner actions.*" (Aleven et al., 2016). Although adaptive learning technologies have been considered an important trend in education, they still have not reached their full potential as of yet, possibly since there has not been enough attention for the role of these technologies in the design of rich learning experiences (Rivera Muñoz et al., 2022; Weber et al., 2019).

In terms of blended learning, adaptive learning technologies are mainly used for a-synchronous learning activities. A-synchronous learning does not require real-time interaction. Students interact with the course content at their own pace, when and where they want, through e.g., learning modules, discussion boards, or pre-recorded videos.

Assuming that students engage with the materials in line with the teacher's blended course design, the idea is that students arrive well-prepared at the synchronous, on campus learning activity (e.g., a classroom lecture or workshop). That would result in more time to interact about course contents with peers and teachers synchronously in order to deepen and/or broaden the students' knowledge. The design of such a blended learning arrangement is frequently illustrated as a "blended wave". A fictitious example is presented in Figure 1 (SURF, 2022).

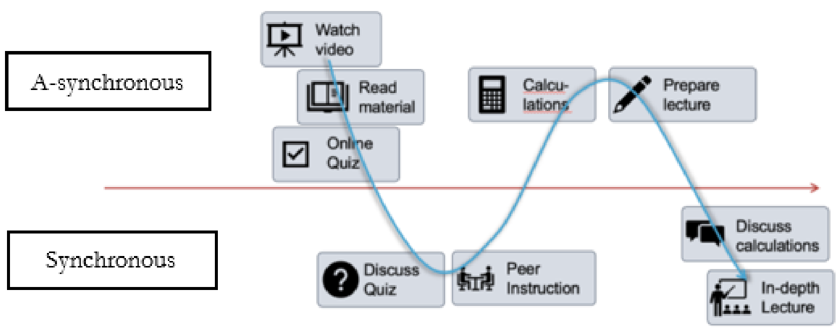

Figure 1: Example of a blended learning arrangement designed as a "blended wave"

3 Methodology

In this study, we want to understand better if and how a course – designed as a "blended wave" and supported by adaptive learning technology (ALT) – works in practice. Ultimately, we want to identify opportunities for (blended) educational improvements. Therefore, we answer the following research question: *"How do teachers and students use adaptive technologies in practice and what can they do to contribute to active learning by students?* To answer this question, we performed a mixed-method single case study (Yin, 2018). Below, we describe the real-world educational context in which the study took place, as well as the participants in the study, and the instruments and the methods that were used.

3.1 Context

The study was performed at a large university of applied sciences in the Netherlands with a focus on the course Introduction to Business Economics in the fall of 2021. This course is offered in both the Human Resources Management ("HRM") and Business Administration ("BA") Bachelor programmes.,during the first quarter of the propaedeutic phase, hence the students in question are on average 17-18 years of age.

The blended learning activities took place during seven consecutive teaching weeks. During these seven weeks, students engaged in the adaptive tool (a-synchronous) and had one (synchronous) lecture per week. Neither engaging in the adaptive tool nor participating in the lectures was compulsory. The eighth week was used for preparing (a-synchronously) for the written exam. This exam was taken in the ninth week.

The *ALT (software)* in this study is provided by a Dutch company: ABC (fictious name). ABC's software supports setting up the aforementioned "blended wave" (see Figure 1). For a student, ABC's software includes among others a question module. For a teacher, ABC's software includes among others a teacher dashboard.

The course in scope of our research is constructed along twelve learning objectives (subjects/themes). These learning objectives have a suggested order (learning objective sequence 1-12 as captured in the trace data; see section 3.2). However, the software does not prescribe a student to start with a specific learning objective in the software, nor which order to follow. Hence, a student can start with learning objective 11 and subsequently go to learning objective #5, from there to #7, etc.

By answering questions in the question module, a student can increase the so-called "ABC score". This is a grade number (1-10) that reflects the students' progress per learning objective and across all learning objectives. The ABC score can be increased or decreased, according to an algorithm, by answering questions in the module correctly or incorrectly. In maximally four steps, the students receive feedback on their incorrect answer attempts to instantly help the student proceed; this is referred to as "scaffolding" (Rivera Muñoz et al., 2022). The ABC score is also disclosed to a teacher via the aforementioned teacher dashboard. Appendix A contains a further explanation about the ALT in this case study.

3.2 Research Design

The research is designed as a mixed-method single case study, where the unit of analysis is the execution of a blended course design using ALT for a-synchronous activities. We applied triangulation (Cohen et al., 2018) in the data collection in several ways: both qualitative and quantitative methods were used, and data was collected from both teachers and students involved in the same course.

Semi-structured *interviews* were conducted with four teachers involved in the course (Table 1). Each interview was audio-recorded, fully transcribed and coded using open coding (Flick, 2018). The interview questions – reviewed by a second researcher – were targeted at teacher knowledge of adaptive learning and the associated technology, their views on the three aspects of the Community of Inquiry Framework, and the usage of the specific ALT applied in the course they were teaching. All teachers were informed of the purposes of our study, the data management and all gave recorded oral consent.

Moreover, a *quantitative analyses* on the log trace data extracted from the ALT which logs most of the students' online actions was performed. The original data file (Excel format) was retrieved anonymised from ABC. The trace data reflects the logging of all student activities in the question module in the period September 2021 to January 2022 for the course. Please refer to Appendix B for a further explanation about the original trace data as well as the cleaning and augmentation actions performed by the researchers. The data analysis was limited to activities in week 1 up to and including week 9 (written exam). The activities of nine students were discarded from the trace data set, either because these students were only enrolled to re-take the exam after failing the year before, or because they were not assigned to a class group which was supervised by a teacher. The final data set thus contains the data of 273 - 9 = 264 (mostly first year) students. No personal information (e.g., gender or age) was collected, since it was deemed unnecessary to answer the research question in this study. The students gave consent for the use of their log data in the system for research and improvement purposes when enrolling in the ALT system.

Table 1: Participant (interviewee) information

Interviewee	Teacher Experience	Used ALT In Scope Before?
A	5 years	Yes, 4 years
B	8 years	Yes, 4 years
C	9 years	Yes, 3 years
D	15 years	No

4 Results

4.1 Interviews with teachers

4.1.1 Ambiguous definitions

The interviewees mentioned various definitions of adaptive learning/adaptivity. The answers had in common that teachers were thinking about more student-tailored education. A few examples can be found in Table 2.

Table 2: Quotes on the definition of adaptive learning

Interviewee	Quote
A	*"Thinking along, giving tips, supporting/promoting the learning process, customisation, individual and immediate insight into 'right or wrong' but especially into why this was the case, adapting to level (of questions), different ways of learning (reading, videos), own pace, own moment."*
B	*"…tailoring your programme to your students. Customisation. And that means you underrstand how a particulat student learns and you take this as a starting point."*
C	*"...that students can partly learn at their own pace. So working on something by themselves and using that to find out for which topic(s) there is a need for help...so that you can match what each individual student needs."*
B+D	*"...time-independent and location-independent, self-paced learning."*

4.1.2 Motivations for deployment of the ALT

The interviewees mentioned several reasons for deploying an ALT such as the one deployed in this study. These vary from provider's sales push to the belief that the language and word usage in the ALT are much more in line with today's students. Most predominant is the belief that an ALT supports the concept "students in the lead": moving from consuming to demand-driven learning. Furthermore, direct, concrete feedback provided by the software means students do not have to wait (long) for a response from a teacher and can move on more quickly. Direct, concrete feedback can avoid misconceptions: "*Suppose the answer is EUR 100,000, a student may start working towards this answer, but not in the correct way. He/she therefore learns an incorrect method at that point. The ALT prevents this.*" Another important motivation is referred to as "no ballast": "*...the ALT compresses the material to its essence; in the previously used textbook, about 2/3rds of the content is not covered in the course.*"

4.1.3 Teachers recognize added value, but also make critical comments

The perceived benefits of using an ALT by the interviewees play an important role in supporting the deployment of an ALT. However, the interviewees also made some critical comments. Most importantly, the ALT is constructed along micro learning objectives. This leads to students *"…continue to 'think micro': students struggle to make connections between the individual learning objectives and/or to oversee the whole course with a helicopter view. Furthermore, students quickly get used to the way questions are formulated in the*

ALT's question module". In the ALT, topics as well as questions are structured per (micro) learning objective. However, during their written exam, students need to combine all information by solving an integrated case. As many students face difficulties with these kinds of cases, teachers need to explicitly address those while offering the blended learning arrangement. Otherwise the required constructive alignment is not in place (Biggs & Tang, 2011). To overcome this, as stated in the interviews, teachers started experimenting with so-called "integration case studies", which have been aligned with the ALT's supplier. These case studies are discussed during the synchronous, on campus, lessons. The preliminary results, based on feedback about the deployment of these "integration case studies" from both teachers and students, are promising.

4.1.4 Teaching presence dominant

The interviewees heavily focussed on interventions related to teaching presence. This is mainly due to the tangibility of and familiarity with the intervention categories related to teaching presence, i.e.: design & organisation, teaching facilitation and direct instruction (Arbaugh et al, 2008). For each of these aspects, without having to think for long, teachers named concrete examples of teaching presence related interventions in the context of this course.

This applies to a much lesser extent to social and cognitive presence. When asked, these two concepts are not directly recognised and the teachers make only (very) limited use of conscious, explicit interventions to promote social and cognitive presence. The deployment of the aforementioned integration case studies is the main example provided by the interviewees concerning cognitive presence. Three of the interviewees explicitly indicated that no specific a-synchronous social presence interventions were organised during this series of lessons, neither to interact with peers nor with teachers. However, research shows that students "…value , above all, regular synchronous and a-synchronous interactions with peers, tutors…" (Armellini et al., 2021).

4.1.5 Teacher dashboard could be used more effectively

The interviewees indicated that the capabilities of the teacher dashboard were only partially used. Teachers reported using the dashboard mainly in the first two weeks. In doing so, some teachers chose to open the dashboard in class ("confrontation"), others to address students 1-on-1. After a few weeks, the use of the teacher dashboard decreased. Reason are that a certain "*dashboard fatigue*" had developed and, in addition, the effect on the students by (publicly) displaying the dashboard seemed to be had worn off by then. Within the teacher dashboard, the ABC score (grade; 1-10) was mainly looked at, much less at the number of activity and attempts. Therefore, the teachers missed relevant information such as: (1) The questions/learning objectives for which the students needed the most response attempts in order to reach a sufficient result; (2) Students who were 'skipping' learning objectives; and (3) Students who were going through the various learning objectives in an undesirable sequence.

4.1.6 Teachers did not sufficiently share or discuss

As a group of teachers, it is important to share and discuss beliefs (or obstacles) considering the aforementioned elements (Gremmen, 2022). Ideally, this is done on a regular basis before (designing), during (adjusting/fine-tuning), and after (evaluating) the series of lessons. The interviewees indicated that mutual discussions heavily focused on course content instead of on beliefs (or obstacles) about active and blended learning in general, adaptive learning (techniques), cognitive and social presence interventions, dashboard deployment, etc.

4.2 Student trace data analysis

The trace data from the ALT was analysed from various perspectives such as number of activities (number of questions answered and number of response attempts per question), learning objectives, and ABC score. The results show a significant drop in students' activities in the ALT after week 2, lasting until week 7 (see Figure 2). The written exam was in week 9; the higher activity in week 8 might indicate a-synchronous last-minute exam preparation. This *cramming behaviour* is not in line with recommendations from research on effective (blended) learning strategies, such as repetition and spaced practice (Yeung et al., 2021).

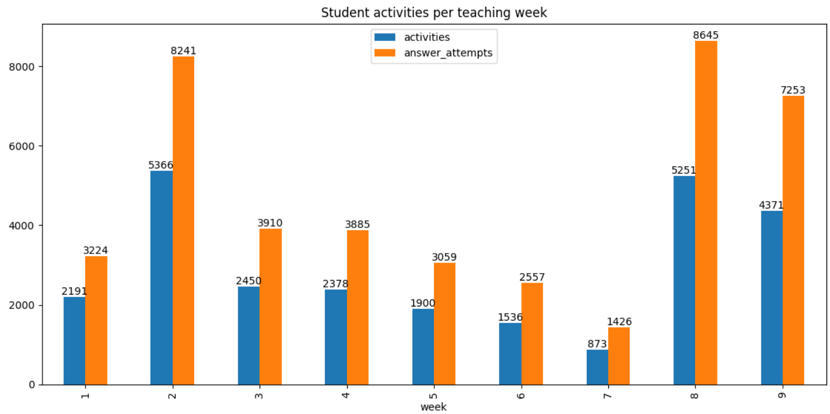

Figure 2: Number of activities and attempts performed by students per week

The ALT does not prescribe a student to start with a specific learning objective in the software, nor which order of learning objectives to follow, whereas the learning objectives do in fact build on the content of the previous one(s). Therefore, it was analysed which learning objective students chose to study in the system, and in which order. Here, *visiting* a learning objective (i.e., attempting at least one question related to this objective) is distinghuished from *completing* it (i.e., gaining a sufficient ABC score of at least 6.0).

Just 136 out of 264 (51%) of the students visited all learning objectives and only 156 (60%) of the students started the final learning objective #12 (See Figure 3) Therefore, it was analysed which learning paths (=learning objective sequence) students chose; see Figure 3 and Figure 4.

In Figure 4, all chosen learning paths are shown as line plots, with line thickness representing the number of students chosing that path. Most students stayed close to the default path, but some outliers exist, choosing for example the learning path (#5, #7, #1, #2, #9, #10, #11). 111 students chose the *default path*, i.e., #1 through #12. Nonetheless, there is a great variety in learning paths, e.g., 13 students never visited learning objective #1, one student started with #6, and one student visited #11 as his/her second objective.

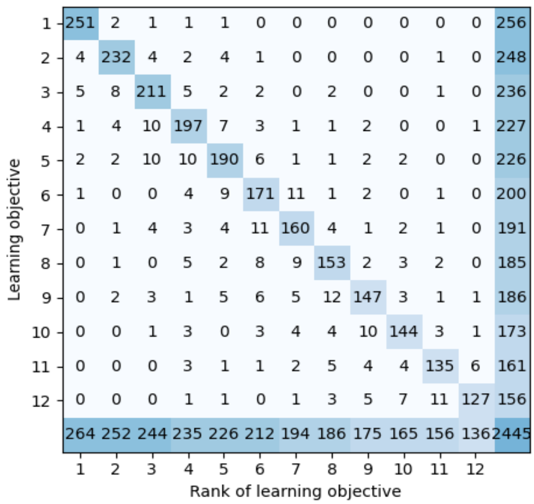

Figure 3: Students visiting a given learning objective at a given rank

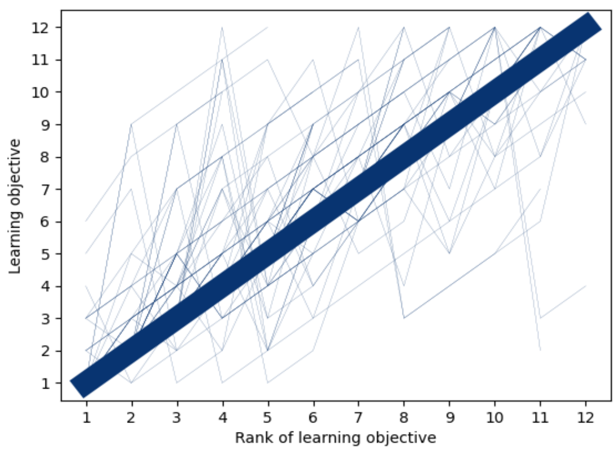

Figure 4: Learning paths chosen by students

Finally, the maximum ABC scores that students achieved on each of the learning objectives to compare scores between students that chose the default path and those that chose different paths was analysed. The complete results are shown in Table 3. An unpaired, two-sided T-test was performed. The difference between the average ABC score for default paths ($M_{default}$=7.70, $SD_{default}$=0.80) and the average ABC score for different paths ($M_{different}$=6.28, $SD_{different}$=1.80) is statistically significant, $t_{222.90485}$=8.65, p=1.00e-15, 95% CI [1.0964, 1.7431]. The results in Table 3 and the T-test point in the direction that students that chose the default learning path outperformed those that didn't, in terms of ABC score.

Table 3: Absolute and relative numbers of students scoring (in)sufficient on learning objectives

	default path (N=111)			different path (N=153)			total visited	% visited (N=264)
learning goal	insufficient	sufficient	% sufficient	insufficient	sufficient	% sufficient		
1	1	110	99.1%	17	128	83.7%	256	97.0%
2	3	108	97.3%	19	118	77.1%	248	93.9%
3	6	105	94.6%	17	108	70.6%	236	89.4%
4	1	110	99.1%	15	101	66.0%	227	86.0%
5	21	90	81.1%	60	55	35.9%	226	85.6%
6	1	110	99.1%	14	75	49.0%	200	75.8%
7	2	109	98.2%	22	58	37.9%	191	72.3%
8	1	110	99.1%	4	70	45.8%	185	70.1%
9	9	102	91.9%	25	50	32.7%	186	70.5%
10	2	109	98.2%	16	46	30.1%	173	65.5%
11	6	105	94.6%	14	36	23.5%	161	61.0%
12	14	97	87.4%	14	31	20.3%	156	59.1%

5 Conclusions and Discussion

In this study, we aimed to answer the question: '*How do teachers use adaptive technologies and what can they do to contribute to active learning by students?*' by interviewing teachers and analysing student trace data. Results show that both groups do not utilize the ALT in question as intended, i.e., to realize active learning through a blended wave in the course design. This is in line with other studies on ALTs, which were not specifically focused on blended learning designs (Harati et al., 2021). Our study adds to the knowledge base on ALT, since studies tend to focus more on technology than on learning (Rivera Muñoz et al., 2022).

Teachers show prominent teaching presence where cognitive and social presence are underrepresented. For an optimal blended learning experience, teachers should employ a balanced mix of these three presences, with cognitive presence being a strong indicator of students' satisfaction (Giannousi & Kioumourtzoglou, 2016). Students display cramming behaviour (no repetition and/or spaced practice), they are selective in which learning objectives they study and a majority chooses a suboptimal learning path.

Based on our research, we formulate some recommendations for educational practice. First, we advise teachers to actively integrate (insights from) the ALT in their synchronous activities, utilising the dashboard, and to use interventions directed at social and cognitive presence such as instruction on effective learning strategies or open communication aimed at community building (Biwer et al., 2020). These recommendations are in line with the recommendations from a recent study Müller et al. (2023). In addition, teachers could share their beliefs and strategies related to active, blended learning and ALTs when implementing a blended course with ALT to learn from each other. The ALT system could be extended to help students overcome drops in engagement by sending reminder notifications or employ (gamified) nudges. In the previous months, we conducted an exploratory study with students to assess the technical feasibility of such nudges based on machine learning analyses, and the preliminary results are promising.

Our study has some limitations. It took place in a specific context, where characteristics of teachers, students and technology may have influenced the results. The student participants group was quite large (264), but a mere four teachers were interviewed. Moreover, quantitative data was not available on teacher behaviour, and we did not include qualitative student data .

To conclude, we identify some interesting directions for future research. First, we would like to perform the same analyses in other educational contexts, in terms of study domain, teacher and students' characteristics, and ALT used. Second, a more qualitative study directed at students' perspective and behaviour could add to the insights presented in this paper. Finally, since our results show that the behaviour of both teachers and students was suboptimal, we think studies on interventions to help both groups to engage in more effective teaching and study behaviour would be very relevant to increase student success.

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References

Aleven, V., Mclaughlin, E., Glenn, A., & Koedinger, K. (2016). Instruction Based on Adaptive Learning Technologies.

Arbaugh, J. B., Cleveland-Innes, M., Diaz, S. R., Garrison, D. R., Ice, P., Richardson, J. C., & Swan, K. P. (2008). Developing a community of inquiry instrument: Testing a measure of the Community of Inquiry framework using a multi-institutional sample. The Internet and Higher Education, 11(3–4), 133–136. https://doi.org/10.1016/j.iheduc.2008.06.003

Armellini, A., Teixeira Antunes, V., & Howe, R. (2021). Student Perspectives on Learning Experiences in a Higher Education Active Blended Learning Context. TechTrends, 65(4), 433–443. https://doi.org/10.1007/s11528-021-00593-w

Bernard, R. M., Borokhovski, E., Schmid, R. F., Tamim, R. M., & Abrami, P. C. (2014). A meta-analysis of blended learning and technology use in higher education: From the general to the applied. Journal of Computing in Higher Education, 26(1), 87–122. https://doi.org/10.1007/s12528-013-9077-3

Biggs, J. B., & Tang, C. S. (2011). Teaching for quality learning at university: What the student does (4th edition). McGraw-Hill, Society for Research into Higher Education & Open University Press.

Biwer, F., Egbrink, M. G. A. oude, Aalten, P., & de Bruin, A. B. H. (2020). Fostering effective learning strategies in higher education—A mixed-methods study. Journal of Applied Research in Memory and Cognition, 9(2), 186–203. https://doi.org/10.1016/j.jarmac.2020.03.004

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). Taxonomy of educational objectives: The classification of educational goals: handbook I: cognitive domain. New York, US: D. Mckay.

Bol, L., & Garner, J. K. (2011). Challenges in supporting self-regulation in distance education environments. Journal of Computing in Higher Education, 23(2–3), 104–123.

Bruggeman, B., Hidding, K., Struyven, K., Pynoo, B., Garone, A., & Tondeur, J. (2022). Negotiating teacher educators' beliefs about blended learning: Using stimulated recall to explore design choices. Australasian Journal of Educational Technology, 100–114. https://doi.org/10.14742/ajet.7175

Cohen, L., Manion, L., & Morrison, K. (2018). Research methods in education (Eighth edition). Routledge.

Dziuban, C., Graham, C. R., Moskal, P. D., Norberg, A., & Sicilia, N. (2018). Blended learning: The new normal and emerging technologies. International Journal of Educational Technology in Higher Education, 15(1), 3. https://doi.org/10.1186/s41239-017-0087-5

Flick, U. (2018). An introduction to qualitative research (6th edition). SAGE Publications.

Garrison, D. R., Anderson, T., & Archer, W. (2001). Critical thinking, cognitive presence, and computer conferencing in distance education. American Journal of Distance Education, 15(1), 7–23. https://doi.org/10.1080/08923640109527071

Garrison, D. R., & Vaughan, N. D. (2008). Blended learning in higher education: Framework, principles, and guidelines (1st ed). Jossey-Bass.

Giannousi, M., & Kioumourtzoglou, E. (2016). Cognitive, Social, and Teaching Presence as Predictors of Students' Satisfaction in Distance Learning. Mediterranean Journal of Social Sciences. https://doi.org/10.5901/mjss.2016.v7n2s1p439

Gremmen, M. (2022). What's on teachers minds? Teachers' helping and hindering beliefs about blended education. European Association for Practitioner Research on Instruction and Learning, Nijmegen.

Harati, H., Sujo-Montes, L., Tu, C.-H., Armfield, S., & Yen, C.-J. (2021). Assessment and Learning in Knowledge Spaces (ALEKS) Adaptive System Impact on Students' Perception and Self-Regulated Learning Skills. Education Sciences, 11(10), 603. https://doi.org/10.3390/educsci11100603

Hedgepath, P. (2014). Active Learning. https://www.slideshare.net/hedgepath/lets-flip-it-2014

Hrastinski, S. (2019). What Do We Mean by Blended Learning? TechTrends, 63(5), 564–569.

Jansen, R. (2021, July 20). Zelfregulatie in blended onderwijs | Onderwijskennis. https://www.onderwijskennis.nl/kennisbank/zelfregulatie-blended-onderwijs

Kat-De Jong, M. (2021). Reflectie op blended onderwijs. Verkenning, speelveld en implementatie van blended onderwijs binnen Avans Hogeschool. Breda: Avans Hogeschool.

Last, B., & Jongen, S. (2023). Blended learning design: From theory to practice. Boom.

Last, B., & Prinsen, F. (2021). Blended learning en onderwijsontwerp. https://www.onderwijskennis.nl/kennisbank/blended-learning-en-onderwijsontwerp

Müller, C., Mildenberger, T., & Steingruber, D. (2023). Learning effectiveness of a flexible learning study programme in a blended learning design: Why are some courses more effective than others? International Journal of Educational Technology in Higher Education, 20(1), 10. https://doi.org/10.1186/s41239-022-00379-x

Rivera Muñoz, J., Berríos, H., & Arias-Gonzales, J. (2022). Systematic Review of Adaptive Learning Technology for Learning in Higher Education. Eurasian Journal of Educational Research (EJER), 98, 221–233. https://doi.org/10.14689/ejer.2022.98.014

SURF. (2022). De blended learning wave. https://communities.surf.nl/blended-learning/artikel/de-blended-learning-wave

Van der Stappen, E. (2022). Keuzes maken in blended en flexibel onderwijs: Hoedan#. https://www.avans.nl/onderzoek/expertisecentra/stand-alone-lectoraten/lectoraten/digitale-didactiek/lectorale-rede

Weber, N., Alexander, B., Ashford-Rowe, K., Barajas-Murphy, N., Dobbin, G., Knott, J., McCormack, M., Pomerantz, J., & Seilhamer, R. (2019). Educause Horizon report: 2019 Higher Education edition. EDUCAUSE.

Yeung, K. L., Carpenter, S. K., & Corral, D. (2021). A Comprehensive Review of Educational Technology on Objective Learning Outcomes in Academic Contexts. Educational Psychology Review, 33(4), 1583–1630. https://doi.org/10.1007/s10648-020-09592-4

Yin, R. K. (2018). Case study research and applications: Design and methods (Sixth edition). SAGE.

Appendix A - Further Explanation ALT

The adaptive software is provided by a Dutch company: ABC (fictious name). ABC's software supports setting up the "blended wave" (see Figure A). ABC has developed several courses (modules) that correspond to topics within a curriculum. Each course contains several learning objectives (subjects/themes) that can be completed independently, but which have a logical structure. For example, the course in scope of our research – Introduction to Business Economics – consists of twelve learning objectives. These learning objectives have a suggested order (learning objective sequence 1-12 as captured in the trace data), however the software does not restrict a student to start with a specific learning objective in the tool. Hence, a student could start with learning objective #4 or even with the last one (#12).

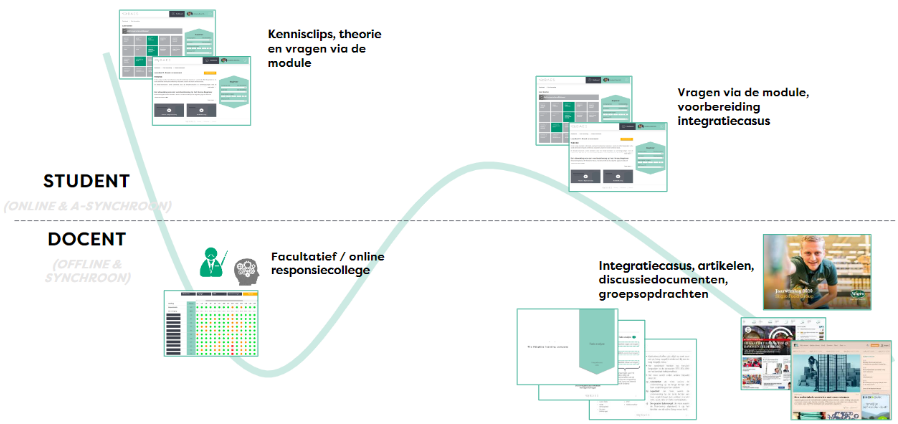

Figure A: The "blended wave" supported by the ALT

This "blended wave" ensures – at least that is the philosophy behind this software – that the student individually takes the first steps towards mastering a particular learning objective. The student takes these 'first steps' where and when he/she wishes (i.e. a-synchronously) by working digitally in the adaptive tool. The student practices with the learning materials per learning objective by reading texts, watching animations, and answering questions. With these 'first steps', the student eventually reaches Bloom's third level ("*apply*") with respect to the learning objective (see Figure B) by him(her)self. Whether and how quickly the student reaches Bloom's third level (Bloom et al., 1956) is calculated by an algorithm that is included in ABC's software.

The outcome of the algorithm is influenced by the number of attempts the individual student needs to correctly answer questions as well as the complexity of a given question. The teacher guides the student to (at least) the fourth Bloom level ("*analysing*") during the synchronous learning activities (e.g. on campus lectures or workshops). To this end, various work formats are deployed, such as integration cases, discussion groups about current news items or group presentations.

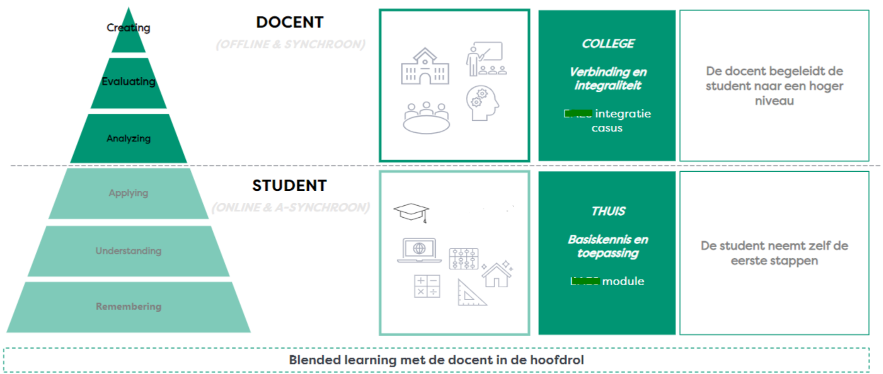

Figure B: Bloom's levels in relation to the "blended wave" and the deployment of the ALT

For a student, ABC's software includes the following components:

- Adaptive question module (arranged per learning objective);
- Instant feedback on answers given in the question module;
- Theory (also downloadable) related to a learning objective as well as animations of and sample questions about that theory;
- Insights into own level, answer attempts and activity;
- Practical tests;
- Asking questions to the teacher and giving feedback on the material in the module.

For a teacher, ABC's software includes the following components:

- Creating and managing classes;
- Gaining insight into level and progress of the (students in the) class through the teacher dashboard (see Figure C for a fictitious example);
- Creating teacher materials, such as newspaper articles and self-developed in-depth questions or (integration) case histories;
- Going through the lesson material in 'student mode';
- Creating, opening and analysing (practice) tests;
- Responding to questions or feedback from students.

Figure C: Snapshot (fictious) of the ALT's teacher dashboard

The teacher dashboard includes the "ABC score". This is a grade number (1-10) that shows a student's (or class's) progress per learning objective and across all learning objectives. The ABC score can be increased, according to the aforementioned algorithm, by answering questions in the module correctly (or decreased in case of an incorrect answer). In maximally four steps, the student receives feedback on his wrong answer attempts to instantly help the student in the learning moment. The ABC score is also disclosed to a student.

Appendix B - Trace Data Explanation

The original data file contains the following columns:

- Student id (number; student's full identity is known by ABC, not by the researchers);
- Question id (number);
- Learning objective[1] id (number; xxx);
- Learning objective sequence id (number; 1-12);
- Type of question (e.g. multiple choice or table question);
- Complexity of the specific question (number; 1-5);
- Time stamp start of answering the specific question;
- Time stamp end of answering the specific question;
- Answer(s) provided by the student to the specific question (text; all answer attempts are captured in one cell in the original data file);
- Question-answer id (number).

Each row in the data file represents a specific student's activity, i.e. answering a specific question in the question module. The student has a maximum of four (scaffolded) attempts to answer a question correctly. All answers attempts were logged in the same row.

A number of adjustments were made to the original data file:

- Split from one to four columns to capture the student's answer attempts to the specific question (text);
- Addition of the following columns:
  - Count (number; 1-4) of the answer attempts to the specific question;
  - Counter id (number) per row;
  - The day of the week (Monday - Friday) the specific student has a classroom lecture (synchronous learning activity);
  - Calendar week (number) of the student's activity in the question module;

[1] A learning objective represent a certain topic in the area of Business Economics, e.g. a company's balance sheet.

- Teaching week (number) of the student's activity in the question module;
- Day of the week (Monday - Sunday) the student was active in the question module;
- Time spent (in minutes) for answering the specific question;
- ABC score (grade; 1-10) as a result of answering the specific question. The ABC score is presented per learning objective and overall;
- Result (grade; 1-10) of the written exam taken in the ninth week.

In this course, 273 students were enrolled. Since our unit of analysis is the execution of a blended course design, it was decided to include in the scope of the data analysis only those students that were able to actually undergo the blended wave of independent (online) preparation (a-synchronous) and classroom attendance (synchronous, usually in a group of 28-32 students). We therefore filtered out students that were not assigned to a class group.

Toward Sovereign Data Exchange Through a Meta-Platform for Data Marketplaces: A Preliminary Evaluation of the Perceived Efficacy of Control Mechanisms

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The landscape of platform ecosystems is becoming increasingly complex, with new types of platforms emerging that glue together otherwise fragmented ecosystems. One recent case is meta-platforms that can contribute to the European Data Economy by interconnecting data marketplaces; however, meta-platforms may intensify data sovereignty concerns: the inability of data providers to own and control the exchanged data. While smart contracts and certification can generally enhance data sovereignty, it is unknown whether data providers perceive these control mechanisms as valuable in the complex meta-platform setting. This study aims to evaluate the perceived efficacy of the control mechanisms to ensure data sovereignty in meta-platforms. The findings from a survey study (n=93) indicate that respondents perceive high data sovereignty. One potential explanation is that smart contracts can potentially enable providers to maintain ownership and control over their exchanged data; meanwhile, certification may signal meta-platforms' responsibility to deliver secure data exchange infrastructure and assist providers in adhering to relevant regulations. This study contributes to advancing design knowledge for meta-platforms, showcasing that meta-platforms can be designed in a way to resolve fragmentation without neglecting data sovereignty principles.

Keywords:
data economy, meta-platforms, data marketplaces, business data exchange, data sovereignty

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1 Introduction

The growing demand to unleash the full potential of the Data Economy has led to the emergence of data marketplaces: multi-sided platforms that facilitate business data exchange among enterprises (Spiekermann, 2019). This phenomenon is particularly evident in the European context, where efforts to strengthen the European Data Economy have accelerated the proliferation of these marketplaces (European Commission, 2020). Due to the specialized nature of data as a commodity, data marketplaces often focus on specific industries, resulting in significant fragmentation and heterogeneity (Aaltonen et al., 2021). This fragmentation is expected to continue, causing lock-in effects and data discovery challenges for data providers and consumers (Santiago & Laoutaris, 2022).

The existing platform literature recognizes meta-platforms as potential measures to reduce fragmentation and achieve critical mass (Mosterd et al., 2021; Pitt et al., 2021). A meta-platform is built on top of two or more existing platforms to connect their ecosystems (Zhang & Williamson, 2021). A typical example of a meta-platform in the tourism industry is Trivago, which federates and coordinates other platforms (e.g., Expedia, Booking, and Airbnb). Other examples in the data marketplace context include the recently developed TRUSTS[1] and i3-Market[2]. Nevertheless, while exchanging business data on a data marketplace is already difficult due to data sovereignty concerns (i.e., the inability of data providers to own and control the exchanged business data), these concerns will likely intensify in a meta-platform setting because data may flow from one data marketplace to another (Zappa et al., 2022). Additionally, complying with data sovereignty principles has recently become a prerequisite for exchanging business data within the European context (European Commission, 2020).

Smart contracts and certification are among the most-discussed control mechanisms to enhance data sovereignty in various data exchange settings (Lauf et al., 2022; Schmidt et al., 2022). For example, smart contracts have been extensively implemented in data marketplace cases to guarantee data sovereignty (Fruhwirth et al., 2020; Precht & Gómez, 2021). Likewise, certification has been implemented in

[1] https://www.trusts-data.eu/, accessed on May 11, 2023
[2] https://www.i3-market.eu/, accessed on May 11, 2023

supply chains (Bastiaansen et al., 2020; Dalmolen et al., 2019) and data ecosystem settings (Azkan et al., 2020). Given the novel and intricate nature of meta-platforms (e.g., allowing data to flow from one data marketplace to another), it is unknown whether data providers view these control mechanisms as valuable. For example, data providers may argue that certification is less valuable due to the difficulty of tracing valid and non-expired certificates in the complex constellations of data marketplaces. Against this backdrop, **this study investigates the perceived efficacy of control mechanisms, namely smart contracts and certification, to enhance data sovereignty in data marketplace meta-platforms.** This research advances design knowledge for meta-platforms to address fragmentation without compromising data sovereignty principles.

2 Research Background

2.1 Meta-platform offerings

Multiple approaches can be adopted to interconnect digital platforms. Digital platforms can create direct application programming interfaces to connect with each other (Hodapp & Hanelt, 2022). Third parties can "bridge" two platforms by creating an application (e.g., the Philips Hue case) (Hilbolling et al., 2020) or "fork" a platform by exploiting its core resources (e.g., Amazon Fire) (Karhu et al., 2018). Meta-platforms, on the other hand, are built on top of two or more existing platforms, thereby connecting their respective ecosystems (Zhang & Williamson, 2021). Because meta-platforms may act as a coordinator to enable collective actions, legitimate governance, and transparency values (Pitt et al., 2021), meta-platforms are potentially suitable for tackling the fragmentation of data marketplaces in the European context.

Trivago is an example of a *meta-platform* where Expedia, Booking, and Airbnb serve as *platform participants*. These platform participants have their provider- and consumer-side (we refer to them as *end-users*). Therefore, meta-platforms cannot exist independently (Lagutin et al., 2019). Meta-platforms have two key offerings to create value for end-users: information aggregation and a one-stop-shop portal. First, meta-platforms aggregate information from platform participants to create new services, for example, by creating a meta-search engine to manage information flow and disseminate information (Lanza et al., 2016; Pitt et al., 2021). Aggregating information often aims to give recommendations to end-users (Floetgen et al., 2021; Yang & Wang, 2019). Second, meta-platforms provide a one-stop-shop portal to enable end-users to seamlessly interact with only a single user interface to perform necessary activities (Floetgen et al., 2021; Reinartz et al., 2019). This portal mediates interoperability between platform participants by providing service or technical integration (Ulrich & Alt, 2021). While participating platforms may be reluctant to standardization (Costabile et al., 2022), a meta-platform creates a common interface or protocol for interaction within its ecosystem without requiring participating platforms to modify their internal standards.

2.2 Data sovereignty dimensions and indicators

Data sovereignty encompasses various dimensions. To maintain a focused analysis, we prioritize the dimensions most closely associated with data sovereignty: *ownership, control, responsibility*, and *security* (Hummel et al., 2021). We also investigate *compliance* as another dimension, given its recent legal prominence in contexts such as the European Data Governance Act (Duisberg, 2022). We define indicators for each dimension to provide observable measurements of data sovereignty as a multi-dimensional construct.

Data ownership is the exclusive right and authority to make decisions regarding data assets (Hummel et al., 2021). Despite the ongoing debate on who should own data assets (e.g., an individual, an organization, or a platform) (Lee et al., 2017), we focus here on the organization as a unit of analysis because end-users of a meta-platform are organizations, not individuals. We define four indicators for data ownership: (1) data providers should be able to express the term of use of data exchange, (2) be involved in determining (monetary) incentives (Dalmolen et al., 2020), (3) define the data type to exchange (Lee et al., 2017), and (4) decide which data marketplace receives the meta-data description (Abbas et al., 2022).

Control over exchanged data is among the most heavily recognized dimension of data sovereignty, referring to the ability of data providers to steer data exchange flows according to pre-defined agreements (Hummel et al., 2021). We define four indicators for data control. First, data providers can technically enforce terms of use of data exchange (Dalmolen et al., 2020). In doing so, data providers can track the data usage history (the second indicator). Third, data providers should be able to determine where they can store the shared (meta-) data (e.g., on the meta-platform, on its infrastructure, or the data consumer infrastructure) (Dalmolen et al., 2020). Finally, if something happens, data providers can withdraw their (meta-)data for a meta-platform and data marketplace participants (Lauf et al., 2022). Another critical data sovereignty dimension relates to *compliance*. As data exchange is subject to specific regulations, data providers should: (1) receive sufficient information to avoid violating laws and regulations, (2) obtain sufficient (technical) procedures to respond to those laws and regulations, and (3) utilize dispute mechanisms to handle conflicts (if any, with data consumers) (Hummel et al., 2021).

One distinguishing dimension of data sovereignty due to the context novelty is the *responsibility* dimension, primarily because of the complex constellations of data marketplaces via a meta-platform. As our previous study reveals (Abbas et al., 2022), it should be clear who is responsible for what to ensure sovereign data exchange. Hence, we propose the three indicators: meta-platforms should (1) responsibly select data marketplace participants that adhere to data exchange standards, (2) clearly divide responsibilities between the meta-platform and the data marketplace participants, and (3) take responsibility if the sensitive data is misused or stolen. Finally, we include an essential data sovereignty component: *security*. Building from the work of Hartono et al. (2014) and Hummel et al. (2021), we propose four indicators for security: (1) meta-platforms should prevent the disclosure of the exchanged data to unauthorized parties, (2) prevent the alteration of the exchanged data, (3) enable data providers to execute data-sharing transactions without system failures, and (4) implement up-to-date security features. In summary, we use these five data sovereignty dimensions to evaluate the perceived efficacy of control mechanisms in the meta-platform setting.

2.3 Control mechanisms: Smart contracts and certification

Control theories explain how and why control mechanisms enacted by controllers can influence the behaviors of controlee (Saunders et al., 2020). Control mechanisms can be divided into formal (input, process, output) and informal (self and clan) control (Wiener et al., 2016). In this study, we want to examine how smart contracts (as a process control) and certification (as an input control) can diminish data sovereignty concerns of data providers. We select the combination of these two mechanisms because they may influence all sovereignty dimensions.

Smart contracts are "…any self-executing program running in the distributed ledger environment, and it is often meant to implement automated transactions agreed by the parties" (Governatori et al., 2018, p. 378). Regarding *ownership*, smart contracts offer a pre-filled template to define use cases of data exchange, which include the term of use, monetary incentives, and the data type to exchange (Moyano et al., 2021). Considering *data control*, smart contracts provide data provenance to enable transparency of data access and usage. At a more advanced level, smart contracts can automatically monitor data compliance usage (Karger et al., 2021; Tuler De Oliveira et al., 2022). Furthermore, data providers can automatically revoke the license if consumers violate use and access rights (Jagals et al., 2021). We hypothesize that smart contracts enhance the data sovereignty dimensions of *ownership* and *control* (H_1).

Certification for sovereign data exchange "…defines a standardized level for security related to technical and organizational aspects" (Menz et al., 2019). Therefore, certification aims to confirm compliance with these pre-conditions (Biegel et al., 2020). Within the meta-platform context, applying certification means that a meta-platform decides pre-conditions that must be fulfilled by data marketplace participants and their end-users (data providers and consumers). They need to, for instance, apply technical integration services such as application programming interfaces (or data ecosystem nodes) to join the meta-platform federation infrastructure. For example, compliance and security can be achieved by incorporating the International Data Space certification, demonstrating compliance with ISO/IEC 27001 (international standard for information security management) and IEC 62443 (cybersecurity for operational technology in automation and control systems). Related to the clarity of responsibility, certification can distinguish actors' roles and responsibilities (Lansing et al., 2018). For example, a meta-platform and data marketplaces can only access the meta-data, not actual business data themselves; a meta-platform and an external third party will act as evaluators to assess certification compliances. We hypothesize that certification can advance the *compliance*, *security*, and *responsibility* dimensions of data sovereignty (H_2). To sum up, Figure 1 summarizes the research model.

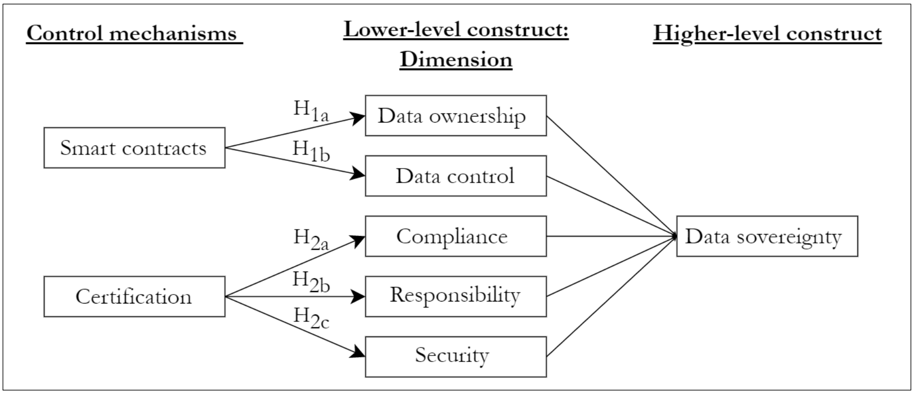

Figure 1: The research model

3 Research approach

This research is part of a larger design science project. We first explored state-of-the-art data marketplaces as federation objects and defined meta-platform boundary conditions. With a focus on data sovereignty concerns, we established metrics to evaluate artifact efficacy. We then examined control mechanisms in various business data exchange contexts, prioritizing smart contracts and certification. We developed a prototype to address data sovereignty concerns in collaboration with an EU project consortium. This paper concentrates explicitly on the final step, evaluating the perceived efficacy of control mechanisms in addressing data sovereignty concerns. We define efficacy as "the ability to produce a desired or intended result."[3] While objective measures of data sovereignty (e.g., Firdausy et al., 2022), smart contracts (e.g., Hai & Liu, 2022), and certifications (e.g., Menz et al., 2019) technically exist, they do not always reflect the subjective experience of data providers interacting with these control mechanisms. The level of control that smart contracts offer may not always match the perceived level of control due to various factors, including the complexity of the smart contracts or the ability to interpret how smart contracts work. Obtaining feedback on the perception of control mechanisms can help

[3] http://www.oxforddictionaries.com/definition/english/efficacy, accessed on 06 April 2023.

identify gaps beyond the technical aspects, which can inform the design of control mechanisms.

We conducted a survey study to achieve our objective, recruiting 93 participants residing in Europe through the Prolific platform (47 female, 46 male). The sample size was determined using G*Power statistical calculations. The majority of participants were young to middle-aged adults (31-45 years old, 51%), followed by young adults (17-30 years old, 40%) and older adults (9%). Educational backgrounds were diverse, with 46% holding a Master's degree and 33% possessing a Bachelor's degree. The target participant profile included employees with management experience and leadership responsibilities. A significant proportion of participants (82%) had planned or conducted business-sensitive data exchanges, and 75% self-reported being knowledgeable about data marketplaces.

The online survey via Qualtrics consisted of three elements: a video explanation, a prototype, and a questionnaire. The video explained a hypothetical scenario where users play the role of a data provider, a telecommunication company so-called TELCO.[4] Data providers will exchange their business data about Call Detail Records via a meta-platform. Next, participants engaged with the prototype by completing a series of pre-defined tasks.[5] Task 1 consisted of simple sub-tasks designed to familiarize participants with the prototype. Task 2 involved describing meta-data associated with the platform, while Task 3 focused on creating and managing contracts. Lastly, Task 4 allowed participants to exercise the control capabilities of the meta-platform. After exercising the prototype, participants filled out a questionnaire. Because the measurement of data sovereignty does not yet exist, we mostly self-developed the indicators of each dimension, as elaborated in Section 2.2. For example, in the data control dimension, we asked the following question for the first indicator (DC_1): *If I would share sensitive data, I believe the meta-platform offers me technical means to enforce data usage policies.* We also employed generic indicators such as (DS_G) "*I believe the meta-platform enables sovereignty for the sensitive data that I would share.*" These generic indicators were utilized as an enabler to check the convergent validity of the data sovereignty dimensions; for a detailed view of these indicators, please

[4] The video can be accessed here: https://www.youtube.com/watch?v=9b7iKM3BiMs.
[5] The prototype can be accessed here: https://www.figma.com/proto/KJUcfObwTZp8GaOrTyVhNi/TRUSTS-meta-platform?page-id=2506%3A47793&node-id=2506-50925&viewport=-444%2C-564%2C0.19&scaling=min-zoom&starting-point-node-id=2506%3A50925.

refer to the online supplementary material.[6] Participants answered the questions on a 5-point Likert scale.

Because we have five dimensions contributing to data sovereignty, our model can be seen as a Hierarchical Component Model (HCM). HCM offers several benefits, for example, minimizing the quantity of path model connections, overcoming the bandwidth-fidelity dilemma, and decreasing collinearity among dimensions (Sarstedt et al., 2019). We employed a standard approach to validate the measurement of the HCM in SmartPLS 4: a joint two-stage approach (Ringle et al., 2012). In the first stage, we evaluated all indicators regarding indicator reliability, internal consistency reliability, convergent validity, and discriminant validity. In the second stage, we formed a latent composite score of each dimension and evaluated their convergent validity, collinearity issues, and relevance (Hair et al., 2021). Following this, we conducted a one-sample t-test in SPSS to assess the extent to which the perceived efficacy of control mechanisms, as reported by participants, is significantly better than the midpoint of our Likert scale.

4 Results

The reliability of each indicator is confirmed, as the outer loading (λ) for all indicators is within the range of 0.6 and 0.9 (Hair et al., 2021). The internal consistency reliability for each aspect is also established, as indicated by the composite reliability (rho_a) score for each greater than 0.7. Convergent validity is likewise confirmed, as the Average Variance Extracted for all aspects surpasses 0.5. Consequently, we opted against removing any indicators. As for discriminant validity, the Heterotrait-monotrait ratio (HTMT) for all dimensions is below the recommended threshold of 0.9, except for Security (S) and Responsibility (R). Thus, we examine cross-loadings and remove one item (S_4), establishing discriminant validity. Our final model comprises five data sovereignty dimensions. Specifically, the dimension of data ownership is represented through four indicators (DO_1, DO_2, DO_3, DO_4), data control through four indicators (DC_1, DC_2, DC_3, DC_4), compliance through four indicators (C_1, C_2, C_3, C_4), responsibility through three indicators (R_1, R_2, R_3), and finally, security through three indicators (S_1, S_2,

[6] The online supplementary material can be accessed here: https://doi.org/10.4121/e4cacfac-31f0-4523-81f4-35383ba958a8.

S_3). We also confirm the validity of a generic data sovereignty construct measured by six indicators.

Next, we calculated the Latent Variable (LV) score for each data sovereignty dimension from the Hierarchical Component Model (HCM) of data sovereignty (Figure 2). The convergent validity is established as ($\beta = 0.713$, $p = 0.00$) and $R^2 >$ 0.5, indicating data these dimensions well represent data sovereignty. The HCM exhibits no collinearity issue, as all dimensions have a Variance Inflation Factor (VIF) less than 5. Although Outer Weight (OW) testing shows significance only for the responsibility (OW = 0.38, $p = 0.01$) and security dimensions (OW = 0.38, $p =$ 0.00), we retain the other dimensions since their outer loadings are greater than 0.5, as suggested by Hair et al. (2021).

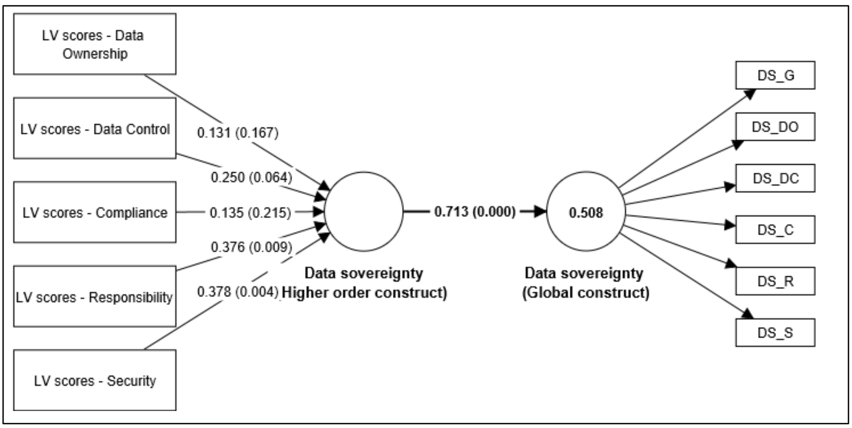

Figure 2: Hierarchical component model of data sovereignty

After validating the HCM measurement model, we conducted a one-sample t-test to compare the mean score of all data sovereignty dimensions against the benchmark value of three. Respondents perceive high data sovereignty when faced with our control mechanisms, as the mean of ownership [$t(92) = 16.1$, $p < 0.01$], control [$t(92) = 16.48$, $p < 0.01$], compliance [$t(92) = 12.41$, $p < 0.01$], security [$t(92) = 9.89$, $p <$ 0.01], and responsibility [$t(92) = 9.06$, $p < 0.01$] are all significantly greater than the benchmark value of three (see Table 1). Detailed elaboration, including raw data, survey indicators, and the complete analytical statistic, is available in the online supplementary material.

Table 1: One-sample t-test calculation (n = 93, test value = 3)

	Descriptive statistic		One-sample t-test		
Dimension	**Mean**	**SD**	**Mean dif.**	***t* value**	***p***
Ownership	4.07	0.64	1.07	16.10	<0.01
Control	4.15	0.67	1.15	16.48	<0.01
Compliance	4.04	0.80	1.04	12.41	<0.01
Security	3.78	0.76	0.78	9.89	<0.01
Responsibility	3.74	0.79	0.74	9.06	<0.01

5 Discussions and conclusions

This research aims to evaluate the perceived efficacy of control mechanisms, namely smart contracts and certification, in enhancing data sovereignty within the context of a meta-platform for data marketplaces. Our findings indicate that the meta-platform prototype containing the control mechanisms is evaluated positively on all data sovereignty dimensions. One possible explanation can be reflected in the proposed hypotheses: smart contracts may play a role in impacting data ownership and control dimensions (H_1); meanwhile, certification may influence compliance, security, and responsibility dimensions (H_2).

We primarily contribute to two streams of literature: 1) multiplatform constellations (or platform ecologies) and 2) data exchange. Specifically, we do so by advancing design knowledge for meta-platforms by providing an initial assessment of the perceived efficacy of control mechanisms in addressing data sovereignty concerns. We are among the first that showcase data sovereignty is evaluated positively in meta-platforms, meaning that, even though meta-platforms exponentially amplify the risks of data exchange, they may still be designed in ways that do not harm data sovereignty.

Considering design knowledge in the problem space, measuring data sovereignty efficacy remains ambiguous and complex. Existing research often equates data sovereignty with control (e.g., Jarke et al., 2019; Otto & Jarke, 2019) while overlooking other dimensions (cf. Hummel et al., 2021). Our findings resolve this tension by offering an alternative approach that captures the multifaceted nature of data sovereignty. To do so, we advance Hummel et al.'s (2021) work in three key aspects: first, by incorporating an added dimension of *responsibility* due to the unique context of meta-platforms with increased governance complexity among data marketplace participants; second, by offering empirical evidence on the collective influence of the five dimensions (ownership, control, security, compliance, and responsibility) on data sovereignty; and third, by enhancing granularity through the introduction of data sovereignty measurement models employed as survey instruments.

Regarding design knowledge in the solution space, our study offers valuable insights into how data providers perceive control mechanisms as valuable for ensuring data sovereignty within the unique context of meta-platforms. Our findings align with existing literature on data exchange, which suggests that smart contracts can technically enable ownership and control (e.g., Saini et al., 2020; Zhang et al., 2018), and certifications can enhance compliance, security, and responsibility (Lansing et al., 2018). However, our contribution extends beyond this general understanding by opening up future discussions for their applicability in distinctive meta-platform characteristics. For instance, smart contracts in meta-platforms are distinct from those in supply chains due to the requirement for seamless interoperability among multiple interconnected marketplaces. This interoperability demands the development of smart contracts that automatically enforce data usage policies and agreements between individual marketplaces and across varied legal and regulatory environments. As a result, smart contracts that leverage interoperable "side chains" emerge as a potential solution to explore (Singh et al., 2020). Alternatively, meta-platforms can offer shared services for data marketplace participants, serving as a backbone infrastructure to facilitate smart contract deployment and alleviate interoperability challenges.

This study has some limitations. First, this study employed a one-sample t-test, thus constraining our comparison to the Likert scale's mid-point. To further improve the validity of the finding, we will continue this research by conducting a between-subject 2x2 factorial experiment. In doing so, we can compare the effect of the presence of these control mechanisms and identify potential interaction effects to confirm the proposed H_1 and H_2. Second, while our study focuses on the most critical dimension of data sovereignty, we are aware of the potential significance of other dimensions (e.g., justice). To account for this, we considered the justice dimension as a control variable in the prototype development by suggesting appropriate data pricing to ensure fair revenue distributions. Finally, the technical aspects of smart contracts and certification are beyond the scope of our work. To what extent these two control mechanisms can be implemented in a large-scale setting needs further research.

This paper has important policy implications as it suggests ways forward to a single European Data Market while allowing specialized data marketplaces (or data spaces) to exist. This resolves tensions in the European policy to promote a single market for data and interoperable data sharing (e.g., in EU Data strategy, Data Act) and promote verticals/sector-specific data platforms (e.g., the eight verticals in the Digital Europe program), while at the same time, adhere to data sovereignty principles.

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References

Aaltonen, A., Alaimo, C., & Kallinikos, J. (2021). The Making of Data Commodities: Data Analytics as an Embedded Process. Journal of management information systems, 38(2), 401-429. https://doi.org/10.1080/07421222.2021.1912928

Abbas, A. E., Ofe, H., Zuiderwijk, A., & de Reuver, M. (2022). Preparing Future Business Data Sharing via a Meta-Platform for Data Marketplaces: Exploring Antecedents and Consequences of Data Sovereignty. 35th Bled eConference - Digital Restructuring and Human (Re-Action), Bled, Slovenia.

Azkan, C., Möller, F., Meisel, L., & Otto, B. (2020). Service dominant Logic Perspective on Data Ecosystems-a Case Study based Morphology. ECIS 2020 Research Papers, Marrakesh, Morocco.

Bastiaansen, H., Dalmolen, S., Kollenstart, M., & van Engers, T. M. (2020). User-Centric Network-Model for Data Control with Interoperable Legal Data Sharing Artefacts. PACIS 2020 Proceedings, Dubai, the United Arab Emirates.

Biegel, F., Bongers, A., Chidambaram, R., Feld, T., Garloff, K., & Ingenrieth, F. (2020). GAIA-X: Driver of digital innovation in Europe. Germany's Federal Ministry for Economic Affairs and Energy (BMWi).

Costabile, C., Iden, J., & Bygstad, B. (2022). Building digital platform ecosystems through standardization: an institutional work approach. Electronic Markets, 32(4), 1877-1889. https://doi.org/10.1007/s12525-022-00552-0

Dalmolen, S., Bastiaansen, H., Kollenstart, M., & Punter, M. (2020). Infrastructural sovereignty over agreement and transaction data ('metadata') in an open network-model for multilateral sharing of sensitive data. 40th International Conference on Information Systems, ICIS 2019, Munich, Germany.

Dalmolen, S., Bastiaansen, H., Somers, E., Djafari, S., Kollenstart, M., & Punter, M. (2019). Maintaining control over sensitive data in the Physical Internet: Towards an open, service oriented, network-model for infrastructural data sovereignty. 6th International Physical Internet Conference (IPIC), London, the United Kingdom.

Duisberg, A. (2022). Legal Aspects of IDS: Data Sovereignty—What Does It Imply? Designing Data Spaces, 61.

European Commission. (2020). A European Strategy for Data. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0066&from=EN

Firdausy, D. R., De Alencar Silva, P., Van Sinderen, M., & Iacob, M.-E. (2022). Towards a Reference Enterprise Architecture to enforce Digital Sovereignty in International Data Spaces. 2022 IEEE 24th Conference on Business Informatics (CBI), Amsterdam, the Netherlands.

Floetgen, R. J., Strauss, J., Weking, J., Hein, A., Urmetzer, F., Böhm, M., & Krcmar, H. (2021). Introducing platform ecosystem resilience: leveraging mobility platforms and their ecosystems for the new normal during COVID-19. European Journal of Information Systems, 1-18. https://doi.org/10.1080/0960085x.2021.1884009

Fruhwirth, M., Rachinger, M., & Prlja, E. (2020). Discovering Business Models of Data Marketplaces. Proceedings of the 53rd Hawaii International Conference on System Sciences, Hawaii, the United States.

Governatori, G., Idelberger, F., Milosevic, Z., Riveret, R., Sartor, G., & Xu, X. (2018). On legal contracts, imperative and declarative smart contracts, and blockchain systems. Artificial Intelligence and Law, 26(4), 377-409. https://doi.org/10.1007/s10506-018-9223-3

Hai, X., & Liu, J. (2022). PPDS: Privacy Preserving Data Sharing for AI applications Based on Smart Contracts. 2022 IEEE 46th Annual Computers, Software, and Applications Conference (COMPSAC), Los Alamitos, the United States.

Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2021). A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM). SAGE Publications.

Hartono, E., Holsapple, C. W., Kim, K.-Y., Na, K.-S., & Simpson, J. T. (2014). Measuring perceived security in B2C electronic commerce website usage: A respecification and validation. Decision Support Systems, 62, 11-21.

Hilbolling, S., Berends, H., Deken, F., & Tuertscher, P. (2020). Complementors as connectors: managing open innovation around digital product platforms. R&D Management, 50(1), 18-30. https://doi.org/10.1111/radm.12371

Hodapp, D., & Hanelt, A. (2022). Interoperability in the era of digital innovation: An information systems research agenda. Journal of Information Technology, 0(0), 1-21. https://doi.org/10.1177/02683962211064304

Hummel, P., Braun, M., Tretter, M., & Dabrock, P. (2021). Data sovereignty: A review. Big Data & Society, 8(1), 1–17. https://doi.org/10.1177/2053951720982012

Jagals, M., Karger, E., Ahlemann, F., & Brée, T. (2021). Enhancing Inter-Organizational Data Governance via Blockchain–Shaping Scopes and Research Avenues. Forty-Second International Conference on Information Systems, Texas, the United States.

Jarke, M., Otto, B., & Ram, S. (2019). Data sovereignty and data space ecosystems. Business & Information Systems Engineering, 61(5), 549-550.

Karger, E., Jagals, M., & Ahlemann, F. (2021). Blockchain for AI Data–State of the Art and Open Research. Forty-Second International Conference on Information Systems, Texas, the United States.

Karhu, K., Gustafsson, R., & Lyytinen, K. (2018). Exploiting and defending open digital platforms with boundary resources: Android's five platform forks. Information Systems Research, 29(2), 479-497.

Lagutin, D., Bellesini, F., Bragatto, T., Cavadenti, A., Croce, V., Kortesniemi, Y., Leligou, H. C., Oikonomidis, Y., Polyzos, G. C., Raveduto, G., Santori, F., Trakadas, P., & Verber, M. (2019). Secure Open Federation of IoT Platforms Through Interledger Technologies - The SOFIE Approach. 2019 European Conference on Networks and Communications (EuCNC), Valencia, Spain.

Lansing, J., Benlian, A., & Sunyaev, A. (2018). "Unblackboxing" Decision Makers' Interpretations of IS Certifications in the Context of Cloud Service Certifications. Journal of the Association for Information Systems, 19(11), 3.

Lanza, J., Sanchez, L., Gomez, D., Elsaleh, T., Steinke, R., & Cirillo, F. (2016). A Proof-of-Concept for Semantically Interoperable Federation of IoT Experimentation Facilities. Sensors, 16(7), 1006. https://doi.org/10.3390/s16071006

Lauf, F., Scheider, S., Bartsch, J., Herrmann, P., Radic, M., Rebbert, M., Nemat, A. T., Schlueter Langdon, C., Konrad, R., & Sunyaev, A. (2022). Linking Data Sovereignty and Data Economy: Arising Areas of Tension. Wirtschaftsinformatik 2022 Proceedings, Nuremberg, Germany.

Lee, S. U., Zhu, L., & Jeffery, R. (2017). Data governance for platform ecosystems: Critical factors and the state of practice. PACIS 2017 Proceedings, Langkawi Island, Malaysia.

Menz, N., Resetko, A., & Winkel, J. (2019). IDS Certification explained.

Mosterd, L., Sobota, V. C. M., Van De Kaa, G., Ding, A. Y., & De Reuver, M. (2021). Context dependent trade-offs around platform-to-platform openness: The case of the Internet of Things. Technovation, 108, 102331. https://doi.org/10.1016/j.technovation.2021.102331

Moyano, J. P., Avital, M., Bühler, M., & Schmedders, K. (2021). Fostering Peer-to-Peer Blockchain-based Data Markets. The 25th Pacific Asia Conference on Information Systems, Dubai, the United Arab Emirates.

Otto, B., & Jarke, M. (2019). Designing a multi-sided data platform: findings from the International Data Spaces case. Electronic Markets, 29(4), 561-580. https://doi.org/10.1007/s12525-019-00362-x

Pitt, S., van Meelis Lacey, M., Scaife, E., & Pitt, J. (2021). No App is an Island: Collective Action and Sustainable Development Goal-Sensitive Design. International Journal of Interactive Multimedia & Artificial Intelligence, 6(5).

Precht, H., & Gómez, J. M. (2021). Towards GDPR Enforcing Blockchain Systems. Wirtschaftsinformatik 2021 Proceedings, Essen, Germany.

Reinartz, W., Wiegand, N., & Imschloss, M. (2019). The impact of digital transformation on the retailing value chain. International Journal of Research in Marketing, 36(3), 350-366.

Ringle, C. M., Sarstedt, M., & Straub, D. W. (2012). Editor's comments: a critical look at the use of PLS-SEM in" MIS Quarterly". MIS quarterly, iii-xiv.

Saini, A., Zhu, Q., Singh, N., Xiang, Y., Gao, L., & Zhang, Y. (2020). A smart-contract-based access control framework for cloud smart healthcare system. IEEE Internet of Things Journal, 8(7), 5914-5925.

Santiago, & Laoutaris, N. (2022). A Survey of Data Marketplaces and Their Business Models. SIGMOD Record, 51(3), 18-29.

Sarstedt, M., Hair Jr, J. F., Cheah, J.-H., Becker, J.-M., & Ringle, C. M. (2019). How to specify, estimate, and validate higher-order constructs in PLS-SEM. Australasian marketing journal, 27(3), 197-211.

Saunders, C., Benlian, A., Henfridsson, O., & Wiener, M. (2020). MIS Quarterly Research Curation: IS Control & Governance. MIS quarterly.

Schmidt, K., Munilla Garrido, G., Mühle, A., & Meinel, C. (2022). Mitigating Sovereign Data Exchange Challenges: A Mapping to Apply Privacy-and Authenticity-Enhancing Technologies. International Conference on Trust and Privacy in Digital Business, Vienna, Austria.

Singh, A., Click, K., Parizi, R. M., Zhang, Q., Dehghantanha, A., & Choo, K.-K. R. (2020). Sidechain technologies in blockchain networks: An examination and state-of-the-art review. Journal of Network and Computer Applications, 149, 102471.

Spiekermann, M. (2019). Data Marketplaces: Trends and Monetisation of Data Goods. Intereconomics, 54(4), 208-216. https://doi.org/10.1007/s10272-019-0826-z

Tuler De Oliveira, M., Reis, L. H. A., Verginadis, Y., Mattos, D. M. F., & Olabarriaga, S. D. (2022). SmartAccess: Attribute-Based Access Control System for Medical Records Based on Smart Contracts. IEEE Access, 10, 117836-117854. https://doi.org/10.1109/access.2022.3217201

Ulrich, D., & Alt, R. (2021). Social networking platforms to close the gender gap: an analysis of female doctoral students in information systems. ECIS 2021 Research Papers, Timişoara, Romania.

Wiener, M., Mähring, M., Remus, U., & Saunders, C. (2016). Control configuration and control enactment in information systems projects: Review and expanded theoretical framework. MIS quarterly, 40(3), 741-774.

Yang, F., & Wang, Y. (2019). Research Status and Trend Analysis of Learning Resource Aggregation in the Era of Big Data. Moscow, Russia.

Zappa, A., Le, C.-H., Serrano, M., & Curry, E. (2022). Connecting Data Spaces and Data Marketplaces and the Progress Toward the European Single Digital Market with Open-Source Software. In (pp. 131-146). Springer International Publishing. https://doi.org/10.1007/978-3-030-98636-0_7

Zhang, M. Y., & Williamson, P. (2021). The emergence of multiplatform ecosystems: insights from China's mobile payments system in overcoming bottlenecks to reach the mass market. Technological Forecasting and Social Change, 173, 121128. https://doi.org/10.1016/j.techfore.2021.121128

Zhang, Y., Kasahara, S., Shen, Y., Jiang, X., & Wan, J. (2018). Smart contract-based access control for the internet of things. IEEE Internet of Things Journal, 6(2), 1594-1605.

An Ethical Perspective on Loot Box Purchasing - Examining Psychosocial Antecedents and the Association with Indebtedness

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Loot boxes are popular random reward mechanisms in digital games, attracting players to invest real money to enhance their gaming experiences. Loot boxes share striking similarities to gambling and might contribute to one's economic strain, but more research is needed on the underlying vulnerabilities and motivational traits in loot box purchasing. This paper examines associations with self-reported increase in loot box purchasing and debt problems during the first year of the COVID-19 pandemic. International survey data were collected in 2021, consisting of Finnish, Swedish, and British respondents (N = 2,991) aged 18 to 75. Partial least squares modeling was used as an analytical technique. The findings bring valuable insight into the underlying psychosocial and motivational factors in loot box purchasing and its association with indebtedness.

Keywords: loot box, indebtedness, resilience, loneliness, social relationships

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1 Introduction

Loot boxes are an example of gambling-gaming convergence, referring to random-reward in-game purchase opportunities present in modern video games (Drummond & Sauer, 2018; Spicer et al., 2022; Zendle et al. 2019). Loot boxes can be defined as chance-based "mystery boxes" containing a selection of game-related items (e.g., weapons, cosmetic features), and they are typically purchasable with real money (Zendle et al., 2020). The chance-based mechanism of loot boxes is often juxtaposed with gambling (Delfabbro & King, 2020; Spicer et al., 2022), and loot box opening even provokes similar physiological and psychological reactions as gambling does (Brady & Prentice, 2021). Since gambling is highly addictive, the gambling-like nature of loot boxes make them an addictive characteristic of video games (Király et al., 2023). From an ethical perspective, this raises concerns particularly regarding vulnerable players such as young people or individuals with psychosocial or financial problems.

Even though loot boxes have gained scholars' attention particularly in relation to disordered gambling, there is a call for research to explore underlying factors and individual characteristics which might contribute to excessive loot box spending and consequent problems (Yokomitsu et al., 2021). There is some evidence that loot box expenditure is associated with financial harm (Carey et al., 2022), but more detailed studies are needed. Additionally, adolescent players with psychosocial problems such as depression are more susceptible to unplanned loot box purchasing (Irie et al., 2022), but more research is needed to gain better insight on psychosocial risks and protective factors. Most studies on loot box purchasing have focused on adolescent players (e.g., Hing et al., 2022; Irie et al., 2022; Kristiansen & Severin, 2020), which is important given the popularity of loot boxes in games that children play (Zendle et al., 2020). However, research on adult gamers is needed as well. Frank, Salo, & Toivakka (2015) conclude that digital gamers' purchasing decisions are dominantly based on hedonic motivations, but loot box purchasing might have unique motivational traits due to their gambling-like nature. Despite the similarities with gambling, ethical issues regarding personal, social, and financial vulnerabilities in loot box purchasing, have to our knowledge, not been researched before.

Additionally, the impact of the COVID-19 pandemic on problematic gambling and gaming behaviors is still topical. Due to shutdowns of societies and excessive social isolation, opportunities for daily recreational activities and enjoyment were highly limited particularly during the first year of the pandemic, making the role of online technologies more emphasized. In the early onset of the pandemic, the World Health Organization recommended digital gaming as a safe activity to spend time and connect with friends and family (King et al., 2020). Some individuals have been more vulnerable to develop harmful habits over the course of the pandemic. For example, problematic online behaviors such as excessive engagement in online gaming or gambling have acted as a response to a crisis and related mental distress for some individuals (Savolainen et al., 2022). Developing harmful habits such as increased purchase behaviors as a response to the pandemic might have long-lasting effects on one's financial wellbeing such as the tendency for indebtedness.

This paper investigates the (self-reported) increase in loot box purchasing and its association with indebtedness during the first year of the COVID-19 pandemic. We approach increased loot box purchasing as a form of problematic behavior because of its potential to harm one's finances (Carey et al., 2022) and its striking resemblance with gambling mechanisms (Delfabbro & King, 2020; Király et al., 2023; Spicer et al., 2022). The aim of this paper is to first examine if loneliness, social support, and COVID-19 worry are drivers for loot box purchasing and if psychological resilience protects consumers from excessive loot box purchasing. Second, we study if loot box purchasing predicts tendencies for indebtedness.

2 Theoretical Framework

Because the chance-based mechanism of loot boxes holds an analogy for gambling (Delfabbro & King, 2020, Király et al., 2023; Spicer et al., 2022), we build our framework on the work of Sirola et al. (2023), who examined the psychosocial drivers on gambling during the COVID-19 pandemic. Sirola et al. (2023) discovered an indirect association between COVID-19 worry and problem gambling through loneliness (H1). Therefore, in a similar manner, we investigate whether there is direct or indirect link between COVID-19 worry and loot box purchasing (H2). In line with prior studies (Sirola et al., 2023), we suggest that social support is negatively associated with loneliness (H3). However, according to a review by Nordmyr & Forsman (2020) there is contradictory evidence on the role of social support in problem gambling. For example, some studies indicate that social support and socializing with peers might be positively associated with problem gambling, and social support might be particularly problematic if it promotes gambling activities (Dowling et al., 2017; Räsänen et al., 2016; Sirola et al., 2023; Yücel et al., 2015). Additionally, social identification and peer-pressure in team-based digital gaming might influence in-game purchase behaviors (Sirola et al., 2021). This makes it worth testing whether social support has a positive association with loot box purchasing (H4). Prior studies have shown social support to have positive associations with psychological resilience (H5) (Cohen & Wills, 1985; Mancini & Bonanno, 2009; Zhang et al., 2022). Existing research has also found positive associations between loneliness and higher problem gambling severity (Khazaal et al., 2017; Sirola et al., 2019; 2023; Vuorinen et al., 2021) and therefore we expect loneliness to have similar association with loot box purchasing (H6).

Lussier et al. (2007) suggest that psychological resilience is a protective factor to gambling particularly among youth, while more recent studies have provided contradictory evidence on the role of resilience among adult gamblers (Mishra et al., 2019; Oei & Goh, 2015; Scholes-Balog et al., 2015; Sirola et al., 2019). Thus, it is also worth testing whether psychological resilience is negatively associated with loot box purchasing (H7). We also expand the framework by Sirola et al. (2023) by examining the consequences of loot box purchasing. Because harmful habits or compulsive behaviors such as excessive purchase behaviors and overspending might have long-lasting effects on one's financial wellbeing (Achtziger, 2022), we postulate that loot box purchasing is positively associated with the tendency for indebtedness (H8). We controlled the research model for the effects of a respondent's age, gender, and level of education. The research hypotheses are listed in Table 1 and the summary of our theoretical framework is illustrated in Figure 1.

Table 1: List of Research Hypotheses

Hypotheses	
H1	*Loneliness is positively associated with COVID-19 worry.*
H2	*COVID-19 worry is positively associated with increased loot box purchasing.*
H3	*Social support is negatively associated with perceived loneliness.*
H4	*Social support is positively associated with increased loot box purchasing.*
H5	*Social support is positively associated with psychological resilience.*
H6	*Loneliness is positively associated with increased loot box purchasing.*
H7	*Psychological resilience is negatively associated with increased loot box purchasing.*
H8	*Loot box purchasing is positively associated with indebtedness.*

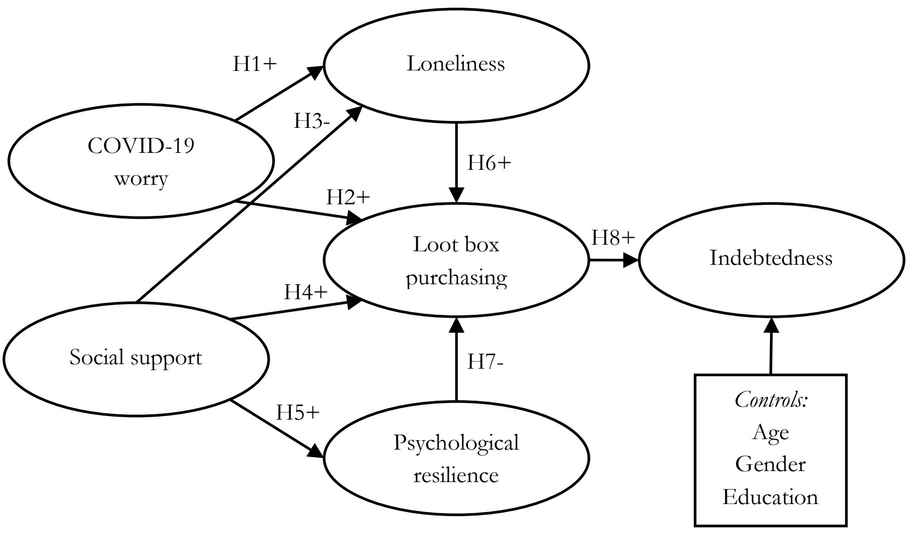

Figure 1: Theoretical framework and hypotheses

3 Methods and Materials

3.1 Sample and Data Collection

The participants in this study's cross-national dataset (N = 2,991) ranged in age from 18 to 75 and originated from Finland (n = 995; mean age = 44.60; 50.4% female; SD = 15.67); Sweden (n = 998; mean age = 43.84; SD = 15.78; 50.3% female); and the UK (n = 998; mean age = 43.56; SD = 15.76; 50.8% female). During the COVID-19 pandemic in April 2021, information was simultaneously collected from these three nations utilizing an anonymous online survey. The questionnaire was created to examine how the pandemic has affected people's general lives, including their online activity, consumption, and wellbeing. We selected Finland, Sweden, and the UK for our study, because these are three technologically advanced and culturally relatively similar European nations. In Finnish, Swedish, and English, the survey's format and metrics were all similar.

A data-provider company recruited respondents from an internet panel (CINT) using a random sample in each nation. Contacts with the panelists were made in a random order. The web panelists are volunteers who select to participate in surveys based on their preferences and areas of interest. Also, the panelists receive rewards and pay in exchange for their time and labor as provided by the research company.

3.2 Measures

The measurement scales comprised of 15 items that involved 4 latent constructs and 2 single items. The scales used to measure loneliness, psychological resilience, and social support were drawn from prior literature. *A three-item loneliness scale* that was created for survey research and is a condensed but comparable version of the complete UCLA loneliness scale (Hughes et al., 2004) was used to measure loneliness during the pandemic. *A condensed version of the Connor-Davidson resilience scale* (CD-RISC) (Campbell-Sills & Stein, 2007; Connor & Davidson, 2003), which evaluates psychological resources to deal with challenging circumstances like crises, was used to measure psychological resilience. *Brief Form of the Perceived Social Support Questionnaire* (F-SozU K-6) was used to measure social support (Kliem et al., 2015; Lin et al., 2019). *COVID-19 worry* was measured using a scale that was modified from previous studies that assessed pandemic-related worry (e.g., Broos et al., 2022; Mónaco et al., 2022; Okruszek et al., 2020; Ranta et al., 2020).

'Loot box purchasing' (Mean = 2.03, Standard Deviation = 1.13) and indebtedness (Mean = 1.17, Standard Deviation = 1.11) were measured using single items. 'Loot box purchasing' was measured with the following item "How have your online consumer habits changed during the coronavirus pandemic regarding the following services in comparison to your previous habits: Loot box purchases in digital games", with a 5-point response scale (1 = I have not purchased at all 2 = I have purchased less 3 = the same amount 4 = more to some degree 5 = considerably more)". The measure for indebtedness was adopted from Wang and Xiao (2009) and it used a 5-point semantic differential scale: "Which of the following statements best describe your indebtedness? Choose the option which best suits your situation: 1 = The payment of bills, payments, and/or payment instalments is not troublesome, and I am able to save money in the process; 2 = The payment of bills, payments, and/or payment instalments is not troublesome, however I am unable to save money in the process; 3 = The payment of bills, payments, and/or payment instalments is continuously challenging for me; 4 = I have received payment notices and have been subject to paying tardiness interest, as I have not had sufficient funds to complete payments when the needed payments have been due; and 5 = I have a compromised credit score/have been subject to reposition actions."

3.3 Nonresponse Bias and Common Method Bias

Nonresponse bias was assessed by comparing the national samples to the structure of the populations aged 18–75 years in Finland, Sweden, and UK. Except for a few categories that are less than 8% over- or underrepresented in the data, the distributions of age, gender, and region are generally within the margin of error when compared to the overall population (see Appendix 1). Therefore, nonresponse bias is unlikely an issue in our data set. Finland had a response rate of 26%, the UK had a response rate of 73%, and Sweden had a response rate of 27%. The standard deviation is 3.1% across all nations. Less than 3.7% of the values for each item in this study were missing.

The following steps were taken to reduce common method bias (CMB) (see Podsakoff et al., 2012). In order to prevent questions measuring the same dimension from being subsequent, the order of the questionnaire items was first mixed. Second, we alternated the scales' answer formats. These two methods were used to lessen the possibility that respondents would rely their following responses on their previous responses. Thirdly, we reduced the ambiguity in the phrases used to describe the items. This method was chosen because, if the questions are not straightforward and clear, respondents may find it difficult to comprehend the meaning of confusing statements and instead rely on systematic answer patterns. The Harman single factor a common latent factor (CLF) test (Harman, 1976; Podsakoff et al., 2003) was run to reveal any potential CMB interference with the results. Because the total variance extracted by one component was 27.34% and was below the 50% criterion in our data set, the findings of Harman's single factor CLF test indicate that CMB was likely not present.

3.4 Analysis Strategy

For the following reasons, we used partial least squares structural equation modeling (PLS-SEM) with SmartPLS 3.2.7 to test our hypotheses: 1) Our work was exploratory in the sense that it examined the multiple new relationships in a complicated model, and many of the variables were not normally distributed; and 2) Hair et al. (2017) emphasize that factor indeterminacy makes covariance-based SEM unsuitable for prediction purposes. Under these conditions, Hair et al. (2017) suggest PLS-SEM as the method to be used.

4 Analysis and Results

4.1 Assessment of Measurement Model

Because the factor loadings were all >.78 (see Table 2), the composite reliabilities were all .75, and the Cronbach's alphas were all >.85 (the suggested cut-off value is .70) (see Table 3), the construct measures demonstrated good reliability and validity (Hair et al. 2017). Also, all Variance Inflation Factors (VIF) were below the threshold value of 5, which indicates that there were no collinearity problems (Hair, Ringle & Sarstedt, 2011). In order to formally attain discriminant validity, the Fornell-Larcker criterion was applied (i.e., a latent variable should better explain the variance of its own indicators than the variance of other latent variables) (See Table 3). The Heterotrait-Monotrait (HTMT) Ratio was also examined (Appendix 2). All HTMT ratios were below the threshold value of.90 (Appendix 2), and the square root of the AVE of each latent variable outperformed the correlations with all the other latent variables (Table 3).

Table 2: Constructs and measures

Construct	Items	M	SD	FL	VIF
Loneliness *(1 = hardly ever, 2 = some of the time, 3 = often)*	*Thinking about the past year, how often have you felt that you lack companionship?*	1.86	.72	.85	1.82
	Thinking about the past year, how often have you felt left out?	1.77	.72	.89	2.03
	Thinking about the past year, how often have you felt isolated from others?	1.86	.73	.84	1.80
COVID-19 worry *(1 = not worried at all; 5 = extremely worried)*	*Concern on the health of your loved ones.*	3.69	1.16	.69	1.66
	Concern on your own mental wellbeing.	3.04	1.28	.93	2.04
	Concern on the mental wellbeing of your loved ones.	3.31	1.21	.91	2.59
Psychological resilience *(0 = not true at all; 4 = true nearly all of the time)*	*I can deal with whatever comes my way.*	2.55	.92	.78	1.63
	I believe I can achieve my goals, even if there are obstacles.	2.50	.97	.84	1.82
	Under pressure, I stay focused and think clearly.	2.41	1.01	.80	1.71
	I think of myself as a strong person when dealing with life's challenges and difficulties.	2.48	1.03	.82	1.76
Social support *(1 = not true at all; 5 = very true)*	*I receive a lot of understanding and security from others.*	3.69	1.16	.80	1.36
	If I need to, I can borrow something from friends or neighbors without any problems.	3.04	1.28	.80	1.56
	I know several people with whom I like to do things.	3.31	1.21	.84	1.63

Notes: M = Mean, SD = Standard Deviation, FL = Factor Loading, VIF = Variance Inflation Factor

Table 3: Construct reliability and validity and discriminant validity

	CA	CR	AVE	1	2	3	4	5	6	7	8	9
1	n/a	n/a	n/a	n/a								
2	.82	.88	.72	-.20	.85							
3	n/a	n/a	n/a	-.07	.03	n/a						
4	n/a	n/a	n/a	-.17	.17	.05	n/a					
5	n/a	n/a	n/a	-.12	.11	-.16	.05	n/a				
6	.83	.90	.74	-.32	.33	-.01	.13	.23	.86			
7	n/a	n/a	n/a	-.34	.11	.01	-.11	.17	.20	n/a		
8	.82	.88	.65	.14	-.12	.13	-.03	-.18	-.29	-.06	.81	
9	.74	.85	.66	.01	.07	.10	.05	-.17	-.28	.03	.40	.81

Notes: CA = Cronbach's Alpha, CR = Composite Reliability, AVE = Average Variance Extracted; n/a = not applicable; 1 = Age, 2 = COVID-19 Worry, 3 = EDUC = Education, 4 = Gender, 5 = Indebtedness, 6 = Loneliness, 7 = Loot box purchasing, 8 = Psychological resilience, 9 = Social support; Square roots of AVES on diagonal

Henseler (2014) suggested that the standardized root mean square residual (SRMR) should be used to assess the model fit in PLS-SEM because it does not give model fit statistics as covariance-based SEM does. In common factor models, values below .08 are regarded as a good fit. In our investigation, the SRMR value was only .05, and thus much below the threshold value.

4.1 Assessment of Structural Model

To test our hypotheses we first analyzed the direct associations. We used the bootstrapping technique with 5,000 re-samples to determine the relevance of the pathways. Table 4 displays the outcomes of the testing of our hypothesis.

Table 4: Results of hypotheses testing

Hyp	**DV**	**IV**	**β**	**f²**	**R²**
H1	Loneliness	COVID-19 worry	.35***	.15	.20
H2	Loot box purchasing	COVID-19 worry	ns		
H3	Loneliness	Social support	-.30***	.11	
H4	Loot box purchasing	Social support	.10***	.01	.05
H5	Psychological resilience	Social support	.40***	.19	.16
H6	Loot box purchasing	Loneliness	.21***	.04	
H7	Loot box purchasing	Psychological resilience	-.04**	.00	
H8	Indebtedness	Loot box purchasing	.16***	.02	.07
Cntl	Indebtedness	Age	-.07***	.00	
	Indebtedness	Gender	.06***	.00	
	Indebtedness	Education	-.17***	.03	

Notes: ns=not significant, **=p < .01, ***=p < .001; Hyp = Hypotheses, Cntrl = Control variables, DV = Dependent variable, IV = Independent variable

As Table 4 presents, the conceptual model for 20% of the variance in 'Loneliness', 5% of the variance in 'Loot box purchasing', 16% of the variance in 'Psychological resilience', and 7% of the variance in 'Indebtedness'. All of our hypotheses with the exception of H2 were supported (Table 4). Thus, only the hypothesised association between 'COVID-19 worry' and 'Loot box purchasing' was found not statistically significant. However, we also tested for mediation and discovered that there was a positive total effect between 'COVID-19 worry' and 'Loot box purchasing' (β = .21, p < .001), and a positive specific indirect effect from 'COVID-19 worry' to 'Loot box purchasing' through 'Loneliness' (β = .07, p < .001). Therefore, the association between 'COVID-19 worry' and 'Loot box purchasing' seems to be indirect and mediated through 'Loneliness'. With respect to H1, 'COVID-19 worry' was positively associated with 'Loneliness' (β = .35, p < .001). 'Social support' had a negative association with 'Loneliness', supporting H3 (β = -.30, p < .001). With respect to H4 and H5, 'Social support' had also positive associations with both, 'Loot box purchasing' (β = .10, p < .001) and 'Psychological resilience' (β = .40, p < .001). 'Loneliness' was positively associated with 'Loot box purchasing' (β = .21, p < .001), supporting H6. Contrary, ' Psychological resilience' had a negative association with 'Loot box purchasing' (β = -.04, p < .01), confirming H7. As hypothesized in H8, 'Loot box purchasing' was positivetively associated with 'Indebtedness' (β = .16, p < .001). The control variables also had significant associations to 'Indebtedness' which is the outcome variable of our model. However, the effec sizes of age and gender were smaller than the effect of 'Loot box purchasing' on 'Indebtedness'. Education had sligthly bigger effect on 'Indebtedness' than 'Loot box purchasing', but it did not efface the effect of 'Loot box purchasing'.

5 Conclusion and Discussion

This paper investigated loot box purchase behavior, indebtedness, and associated psychosocial factors during the first year of the COVID-19 pandemic. The findings supported most of the proposed hypotheses, and bring valuable insight into psychosocial and financial vulnerabilities in loot box buying behavior. Thus, the findings also serve as a ground for digital ethics issues related to the phenomena.

Psychological resilience was negatively associated with loot box purchasing, indicating that psychological resources can protect from the development of problem behaviors particuarly during crises situations (Brailovskaia & Margraf, 2022; Fletcher & Sarkar, 2013). COVID-19 worry, however, was not associated with increased loot box purchasing. Even though worrying about coronavirus was a common experience during the first year of the pandemic, with excessive worry making people vulnerable to problems such as addictive behaviors (Avena et al., 2021), our results did not support this idea in relation to increased loot box buying.

The findings regarding the role of loneliness and its association with loot box purchasing indicates that loneliness is a major risk to problematic monetary behaviors. Indeed, loneliness is associated with a myriad of harms and problems such as online addictive behaviors (Kuss et al., 2014) and problematic gambling (Sirola et al., 2023). However, given that social support was positively associated with loot box purchasing, it is important to understand the sources and quality of support. Even though meaningful social relationships are crucial for wellbeing, social support is not always beneficial and can promote or help to maintain harmful behaviors (Savolainen et al., 2022; Sirola et al., 2021). Given that social motives are a central aspect for team-based digital gaming and in-game purchases (Sirola et al, 2021), it is possible that social relationships and peer pressure inside the game might lead to excessive loot box purchasing. Individuals who are already socially excluded from meaningful in-person relationships, and thus prone to loneliness, may seek out meaningful social contacts via video games and video game communities.

The findings also revealed an association between loot box purchasing and indebtedness. However, it is likely that loot box purchasing is not the only reason for debt problems. For example, excessive loot box purchasing often co-occurs with problematic gambling (Delfabbro & King, 2020), and thus, underlying gambling problems might at least partially explain the association between loot box purchasing and debt problems. Nevertheless, loot box purchasing can add to one's financial strain particularly when problematic (Hing et al., 2022) and thus reinforce financial problems and vulnerabilities. Loot boxes are typically made attractive for gamers, and their mechanisms encourage players to make hasty purchase decisions, thus posing risks for vulnerable individuals in particular. These kinds of monetary mechanisms and their resemblance with mechanisms of gambling in digital games are an essential contributor to develop addictive or disordered gaming habits and consequent problems (Király et al., 2023).

Our findings higlight that ethical concerns that are related to gambling apply also to loot boxes. Policy makers and game companies should consider these ethical aspects when fostering responsible gaming, similarly to how legislation, regulation and the industry's own self-regulation is applied to gambling. These regulation practices would be crucial to protect particularly vulnerable players such as minors and individuals with psychosocial problems.

This study is not without limitations. First, data were cross-sectional and thus, causal interpretations between the studied variables are theoretical. Second, the self-reported nature of the survey items might be prone to biases. Third, the amount of money used in loot box purchasing, motives for buying loot boxes, or the particular games played were not asked, and these should be targeted by future studies. Additionally, the source of social support was not specified. Given that social support from other gamers or online networks is likely to work differently compared to support from one's family members, for example, future studies should also investigate different sources of social support in more detail. It would be important to study how other (excessive) purchase behaviors, such as excessive gambling, overlap with loot box spending and contribute to debt problems. Our study focused on three culturally relatively similar European countries; thus, more cross-national studies would provide insight on potential cultural differences in loot box purchasing and associated factors. Finally, longitudinal studies are needed to gain evidence on the causal mechanisms in loot box purchasing.

References

Achtziger, A. (2022). Overspending, debt, and poverty. Current opinion in psychology, 101342.

Avena, N. M., Simkus, J., Lewandowski, A., Gold, M. S., & Potenza, M. N. (2021). Substance use disorders and behavioral addictions during the COVID-19 pandemic and COVID-19-related restrictions. Frontiers in Psychiatry, 12, 653674.

Brady, A., & Prentice, G. (2021). Are loot boxes addictive? Analyzing participant's physiological arousal while opening a loot box. Games and Culture, 16(4), 419-433.

Brailovskaia, J., & Margraf, J. (2022). Addictive social media use during Covid-19 outbreak: Validation of the Bergen Social Media Addiction Scale (BSMAS) and investigation of protective factors in nine countries. Current Psychology, 1-19.

Broos, H. C., Llabre, M. M., Saab, P. G., Leite, R. O., Port, J. H., & Timpano, K. R. (2023). The relationship between health worry, work distress, and affective symptoms during the COVID-19 pandemic: The mediating role of hopelessness and helplessness. British journal of clinical psychology, 62(1), 10-27.

Campbell-Sills, L., & Stein, M. B. (2007). Psychometric analysis and refinement of the Connor–Davidson resilience scale (CD-RISC): validation of a 10-item measure of resilience. Journal of Traumatic Stress: Official Publication of The International Society for Traumatic Stress Studies, 20(6), 1019–1028.

Carey, P. A. K., Delfabbro, P., & King, D. (2022). An evaluation of gaming-related harms in relation to gaming disorder and loot box involvement. International Journal of Mental Health and Addiction, 20(5), 2906-2921.

Cohen, S., & Wills, T. A. (1985). Stress, social support, and the buffering hypothesis. Psychological Bulletin, 98(2), 310.

Connor, K. M., & Davidson, J. R. (2003). Development of a new resilience scale: the Connor–Davidson resilience scale (CD-RISC). Depression and Anxiety, 18(2), 76–82.

Delfabbro, P., & King, D. L. (2020). Gaming-gambling convergence: Evaluating evidence for the 'gateway'hypothesis. International Gambling Studies, 20(3), 380-392.

Dowling, N. A., Merkouris, S. S., Greenwood, C. J., Oldenhof, E., Toumbourou, J. W., & Youssef, G. J. (2017). Early risk and protective factors for problem gambling: a systematic review and meta-analysis of longitudinal studies. Clinical Psychology Review, 51, 109–124.

Drummond, A., & Sauer, J. D. (2018). Video game loot boxes are psychologically akin to gambling. Nature human behaviour, 2(8), 530-532.

Fletcher, D., & Sarkar, M. (2013). Psychological resilience. European Psychologist, 18(1).

Frank, L., Salo, M.; & Toivakka, A. (2015). Why Buy Virtual Helmets and Weapons? Introducing a Typology of Gamers. BLED 2015 Proceedings. 25. https://aisel.aisnet.org/bled2015/25

Hing, N., Rockloff, M., Russell, A. M., Browne, M., Newall, P., Greer, N., ... & Thorne, H. (2022). Loot box purchasing is linked to problem gambling in adolescents when controlling for monetary gambling participation. Journal of Behavioral Addictions.

Hughes, M. E., Waite, L. J., Hawkley, L. C., & Cacioppo, J. T. (2004). A short scale for measuring loneliness in large surveys: results from two population-based studies. Research on Aging, 26(6), 655–672.

Irie, T., Shinkawa, H., Tanaka, M., & Yokomitsu, K. (2022). Online-gaming and mental health: Loot boxes and in-game purchases are related to problematic online gaming and depression in adolescents. Current Psychology, 1-12.

Khazaal, Y., Chatton, A., Achab, S., Monney, G., Thorens, G., Dufour, M., & Rothen, S. (2017). Internet gamblers differ on social variables: a latent class analysis. Journal of Gambling Studies, 33(3), 881–897.

King, D. L., Delfabbro, P. H., Billieux, J., & Potenza, M. N. (2020). Problematic online gaming and the COVID-19 pandemic. Journal of Behavioral Addictions, 9(2), 184-186.

Király, O., Koncz, P., Griffiths, M. D., & Demetrovics, Z. (2023). Gaming disorder: A summary of its characteristics and aetiology. Comprehensive Psychiatry, 152376.

Kliem, S., Mößle, T., Rehbein, F., Hellmann, D. F., Zenger, M., & Brähler, E. (2015). A brief form of the Perceived Social Support Questionnaire (F-SozU) was developed, validated, and standardized. Journal of Clinical Epidemiology, 68(5), 551–562.

Kuss, J. D., Griffiths, M. D., Karila, L., & Billieux, J. (2014). Internet addiction: A systematic review of epidemiological research for the last decade. Current pharmaceutical design, 20(25), 4026-4052.

Lin, M., Hirschfeld, G., & Margraf, J. (2019). Brief form of the Perceived Social Support Questionnaire (F-SozU K-6): validation, norms, and cross-cultural measurement invariance in the USA, Germany, Russia, and China. Psychological Assessment, 31(5), 609.

Lussier, I., Derevensky, J. L., Gupta, R., Bergevin, T., & Ellenbogen, S. (2007). Youth gambling behaviors: an examination of the role of resilience. Psychology of Addictive Behaviors, 21(2), 165.

Mancini, A. D., & Bonanno, G. A. (2009). Predictors and parameters of resilience to loss: toward an individual differences model. Journal of Personality, 77(6), 1805–1832.

Mishra, S., Beshai, S., Wuth, A., & Refaie, N. (2019). Risk and protective factors in problem gambling: an examination of psychological resilience. International Gambling Studies, 19(2), 241–264.

Mónaco, E., Schoeps, K., Valero-Moreno, S., Castro-Calvo, J., Montoya-Castilla, I., Del Rosario, C., & Esparza, N. A. A. (2022). Cross-cultural validation of the worries about COVID-19 and its consequences scale (W-COV) in adolescents and young people. Archives of Psychiatric Nursing, 40, 158–166.

Nordmyr, J., & Forsman, A. K. (2020). A systematic review of psychosocial risks for gambling and problem gambling in the nordic countries. Health Risk & Society, 22(3–4), 266–290.

Oei, T. P., & Goh, Z. (2015). Interactions between risk and protective factors on problem gambling in Asia. Journal of Gambling Studies, 31(2), 557–572.

Okruszek, Ł., Aniszewska-Stańczuk, A., Piejka, A., Wiśniewska, M., & Żurek, K. (2020). Safe but lonely? Loneliness, anxiety, and depression symptoms and COVID-19. Frontiers in Psychology, 11, 579181.

Ranta, M., Silinskas, G., & Wilska, T. A. (2020). Young adults' personal concerns during the COVID-19 pandemic in Finland: an issue for social concern. International Journal of Sociology and Social Policy, 40, 1201–1219.

Räsänen, T., Lintonen, T., Tolvanen, A., & Konu, A. (2016). Social support as a mediator between problem behaviour and gambling: a cross-sectional study among 14–16-year-old finnish adolescents. BMJ Open, 6(12), e012468.

Savolainen, I., Sirola, A., Vuorinen, I., Mantere, E., & Oksanen, A. (2022). Online communities and gambling behaviors—A systematic review. Current Addiction Reports, 9(4), 400-409.

Scholes-Balog, K. E., Hemphill, S. A., Toumbourou, J. W., & Dowling, N. A. (2015). Problem gambling and internalising symptoms: a longitudinal analysis of common and specific social environmental protective factors. Addictive Behaviors, 46, 86–93.

Sirola, A., Nyrhinen, J., & Wilska, T. A. (2023). Psychosocial Perspective on Problem Gambling: The role of Social Relationships, Resilience, and COVID-19 Worry. Journal of gambling studies, 1-19.

Sirola, A., Kaakinen, M., Savolainen, I., & Oksanen, A. (2019). Loneliness and online gambling-community participation of young social media users. Computers in Human Behavior, 95, 136–145.

Sirola, A., Savela, N., Savolainen, I., Kaakinen, M., & Oksanen, A. (2021). The role of virtual communities in gambling and gaming behaviors: A systematic review. Journal of Gambling Studies, 37(1), 165-187.

Spicer, S. G., Nicklin, L. L., Uther, M., Lloyd, J., Lloyd, H., & Close, J. (2022). Loot boxes, problem gambling and problem video gaming: A systematic review and meta-synthesis. New Media & Society, 24(4), 1001-1022.

Vuorinen, I., Oksanen, A., Savolainen, I., Sirola, A., Kaakinen, M., Paek, H. J., & Zych, I. (2021). The mediating role of psychological distress in excessive gambling among young people: a four-country study. International Journal of Environmental Research and Public Health, 18(13), 6973.

Yokomitsu, K., Irie, T., Shinkawa, H., & Tanaka, M. (2021). Characteristics of gamers who purchase loot box: a systematic literature review. Current Addiction Reports, 8, 481-493.

Yücel, M., Whittle, S., Youssef, G. J., Kashyap, H., Simmons, J. G., Schwartz, O., & Allen, N. B. (2015). The influence of sex, temperament, risk-taking and mental health on the emergence of gambling: a longitudinal study of young people. International Gambling Studies, 15(1), 108–123.

Zendle, D., Meyer, R., & Over, H. (2019). Adolescents and loot boxes: Links with problem gambling and motivations for purchase. Royal Society Open Science, 6(6), 190049.

Zhang, N., Yang, S., & Jia, P. (2022). Cultivating resilience during the COVID-19 pandemic: A socioecological perspective. Annual Review of Psychology, 73.

Appendix 1 Sample Characteristics

FINLAND			SWEDEN			GREAT BRITAIN		
Gend.	**Smp**	**Pop.**	**Gend.**	**Smp**	**Pop.**	**Gend.**	**Smp**	**Pop.**
Man	50 %	50 %	Man	50 %	50 %	Man	49 %	49 %
Woman	50 %	50 %	Woman	50 %	50 %	Woman	51 %	51 %
Age	**Smp**	**Pop.**	**Age**	**Smp**	**Pop.**	**Age**	**Smp**	**Age**
18–22	8 %	8 %	18–22	8 %	8 %	18–22	6 %	8 %
23–35	26 %	23 %	23–35	24 %	25 %	23–35	30 %	24 %
36–55	38 %	34 %	36–55	40 %	36 %	36–55	38 %	37 %
56–75	29 %	36 %	56–75	28 %	31 %	56–75	26 %	30 %
Region	**Smp**	**Pop.**	**Region**	**Smp**	**Pop**	**Region**	**Smp**	**Pop**
S.Fin.	46 %	52 %	Mid-Nrdlnd	4 %	4 %	East England	9 %	11 %
E.Fin.	11 %	11 %	NCentral Sweden	9 %	8 %	London	14 %	15 %
W.Fin	31 %	25 %	Småland islands incl.	9 %	8 %	Midlands	16 %	10 %
N.Fin	12 %	12 %	Stockholm	21 %	23 %	Yorkshire and Humber	12 %	9 %
			S. Swe	15 %	15 %	Northwestern	11 %	12 %
			W.Swe	19 %	20 %	N.Ireland	3 %	3 %
			E.Central Sweden	17 %	17 %	Scotland	8 %	9 %
			Uppr. Norland	6 %	5 %	SE.England	15 %	16 %
						SW.England	8 %	9 %
						Wales	5 %	5 %

Appendix 2 The Heterotrait-Monotrait Ratio

	Age (1)	2	3	4	5	6	7	8
COVID-19 Worry (2)	.19							
Education (3)	.07	.04						
Gender (4)	.17	.18	.04					
Indebtedness (5)	.12	.10	.16	.05				
Loneliness (6)	.35	.35	.01	.15	.25			
Loot box purchasing (7)	.34	.10	.01	.11	.17	.22		
Resilience (8)	.16	.13	.14	.03	.20	.36	.07	
Social support (9)	.03	.13	.12	.06	.19	.35	.04	.51

How Do QR Codes Enhance Customer Experience? Omnichannel Customer Experiences in a Brick-and-Mortar Fashion Store

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In this qualitative study, we investigate how customers perceive QR codes enhancing their customer experience (CX) in the brick-and-mortar (B&M) store environment. Introducing QR codes to B&M stores is a part of the larger phenomenon of retailers creating omnichannel CXs by utilizing digital and cyber-physical elements in B&M stores. To collect data from real customers' CXs, we displayed QR codes in a Finnish fashion brand's B&M store and interviewed customers who had authentically visited the store. The QR codes displayed in the store were linked to a product information page on the brand's online store, a brand ambassador's Instagram posts, and an online survey. The data consist of 15 individual semi-structured thematic interviews of customers aged under 50 years. By conducting qualitative content analysis, we found six main advantages (i.e., interestingness, informativeness, usability, attractiveness, interaction, and innovativeness) and 14 subgroups of QR codes' advantages in enhancing the CX.

Keywords:
QR codes,
brick-and-mortar,
omnichannel,
customer experience,
store environment,
cyber-physical,
B&M,
retail

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1 Introduction

The advancements in information and communication technologies, such as smartphones and Quick Response (QR) codes, enable today's consumers to gain additional information on products during their brick-and-mortar (B&M) store visits. According to Briedis et al. (2020), customers prefer omnichannel customer experiences, where they can seamlessly utilize physical and digital channels (Rigby, 2011). During their B&M store visits, it is more common for customers to use the competing retailers' online channels than the online channels of that same B&M retailer (Spaid et al., 2019). For B&M retailers, this means losing potential customers due to showrooming (i.e., gathering information offline but comparing options and purchasing online) as well as online shopping. Thus, B&M retailers have begun to include digital and cyber-physical elements in store environments to offer unique customer experiences in B&M stores (Lemon & Verhoef, 2016). For example, QR codes (Yoon & Kim, 2014), robot assistants, and smart mirrors (Sheth, 2021) have been implemented in B&M store environments. Sheth (2021) presents that "B&M retailers can not only survive but also thrive by fusion of physical and digital [worlds]".

QR codes have been shown to enhance customer experience (CX) in online shopping (Hossain et al., 2018) and shopping in general (Albăstroiu & Felea, 2015), but there is a research gap in how QR codes can enhance CX in B&M fashion stores. The topic is important from both theoretical and practical perspectives because enhancing the CX in B&M stores with omnichannel elements is recommended (Sheth, 2021), but the research on QR codes' potential in offering additional information, product reviews, and relevant social media content for B&M fashion store customers is still scarce (Albăstroiu & Felea, 2015). Also, research on QR codes' technological attributes (Kim & Yoon, 2014), consumer acceptance (Kim & Woo, 2016; Kim et al., 2014), and efficiency in providing product information (Rotsios et al., 2022) has been called for. According to Albăstroiu and Felea (2015), QR codes have usually been studied from a technology use perspective, such as the design and functionality of digital technologies in B&M stores (Zimmermann et al., 2022). However, there is also a research gap in studying how also the mere presence of QR codes can enhance the CX as a physical in-store stimulus (Bitner, 1992).

Therefore, in this qualitative study, we investigate how customers perceive QR codes enhancing their CX in a B&M store. The data collection was conducted by displaying QR codes within a Finnish B&M fashion store and, after that, interviewing the customers who had visited the store. In the next section, we present the relevant research on CX in omnichannel B&M store environments and on QR codes. In the third section, we introduce our QR code intervention case, research data, and methods used. In the fourth section, we present the findings and discussion of this study. Finally, in the fifth section, we conclude with the conclusion, theoretical and practical implications, limitations of the study, and our suggestions for future research.

2 Theoretical Background

2.1 Omnichannel CX in B&M Store Environments

CX consists of customers' subjective responses, feelings, and interpretations (Gentile et al., 2007). It has been researched from many overlapping dimensions (Holkkola et al., 2022a), such as cognitive and physical dimensions (Verhoef et al., 2009). The cognitive dimension includes customers' curiosity (Schmitt, 1999) and experiences of flow (Novak et al., 2000). The physical dimension is traditionally associated with offline elements, such as temperature, odor, furnishing, and signage (Bitner, 1992). There are plenty of studies on the physical dimension of CX in B&M stores, but as retailers have introduced digital and cyber-physical elements into their B&M stores, a new wave of CX research focuses on these novel elements (Zimmermann et al., 2022). To stand out in this omnichannel era, Parise et al. (2016) advise that new digital and cyber-physical elements should be introduced to B&M stores to create immersive, distinctive (Briedis et al., 2020), and customized CXs (Zimmermann et al., 2022). For instance, virtual mirrors are described as "something the customers will remember" (Parise et al., 2016). These kinds of elements can enhance CX by immersion and flow among customer touchpoints, which will positively affect customer behavior and attitudes (Parise et al., 2016).

For example, an augmented reality (AR) assistive shopping mobile app was found to increase informativeness and usefulness in CX (Zimmermann et al., 2022). Informativeness consists of good and relevant product information (Hausman and Siekpe, 2009), such as product availability and price comparison information in a store (Parise et al., 2016). Usefulness consists of perceived shopping performance, productivity, and effectiveness (Hausman & Siekpe, 2009). In addition, digital and cyber-physical elements, such as remote experts and digital assistants, can create highly immersive engagement with products as they can build a narrative behind the product simultaneously during the B&M store visit. This will result in a closer connection between the consumer and the brand, such as return visits and loyalty to the brand (Parise et al., 2016). Digital and cyber-physical elements can also enhance CX with personalization and interactivity (Parise et al., 2016). Interactivity gives consumers a sense of control as they can have an active part in engaging with the brand (Klein, 2003).

2.2 QR Codes

QR codes are two-dimensional barcodes that can hold more information than one-dimensional Universal Product Codes (UPC) and can be scanned with a device that has a camera, a QR code reader software, and an Internet connection (Crompton et al., 2012). QR codes were first used in the auto industry (Denso Wave, 2022) and have since become common in many areas. QR code usage increased by 98% from 2018 to 2020 and is predicted to cover 80% of check-out services, orders, and payments by 2024 (Scanova Blog, 2022). In prior QR code research, customers have shown positive and negative attitudes toward and experiences with QR codes. Negative experiences include, for example, privacy concerns towards QR codes (Okazaki et al., 2012) and irritation from mobile tools usage in a B&M store (Zimmermann et al., 2022). However, many positive customer perceptions, attitudes, and effects of QR codes have also been found in prior research.

Consumers have perceived QR codes to enhance their CX in multiple contexts (Albăstroiu & Felea, 2015) and in an imaginary B&M store scenario (Kjeldsen et al., 2023). In a smart shopping context, Kim and Yoon (2014) studied QR code virtual grocery and fashion stores that could be visited by scanning a QR code on the screen in South Korean subway stations. They identified the technological attributes of QR codes, including ubiquity, instant interactivity, digital signage, and wireless infrastructure, which were valued by fashion shoppers. Also, B&M grocery store customers found food traceability QR codes informative, useful, easy to use, and a positive invention (Kim & Woo, 2016). Yoon and Kim (2014) found QR codes important for B&M retailers' multichannel strategies in integrating online channels into B&M stores, as QR codes can offer customers additional and abundant information and channel integration. In the advertising context, young consumers were suggested to value the informativeness of QR codes as this perceived benefit strongly predicted their intention to scan them (Jung et al., 2012). In educational work, in turn, teachers perceived QR codes as being fun, interesting, engaging, attractive, enjoyable, and a new way of learning (Ali et al., 2017). Similarly, younger consumers found QR codes attractive and useful (Ertekin & Pelton, 2015). According to Dou and Li (2008), QR codes' advantages for customers include being less intrusive and more engaging communication tools than shortcodes and image codes. QR codes have also proven to be a good tool from a cognitive perspective, and in brands' communication, they have been suggested to arise customers' curiosity (Srinounpan et al., 2020). Curiosity was also reported as one of the main reasons to scan QR codes for Polish consumers (Nogieć, 2017).

3 Methodology

To collect data from real customers in an authentic QR code setting, we displayed QR codes inside a B&M factory store of a well-known Finnish fashion brand. The QR codes were printed with suitable texts and pictures in A4 and smaller papers, laminated, and displayed inside the store from May 2022 to September 2022. Three different sets of QR codes were used and placed in the store. The first set of QR codes (cf. Appendix 2) was placed with a product, anorak jackets, and their landing page was the product information page on the brand's online store. The second set of QR codes directed to a brand ambassador's Instagram posts, where she promoted the brand's selected clothes, also displayed on a separate clothes rack in the B&M store. Thus, both the online and social media channels of the brand were utilized in providing additional information and inspiration for customers. The third set of QR codes directed customers to our online survey where one could also volunteer for individual interviews and be rewarded with a prize (a canvas bag). This set of QR codes was also printed and handed with one's purchases by store personnel.

During the time the QR codes were on display, we recruited participants for individual interviews with the third set of QR codes as well as pen-and-paper surveys in the B&M store. Due to our target group, B&M store customers under 50 years of age were eligible to participate in the interviews. This was because using mobile devices for searching information in B&M stores is common for consumers aged under 50 years and significantly less common for older consumers (Holkkola et al., 2022b) who are suggested to have lower self-efficacy in mobile and omnichannel shopping (Makkonen et al., 2022). Similarly, Ertekin and Pelton (2015) excluded consumers born in the 1960s or earlier from their QR code study. For a data collection method, semi-structured individual thematic interviews were chosen since we wanted a profound understanding of CXs. We used semi-structured interviews as they allow more free discussion and enable additional questions (Myers & Newman, 2007). Before the interviews, we conducted a test interview to try out our interview framework. The interviews were conducted in September 2022. Due to our recruiting technique, the participants were the brand's real customers who had visited the B&M store while the QR codes were on display. The number of interviews was determined by saturation (Fusch & Ness, 2015). The participants (referred to as Participants 1–15: P1–P15) consisted of twelve females and three males who were 23–42 years old (for details, see Appendix 1). Instead of statistically representative results, the qualitative approach of this study aims to gain an in-depth understanding of the customers' perceptions and was chosen because it is suitable for studying experiences and phenomena with little prior research.

The interviews were held remotely via Microsoft Teams. The average duration of the interviews was 58 minutes. The interview themes covered omnichannel behavior, previous experiences with QR codes, the QR codes in the case B&M store, and customer engagement with the case brand. During the theme of QR codes in the case B&M store, we showed the participants pictures of the B&M store with QR codes (Appendix 2) to make it easier for them to share their experiences. The interviews were recorded and transcribed. In the analysis, we used qualitative content analysis in a data-driven manner because of the experimental nature of this study. As tools, the ATLAS.ti software and Microsoft Word were utilized for coding the data inductively with two coding cycles (Gioia et al., 2013). This resulted in 14 codes which were used as 14 subgroups of the findings, respectively. These 14 subgroups could ultimately be classified under six broader themes that form the main findings and are presented in the next section. The six themes and the 14 subgroups are also displayed in Figure 1 in the fifth section.

4 Findings and Discussion

In the participants' CXs in the B&M environment, we found six main advantages of QR codes: interestingness, informativeness, usability, attractiveness, interaction, and innovativeness. Next, we present these in relation to earlier research. The citations have been translated from Finnish to English.

Interestingness. Firstly, the displayed QR codes were found interesting and aroused the participants' curiosity for multiple reasons. Some perceived them as new technology, and others found them curious in the B&M environment. The participants were interested in "where the QR code leads and what it brings me" (P14). This is consistent with the findings of Srinounpan et al. (2020) and Nogieć (2017) and supports Ali et al.'s (2017) school context findings of QR codes being perceived as interesting and engaging. P12 described how QR codes are like "mysteries" because one cannot see their contents from the outside. All in all, QR codes attracted attention and got some participants to scan them for fun.

"I think QR codes in the store bring something new and interesting to you, like 'hey, what's this about'. Probably because they are still quite a new thing for me that I haven't quite got utilizing yet." – Female, 29 (P5)
"Even though the anoraks were not relevant to me, I did notice the QR codes when I passed by and checked what the trick here is." – Female, 32 (P14)

For some, specifically the B&M environment enabled scanning QR codes out of pure curiosity since it was perceived as a safe environment for digital experimentation. This was because information security of a B&M store's QR codes was perceived as more reliable compared to, for example, renting electric scooters P14 mentioned as an example. This finding is in line with Okazaki et al.'s (2012) QR code privacy concern findings in urban outdoor spaces. Thus, the participants felt safe scanning the QR codes in the B&M environment and perceived this as fun and entertaining, consistent with Zimmermann et al.'s (2022) findings on digital elements creating more entertaining CXs. P14 describes her experience as follows: "I thought it was fun to be able to search on their pages how the product looks on a model. That was quite a nice idea".

Informativeness. In addition to their interestingness, QR codes were scanned because the participants valued information. The participants found QR codes with additional information useful and thought that they contribute positively to their CX in B&M, which is consistent with Zimmermann et al.'s (2022) digital B&M store element findings. The participants wanted to get information before the purchase decision, for example, on the materials, caretaking instructions, available colors and sizes, and sustainability. This finding is also consistent with studies on other product groups, such as food traceability QR codes that customers also found informative (Kim & Woo, 2016). For example, P14 describes her wishes for more information as follows: "While shopping, I thought that these QR codes could be on all the products, so that you could search available colors of those shorts, for example, as they all weren't on display."

Additional information was valued, and it also mattered where this information was obtained from. It was remarkable that the participants valued that the QR codes led to the brand's online store and the integration of the online and offline channels. The participants perceived linking the brand's online store to the B&M store as "smart" (P2) and "fun" (P14), and for some, it was a nice surprise.

"I thought that the QR code would just lead to some additional information page, I somehow didn't expect it to go on the brand's website. I expected maybe some kind of an additional page with a menu, but it was very nice that it led to the website." – Female, 32 (P14)

Like P14, the participants described their positive thoughts about this online store linkage. Indeed, improving the flow among customer touchpoints is suggested to be important in the omnichannel era (Parise et al., 2016). The participants perceived connecting the online store to the B&M store with QR codes as a good idea to advertise and remind customers of this channel's existence.

"I don't think the [brand's] webpage has otherwise been very advertised. There could be something or someone near the cash desk mentioning the webpage, but I'd say they don't advertise it in the stores." – Female, 42 (P9)

Usability. QR codes were found usable and useful since they were perceived as easy to use and quick and enabled independent shopping. Perceived ease of use is consistent with the findings of Kim and Woo (2016) and was explained by many reasons. Using a smartphone in the B&M environment "felt easy because you're so used to fiddling with your phone" (P2) and using the phone's QR code reader felt easier than going to the online store by typing the web address to the web browser. The ease of use of QR codes is identified also by Kim and Woo (2016). QR codes in the B&M environment were considered "a simplified way to find somewhere" (P8). Even though the participants did not primarily associate QR codes with B&M stores, many were already familiar with QR codes.

"It's very easy because via your camera, the QR code leads you directly to the page, and you don't need to type any addresses. So, it's handy in that sense." – Female, 24 (P13)

QR codes were also perceived as quick. Similarly, in Hausman and Siekpe's (2009) model, shopping effectiveness is one aspect of digital shopping elements' usability. Many participants emphasized the quickness of the direct linkage that QR codes enabled. The participants felt that the brand is striving to make information search quick and easy, contributing positively to their CX.

"If the QR code leads me directly to the product page to get more information, it's no doubt faster than if I started googling that additional information on the Internet." – Female, 30 (P2)

The usability of QR codes was also praised because of the enabled independence. Some participants preferred to not socialize with salespersons or send messages to their friends when shopping. Instead, their smartphone was their shopping assistant, which they even used to "signal the salesperson that you want to be in peace" (P2). In contrast to 50-year-old and older consumers who are unlikely to utilize mobile phones while in a B&M store (Holkkola et al., 2022b), using a mobile phone in B&M stores felt natural for these independent shoppers.

"I know that the salespersons are happy to help, but if you're like me, who wants to look for information yourself before asking, then QR codes are an easy way to do that." – Female, 32 (P14)

Attractiveness. The participants perceived that QR codes contribute to the B&M environment by making it look attractive. This was due to QR codes being visually compact solutions as digital signage (Kim & Yoon, 2014). Similarly, under-50-year-old consumers (Ertekin & Pelton, 2015) and teachers (Ali et al., 2017) found QR codes attractive. In addition to their compactness, the participants perceived QR codes as a natural addition to a B&M store and, similarly to Dou and Li's (2008) findings, seeing them around was not found intrusive for most of the participants.

The participants perceived QR codes as compact tools for tastefully sharing additional information. They did not want the store environment to be visually crammed with product information, nor did they want the QR codes to be "the main point" (P10) in the store environment. Instead, the participants valued "a clear overall appearance" (P14). For example, P7 found QR codes "pleasant", "restrained", "simple", and "straightforward". QR codes as a space solution were seen to also respect those who did not need additional information.

"Compared to, say, big posters with a lot of information, using QR codes is a simpler and more tasteful way, so that the information is available for those who want it." – Female, 33 (P12)
"QR codes make my store experience more comfortable because the store is not flooded from every corner with information, but it's offered in a restrained way." – Male, 24 (P7)

In addition to compactness and respectfulness, the participants considered QR codes to be a natural element in the B&M environment. Many said that QR codes fit well into the store environment and are displayed nicely. P12 describes how "it somehow seemed natural that 'ah, there are QR codes here', so if someone needs, they can use them". Although many had not seen QR codes in B&M stores before, the participants mostly accepted this technology in the B&M environment.

"The whole store had been renovated since my last visit, it was overall much fresher than before. So, I just thought that those [QR] codes are now part of it." – Female, 30 (P2)

Interaction. QR codes, especially the ones that led to our online survey, were associated with the brand actively wanting to interact with its customers. P2 describes how she seized the opportunity to interact with the brand in the B&M store: "I thought that since I like the brand, I want to give feedback and then try to influence it." Similarly, Klein (2003) found that interactivity gives consumers a sense of control as they can have an active part in engaging with the brand. According to Parise et al. (2016), digital and cyber-physical elements can also enhance CX in B&M stores with their interactivity. Indeed, QR codes were considered a good tool to interact with customers, since "many certainly have a phone with them" (P14) when visiting a B&M store. QR codes are found as engaging communication tools also in Dou and Li's (2008) study. "Even though not being a super customer from [the brand's] perspective", P8 described the positive atmosphere the QR codes created for her during the B&M store visit:

"The store environment looks a little different when those QR codes are there. It arises the thought that the place is not only for buying but that the brand also wants to know something about the customers' thoughts … The atmosphere of being interested in the customers' thoughts is created there." – Female, 33 (P8)

Innovativeness. QR codes were perceived to enrich the CX in a B&M store and talk about the brand's development. The participants valued that, besides traditional B&M shopping behaviors, they could get to know the products in new and enriched ways. Similarly, Ali et al. (2017) found that teachers perceived QR codes as a new way of learning, and Parise et al. (2016) found that rememberable digital elements improve CX. As P6 put it, "the brand bringing new ways of presenting information" was appreciated. For example, the participants found it creative that they could see how the products look on a model by scanning the QR code. These additional cyber-physical elements were perceived as "quite a good addition" (P2) and to have a positive influence on the whole brand.

"Just by moving your thumb, you could get the same thing done as by flipping through big clothes racks and going around the store, so [with the QR codes] you got a quick overview of what they have here." – Male, 24 (P7)

This kind of digital enrichment was perceived as a sign of the brand's development. For the participants, QR codes symbolized modernity, development, pioneering, and alternativeness. Similarly, QR codes are found to be perceived as a positive invention (Kim & Woo, 2016). Bringing QR codes to the B&M environment was associated with the B&M store and the whole brand being developed, in order "to keep up with the times" (P2). QR codes positively affected the store environment, which, in turn, affected the image of the whole brand.

"Those QR codes as a final touch to the new look of the renovated store, it seems that the whole store has generally moved into a new era with a more modern touch. It certainly is a good thing." – Female, 24 (P13)

"The QR codes affect the brand image. They tell of the desire to develop something. Like [the brand] is not stuck in place but is constantly trying to reform their business model." – Female, 25 (P10)

5 Conclusion, Limitations, and Future Research

In this qualitative study, we investigated how QR codes can enhance CX in B&M stores and we found six main advantages: interestingness, informativeness, usability, attractiveness, interaction, and innovativeness. The findings are summarized in detail in Figure 1 below.

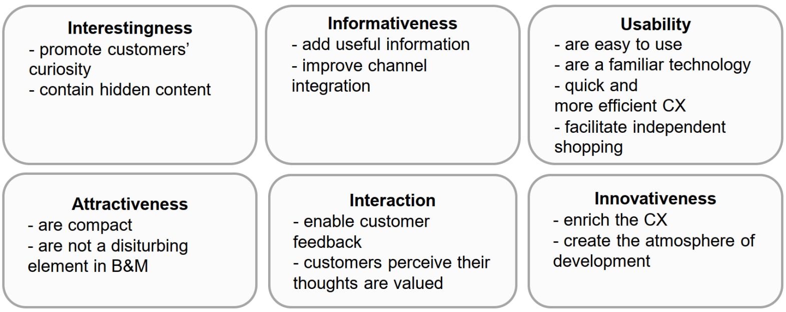

Figure 1: Summary of the findings on how QR codes enhance CX in B&M stores

In conclusion, this study addresses the research gap of the multiple ways how QR codes can enhance CX in fashion B&M environments. As a novel finding, we suggest that independent engagement with the products enabled by QR codes enhances some B&M customers' CX. This study also shows that channel integration provided by QR codes enhances CX because, in line with Jung et al. (2012) and Kjeldsen et al. (2023), customers value additional information. In line with Kim and Woo (2016), engaging with the products and the brand is perceived as easy and quick with QR codes, making them usable tools that enable customer-company interaction (Klein, 2003). This results in enriched and yet effortless CX in B&M. QR codes also enhance the cognitive dimension of CX, as they arise curiosity among B&M store customers, which is in line with Srinounpan et al. (2020). Consistent with Nogieć (2017), it seems that the interestingness of QR codes stems partly from their novelty in B&M store environments. Additionally, the curiosity about QR codes is not likely to disappear soon due to their appearance which contains hidden information. In addition, bringing QR codes to the B&M environment resulted in positive associations with the whole brand, such as perceived development and perceived openness towards customer feedback enabled by QR codes as easy interaction possibilities (Kim & Yoon, 2014). These brand-related positive associations during the B&M store visit contribute to CX (Parise et al., 2016) and, ultimately, may deepen the brand relationship (Paananen et al., 2022a; 2022b). In sum, we suggest that the presence of QR codes expands the physical B&M store environment practically into an omnichannel environment preferred by customers (Briedis et al., 2020). As a practical implication, we recommend B&M retailers to offer additional information with QR codes because of the identified six advantages. Integrating online channels with QR codes into B&M stores (Yoon & Kim, 2014) may also reduce the loss of today's and tomorrow's customers to competing retailers' online channels (Spaid et al., 2019).

Finally, this study does not come without limitations. Firstly, studying experiences is always situational, so the generalizability of the findings to other B&M stores and other cultural contexts needs future research with different product groups and in different countries. Secondly, this study focuses on how QR codes enhance CX, so research on QR codes' possible negative contributions to CX is also needed. In addition, regardless of whether QR codes are used, it seems that their mere presence in the B&M store environment affects CX, which needs more research. For quantitative research on QR codes, interestingness, informativeness, usability, attractiveness, interaction, and innovativeness could be operationalized as empirically measurable constructs. We also call for more holistic omnichannel research on CX that recognizes digital and cyber-physical elements' tangible and intangible interfaces and consequences in B&M environments.

References

Albăstroiu, I., Felea, M. (2015). Enhancing the shopping experience through QR codes: the perspective of the Romanian users. Amfiteatru Economic, 17(39), 553–566

Ali, N., Santos, I., Areepattamannil, S. (2017). Pre-service Teachers' Perception of Quick Response (QR) Code integration in Classroom Activities. TOJET the Turkish online journal of educational technology, 16(1).

Bitner, M. J. (1992). Servicescapes: The Impact of Physical Surroundings on Customers and Employees. Journal of Marketing, 56(2), 57–71.

Briedis, H., Kronschnabl, A., Rodriguez, A. and Ungerman, K. (2020). Adapting to the Next Normal in Retail: the Customer Experience Imperative. McKinsey & Company.

Crompton, H., LaFrance, J., & van't Hooft, M. (2012). QR Codes 101. Learning and leading with technology, 39(8), 22.

Denso Wave (2022). QR development story. https://www.denso-wave.com/en/technology/vol1.html (2022), Accessed 3rd March 2023.

Dou, X., Li., H. (2008). Creative Use of Qr Codes in Consumer Communication. International Journal of Mobile Marketing, 3(2), 61–67.

Ertekin, S., Pelton, L.E. (2015). An exploratory study of consumer attitudes towards QR code reader applications. In Kubacki, K. (Ed.), Ideas in Marketing: Finding the New and Polishing the Old. Springer, Cham, 185–191.

Fusch, P. I., Ness, L. R. (2015). Are We There Yet? Data Saturation in Qualitative Research. The Qualitative Report, 20(9), How To Article 1, 1408–1416.

Gentile, C., Spiller, N., Noci, G. (2007). How to Sustain the Customer Experience: An Overview of Experience Components that Co-create Value With the Customer. European Management Journal, 25, 395–410.

Gioia, D. A., Corley, K. G., Hamilton, A. L. (2013). Seeking Qualitative Rigor in Inductive Research: Notes on the Gioia Methodology. Organizational Research Methods, 16(1), 15–31.

Hausman, A.V., Siekpe, J.S. (2009). The effect of web interface features on consumer online purchase intentions. Journal of Business Research, 62(1), 5–13.

Holkkola, M., Frank, L., Kemppainen, T., Paananen, T., Luhtanen, V. (2022a). The role of sustainability in online customer experiences : a qualitative study on female fashion shoppers. In MCIS 2022 : Proceedings of the 14th Mediterranean Conference on Information Systems. Association for Information Systems.

Holkkola, M., Nyrhinen, J., Makkonen, M., Frank, L., Karjaluoto, H., Wilska, T.-A. (2022b). Who are the showroomers? Socio-demographic factors behind the showrooming behavior on mobile devices. In A. Pucihar, M. Kljajić Borštnar, R. Bons, A. Sheombar, G. Ongena, & D. Vidmar (Eds.), Proceedings of the 35th Bled eConference: Digital restructuring and human (re)action. 113–128. University of Maribor Press.

Hossain M. S., Zhou X, Rahman M. F. (2018). Examining the impact of QR codes on purchase intention and customer satisfaction on the basis of perceived flow. International Journal of Engineering Business Management 10.

Jung, J., Somerstein, R., Kwon, E. (2012). Should I scan or should I go?: Young consumers' motivations for scanning QR code advertising. International Journal of Mobile Marketing, 7(3).

Kim, E. Y., Yoon, N. (2014). Perceived QR code technological attributes in the smart shopping context. Journal of global fashion marketing, 5(4), 297–307.

Kim, Y. G., Woo, E. (2016). Consumer acceptance of a quick response (QR) code for the food traceability system: Application of an extended technology acceptance model (TAM). Food Research International, 85, 266–272.

Kjeldsen, K., Nodeland, M., Fagerstrøm, A., Pawar, S. (2023). The relative impact of QR codes on omnichannel customer experience and purchase intention. Procedia Computer Science 219, 1049–1056.

Klein, L. (2003). Creating virtual product experiences: The role of telepresence Journal of Interactive Marketing, 17(1), 41–55.

Lemon, K.N., Verhoef, P.C. (2016). Understanding customer experience throughout the customer journey. Journal of Marketing, 80(6), 69–96.

Makkonen, M., Nyrhinen, J., Frank, L., Karjaluoto, H. (2022). The Effects of General and Mobile Online Shopping Skilfulness and Multichannel Self-Efficacy on Consumer Showrooming Behaviour . In A. Pucihar, M. Kljajić Borštnar, R. Bons, A. Sheombar, G. Ongena, & D. Vidmar (Eds.), 35th Bled eConference : Digital Restructuring and Human (Re)action, 479–494. University of Maribor.

Myers, M. D., Newman, M. (2007). The qualitative interview in IS research: Examining the craft. Information and Organization, 17(1), 2–26.

Nogieć, J. (2017). Sposoby postrzegania i wykorzystywania fotokodów przez klientów indywidualnych. Marketing i Zarządzanie, 47(1), 281–290.

Novak, T. P., Hoffman, D. L., Yung, Y. F. (2000). Measuring the Customer Experience in Online Environments: A Structural Modeling Approach. Marketing Science 19(1), 22–42.

Okazaki, S., Li, H., Hirose, M. (2012). Benchmarking the Use of QR Code in Mobile Promotion. Journal of Advertising Research, 52(1), 102–117.

Paananen, T., Frank, L. & Kemppainen, T. (2022a). Customer-brand relationships in the context of digital brands. In A. Pucihar, M. Kljajić Borštnar, R. Bons, A. Sheombar, G. Ongena, & D.

Vidmar (Eds.), 35th Bled eConference : Digital Restructuring and Human (Re)action (pp. 495-510). Maribor: University of Maribor Press.

Paananen, T., Kemppainen, T., Frank, L., Holkkola, M., Mali, E. (2022b). Reinforcement of brand relationships in an omnichannel environment: A qualitative study on clothing shopping. In Proceedings of the 14th Mediterranean Conference on Information Systems (MCIS).

Parise, S., Guinan, P., Kafka, R. (2016). Solving the crisis of immediacy: How digital technology can transform the customer experience. Business Horizons 59(4), 411–420.

Rigby, D. (2011). The Future of Shopping. Harvard Business Review, 89(12), 64–75.

Rotsios, K., Konstantoglou, A., Folinas, D., Fotiadis, T., Hatzithomas, L., Boutsouki, C. (2022). Evaluating the Use of QR Codes on Food Products. Sustainability (Basel, Switzerland), 14(8), 4437.

Scanova Blog. (2023). QR Code Statistics 2023: Up-To-Date Numbers On Global QR Code Usage Retrieved March 8, 2023 from https://scanova.io/blog/qr-code-statistics/#: :text=Also%2C%20according%20to%20a%20recent,9.76%20Million%20scans%20in%202018

Schmitt, B.H. (1999). Experiential Marketing. Journal of Marketing Management 15(1/3), 53–67.

Sheth, J. (2021) Future of brick and mortar retailing: how will it survive and thrive? Journal of Strategic Marketing, 29(7), 598–607.

Spaid, B., O'Neill, B., Ow, T. (2019). The upside of showrooming: How online information creates positive spill-over for the brick-and-mortar retailer. Journal of Organizational Computing and Electronic Commerce, 29(4), 294–315.

Srinounpan, B., Srinounpan, C., Sumethokul, P., Patwary, A. K. (2020). The Application of QR Code Technology to Create the Value-Added Products for The Baan Klong Peek Neur Beehive Community Enterprise Groupat Tambon Suankhan, Nakhon Si Thammarat Province. Systematic Reviews in Pharmacy, 11(7), 519–528.

Verhoef, P. C., Lemon, K. N., Parasuraman, A., Roggeveen, A., Tsiros, M., Schlesinger, L. A. (2009). Customer Experience Creation: Determinants, Dynamics and Management Strategies. Journal of Retailing 85(1), 31–41.

Yoon, N., Kim, E. Y. (2014). An Exploratory Study of QR Code Utilization for Retailers' Multichannel Strategy. Fashion & Textile Research Journal, 16 (5), 730–744.

Zimmermann, R., Mora, D., Cirqueira, D., Helfert, M., Bezbradica, M., Werth, D., Weitzl, W.J., Riedl, R., Auinger, A. (2022). Enhancing brick-and-mortar store shopping experience with an augmented reality shopping assistant application using personalized recommendations and explainable artificial intelligence. Journal of Research in Interactive Marketing.

Appendix 1: Information on the participants

	Gender	Age	Status	Interview duration (min)
P1	Female	37	Employee	43
P2	Female	30	Student, employee	53
P3	Female	23	Student	64
P4	Female	40	Employee	84
P5	Female	29	Employee	47
P6	Male	29	Student, employee	65
P7	Male	24	Student, employee	52
P8	Female	33	Employee	58
P9	Female	42	Employee	49
P10	Female	25	Student	40
P11	Male	38	Employee	69
P12	Female	33	Employee	70
P13	Female	24	Student	51
P14	Female	32	Employee	65
P15	Female	29	Employee	64

Appendix 2: QR codes on display in the B&M store

What Prevents Consumers from Making Responsible Online Purchases?

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The objective of this qualitative study is to examine and describe what prevents consumers from making responsible online purchases. The data were collected during February and March 2023 with an online survey. The data comprises the respondents' (N=245) free-form written responses, in which they articulated and explained the factors that prevent their responsible online purchases. The findings indicate that external and internal factors can prevent consumers' responsible online purchases. While external factors – online stores – are mainly blamed for promoting irresponsible buying behavior, internal factors – consumers' individual characteristics – are also recognized to have an important role in irresponsible purchasing behavior. The external factors identified in this study include 1) pricing, 2) information, and 3) availability. The internal factors include 1) self-indulgence and 2) trust.

Keywords: responsible online purchasing, sustainability, online shopping, e-commerce, Bled eConference

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1 Introduction

Online purchasing has increased significantly during the last decade. This growth can largely be attributed to the increased use of the internet and benefits that e-commerce provides to consumers, such as the ability to search for low prices, access an extensive product range, and the convenience of shopping from home. Online purchasing has also been encouraged by the COVID-19 pandemic. Due to the restrictions during the pandemic, many consumers discovered novel ways of utilizing online retailers and service providers. This shift in consumer behavior has led to a boom in e-commerce, with many businesses having to rapidly adapt to meet the increased demand for online shopping.

While online purchasing has become increasingly vital and provides various advantages for consumers, it has also led to unfavorable ecological outcomes such as increased waste, carbon emissions, and energy consumption. The ecological implications of e-ecommerce have been extensively discussed, with adverse effects arising from packaging materials, delivery methods, unsold products, and product returns (Tiwari & Singh, 2011), to name a few. In addition, studies show that the significance of environmental considerations in consumer shopping choices is on the rise (e.g., De Canio et al., 2021). As a result, in recent years, the heightened environmental concerns and competitive pressure have spurred a greater emphasis on sustainability issues by both researchers and practitioners in the e-commerce industry.

However, despite the discussion surrounding the environmental and ethical impacts of online purchasing, there remains a lack of comprehensive understanding of the topic. Studies have only partially investigated sustainable e-commerce, focusing on retailer-related issues such as packaging materials, logistic management aimed at reducing carbon emissions, and minimizing adverse environmental effects (Zhang, 2023). There is a particular need for further investigation on the consumer perspectives. Although there is a prevailing trend towards pro-green attitudes, it is common for consumers to opt for non-green alternatives when making purchases (e.g., Park & Lin, 2020; Su et al., 2022). Thus, studies should investigate what hinders responsible shopping and the ways in which retailers can encourage their customers to adopt more responsible behaviors (Wiese et al., 2015).

The objective of this qualitative study is to examine and describe what prevents consumers from making responsible online purchases. By comprehending these factors, it becomes possible to better understand the attitude-behavior gap identified in responsible consumption (e.g., Park & Lin, 2020; Su et al., 2022). The findings can be utilized to pinpoint the specific areas where consumers require assistance in making more responsible purchasing decisions and where online businesses should take measures to encourage sustainable shopping practices.

Next, Section 2 discusses previous studies on responsible online purchasing. Section 3 describes the methods used for data collection and analysis. Section 4 presents the results of the study, and Section 5 discusses the contributions of the study, its implications for management, and recommendations for future research.

2 Responsible online purchasing and its obstacles

The topic of responsible purchasing has been explored using various concepts, with sustainability and responsibility being among the prevalent ones. Sustainability and responsibility are interdependent concepts that reinforce and complement each other. Sustainability refers to the ability to maintain or preserve resources for future generations. Sustainability encompasses a range of issues, including environmental protection, social equity, and economic viability. (Armstrong et al., 2019) Responsibility, on the other hand, refers to the obligation or duty to act in a way that is ethical and accountable. It involves being aware of the impact of one's actions on others and the environment and taking steps to minimize harm. Responsible behavior is often necessary to achieve sustainability goals, such as reducing waste, conserving resources, and mitigating environmental impacts. The concept of responsible purchasing is centered around engaging in activities that aim to minimize the impact of purchased goods or services on the environment (Follows & Jobber, 2000), and opting for socially and ethically responsible purchases (Jain et al., 2022).

Previous research has predominantly explored responsible consumption in a general sense, rather than delving into the specifics of purchasing channels (online/offline). The purchase of responsible products is influenced by factors such as engagement in sustainable consumption, the degree of environmental and health consciousness, social influences (Carter et al., 2021), and the reputation of a company's environmental performance (Grimmer & Bingham, 2013). As evidenced by studies, several obstacles can prevent consumers from making responsible purchasing decisions. It has been shown, for example, that low availability hinders the consumption of sustainable products and social pressure increases purchase intentions (Vermeir & Verbeke, 2006). Responsible consumption is barriered by consumers' materialism, and thus may be facilitated by an increase in consumers' environmental concern (Kilbourne & Pickett, 2008). Sustainable consumption decisions are directly hindered by a lack of opportunity, and indirectly by lack of motivation to consume sustainably (Tong et al., 2023). Choosing to purchase responsible products often involves immediate costs for individuals, such as financial expenses or the effort required to change their behavior (Demarque et al., 2015). Despite holding pro-environmental attitudes, even environmentally conscious consumers often face a trade-off between sustainability and other attributes such as price, quality, and performance. As a result, non-environmentally friendly alternatives are chosen. (Olson, 2013)

In prior research, only a few studies have concentrated on responsible online shopping, with most of these studies examining it only in quite limited product or service contexts, such as fashion retailing (e.g., Kemppainen et al., 2021, 2022). In contrast, considerably more studies have been done on sustainable online shopping. For example, Yang et al. (2018) examined the adoption of sustainable online shopping in the context of the China's Double-11 shopping festival and found sustainable online shopping intention to be positively affected by the attitude, subjective norm, and perceived behavioral control related to sustainable online shopping and negatively affected by the atmospheric factors related to the shopping festival itself. In contrast, Song et al. (2020) found the lack of policy support, insufficient knowledge of sustainable consumption, and the lack of awareness of sustainable consumption to act as the main barriers to the adoption of sustainable online shopping, whereas Schumacher et al. (2022) found technostress to act as an additional barrier by weakening the link between the general preference for sustainable products and the actual choice of sustainable products in an online shopping situation. In turn, Kanay et al. (2021) examined the potential of goal setting to promote sustainable online shopping, finding that both the goal setting and the feedback concerning the carbon footprint of a shopping basket together promote more sustainable online consumption. Finally, Demarque et al. (2015), Antonides and Welvaarts (2020), Berger et al. (2020), Gossen et al. (2022), Hollaus and Schantl (2022), and Michels et al. (2022) all examined the potential of different kinds of nudging techniques (cf. Thaler & Sunstein, 2008; Lehner et al., 2016) to promote sustainable online shopping, finding many of them to be highly effective for this purpose.

3 Data collection and analysis

The data for this study were collected during February and March 2023 with an online survey that was conducted by using the LimeSurvey service. The survey respondents were recruited by promoting the survey on social media and via the communication channels of Finnish universities and student associations. To promote the response rate, all the respondents who completed the survey were able to participate in a prize drawing of ten gift boxes worth about 25 € each. The survey questionnaire consisted of three sections, of which the first section concentrated on the general background information of the respondents, the second section on their general online shopping behaviour, and the third section more specifically on their responsible online shopping behaviour. This last section also contained the three open-ended questions concerning responsible online shopping behaviour. Answers to the question n:o 3 "What kind of factors promote you to be or prohibit you from being responsible when making online purchases? Why?" were utilized as the data of this study. Respondents who provided written responses that clearly identified a factor hindering their responsible purchasing were eligible for inclusion in the final analysis.

In total, 245 respondents provided explanations regarding the prohibiting factors. Their average response time for the whole survey was about 20 minutes. The sample statistics in terms of the gender, age, yearly taxable income, socioeconomic status, and average online shopping frequency of the respondents are reported in Table 1. As can be seen, most of the respondents were women, students, and relatively young. Their age varied between 19 and 66 years, with a mean of 27.8 years and a standard deviation of 8.1 years. However, most of the respondents were relatively active online shoppers who shopped online at least monthly on average. All of them also had at least some experience in online shopping.

Table 1: Sample statistics (N = 245)

	N	%		N	%
Gender			**Socioeconomic status**		
Man	44	18.0	Student	190	77.6
Woman	189	77.1	Employee or self-employed	53	21.6
Other	12	4.9	Unemployed or unable to work	6	2.4
Age			Pensioner	1	0.4
Under 25 years	105	42.9	Other	2	0.8
25–49 years	133	54.3	**Online shopping frequency**		
50 years or over	7	2.9	At least weekly	10	4.1
Yearly personal taxable income			At least monthly	141	57.6
Under 15,000 €	160	65.3	At least yearly	88	35.9
15,000–29,999 €	33	13.5	Less frequently than yearly	5	2.0
30,000 € or over	39	15.9	Has never shopped online	0	0.0
No response	13	5.3	No response	1	0.4

The data analysis was conducted using NVivo 12 Pro qualitative analysis software. First, factors that represented the challenges of responsible online purchasing were extracted from each respondent and coded based on their content. Second, after identifying the initial codes describing the obstacles, they were grouped and labelled based on the common themes identified within the codes. Consequently, the study identified five primary themes that describe what prevents consumers from making responsible online purchases.

4 Findings

The findings indicate that external and internal factors can prevent consumers' responsible online purchases. While external factors – online stores – are mainly blamed for promoting irresponsible buying behavior, internal factors – consumers' individual characteristics – are also recognized to have an important role in irresponsible purchasing behavior. The external factors identified in this study include 1) pricing, 2) information, and 3) availability. The internal factors include 1) self-indulgence and 2) trust. The following sections will discuss these themes and their corresponding content.

4.1 External online store related factors

Pricing. The primary obstacle to responsible online purchases was the pricing of responsible products (157 references). The respondents perceived responsible products to be costly, or more expensive than their conventional counterparts. Some participants noted that domestic products and brands were particularly expensive compared to their foreign counterparts. The experience of the price difference between responsible and irresponsible products discouraged respondents from choosing the responsible option: the perceived financial sacrifice was often considered too high. The difference in price is noteworthy particularly when the perceived quality of the responsible product does not outweigh the drawbacks of choosing a less responsible alternative. Conversely, if the difference in price is perceived as negligible, the responsible option is chosen.

> If the responsible choice is only slightly more expensive than the other options, I'm usually willing to pay for it. – Female, 23

The respondents frequently cited their financial situation as a reason for price-sensitivity, indicating that they are not able to afford responsible alternatives, even if they desire to purchase them. Opting for responsible alternatives was seen as difficult or unfeasible for those facing financial constraints and low incomes. When struggling to make ends meet, prioritizing responsibility over essentials becomes challenging or even impossible, as the following quote demonstrates.

> It would be great to buy organic and organically produced/certified products, but at this income level, you choose the cheapest or don't buy at all. – Female, 46

Despite facing obstacles, a number of respondents asserted that they were making their best effort to be responsible, and believed that they would be more inclined to do so if they had more financial means. Purchasing used items, such as those found at online flea markets, was seen as a practical way to make responsible choices. Nevertheless, some respondents also acknowledged that their stinginess contributed negatively to responsible purchasing; they incline to prioritize low prices over responsibility, opting for less sustainable alternatives to save money.

Information. The lack of information regarding responsible practices posed an important hindrance to making responsible online purchases (81 references). Obtaining information on the responsibility of companies or their products was considered a challenging task, with inadequate transparency and quality of available information. According to the respondents, detecting the product's origin is complicated. Online stores do not provide sufficient details about the raw materials used in the products, their origin, the parties and methods involved in the production process, and the manufacturing country. Consequently, it is difficult to determine responsibility; there is no means to verify if unethical practices such as child labor were involved in the production, for example. Despite having good intentions, one may engage in irresponsible purchasing because of lack of information and knowledge.

> Reliable information about the entire value chain of the product is not available. […] The ecological, social and ethical responsibility of the product cannot be traced. – Nonbinary person, 48

> Information about the manufacturing process of the products is not easily available, so an unethical product may be bought by mistake.
> – Female, 19

There was an expectation for online retailers to offer greater transparency throughout the entire customer journey, encompassing not only the source of the products but also post-purchase events. Specifically, there was a desire for more comprehensive information from these retailers regarding the fate of returned products, including whether they are discarded as waste or resold.

> Almost all online stores have very poor transparency, e.g., about what happens if you return something. Do they, for example, go straight to the trash? – Female, 22

Additionally, the topic of used products was raised, with a recognition of their inherent responsibility in recycling, but also acknowledging that information on these items is often even more challenging to obtain than for new products.

> Responsibility can be achieved by facilitating the online search for used products, ensuring their appeal to customers, and presenting relevant product information in a manner consistent with that of new items.
> – Female, 23

Due to the insufficient information available, the buyer needs to make even more assumptions regarding the responsibility of a product when dealing with used items.

Availability. The availability of responsible products (74 references) was found to be inferior to that of non-sustainable options. In some product categories, it is possible that responsible alternatives may not be available at all, which limits the consumer's ability to make sustainable choices. Furthermore, even when responsible options are available, the selection may be inadequate in terms of product characteristics such as size and design. Foreign online retailers may offer a better selection, but this comes at the cost of longer transportation distances. Therefore, buyers must consider whether their ultimate choice is more responsible, weighing the environmental impact of delivery against their preference for sustainable products.

> Narrow selection. For example, I'm looking for a certain product that needs to be ordered from abroad, which potentially increases emissions. – Female, 21

On the other hand, it was noted that buying from foreign stores can also be difficult, because not all stores deliver products to foreign countries, such as Finland.

4.2 Internal customer related factors

Self-indulgence. The respondents also emphasized self-indulgence (52 references) – the role of their own consumer attributes and the desire for convenience in terms of the shopping process and the product that is purchased. A purchasing process that is quick and uncomplicated is preferred, and products are expected to possess certain features that may not be available in responsible alternatives.

> There are many online stores that are very irresponsible. So a large selection and an easy shopping experience can be tempting at times.
> – Female, 22

One of the reasons for irresponsible choices was the fast-paced nature of daily life. It was observed that addressing sustainability concerns is time-consuming and often impractical, especially when purchases need to be made quickly. Several respondents also admitted to being lazy and neglecting their responsibility due to this. While responsible shopping is acknowledged as an important concept, it often takes a backseat to other pressing concerns in everyday life.

> The preventing factors are probably hurry and laziness. – Female, 28

Consequently, many respondents reported having inadequate knowledge about responsibility and emphasized the need to start with the basics. In addition, some respondents revealed that they are impulsive and easily swayed by attractive deals, making shopping a source of pleasure rather than a responsibility issue.

Trust. Issues of trust (48 references) were also highlighted as a barrier to responsible purchases. Numerous respondents expressed skepticism towards the notion of sustainability, suspecting that companies engage in greenwashing when communicating their efforts to be responsible. This is due to a lack of evidence to support their claims, or the provision of insufficient evidence. There was a perception among many respondents that online stores engage in deceptive practices, misleading or cheating consumers. It was believed that online stores are withholding information about products, misleading consumers with inaccurate information, using certificates without authorization, and leveraging claims of responsibility as marketing tools.

> The consumer is being cheated. Many products are advertised as green and responsible, and there are many certificates that ultimately do not guarantee anything. – Female, 27

Many respondents expressed difficulties in distinguishing genuine responsibility claims made by companies. To address this problem, responsible and familiar stores were prioritized. By shopping at stores that exclusively offer responsible products or if the store has been previously self-evaluated as responsible, there is no need to evaluate each product individually.

Trust-related factors were found to be relevant also in the context of online C2C (consumer to consumer) trade and flea markets. Even though flea markets inherently promote responsible behavior by facilitating recycling, there may be apprehension and unease associated with making purchases. When consumers engage in transactions with each other, the absence of easily accessible aid can create challenging situations. Moreover, assessing the quality of second-hand products, particularly when shopping online, can pose a challenge because the product cannot be physically experienced before the purchase.

5 Discussion

This study's findings enhance comprehension of the factors that contribute to the discrepancy between attitudes and actions (e.g, Park & Lin, 2020; Su et al., 2022) regarding responsible online purchasing. The study demonstrates that external factors related to online store and internal factors related to consumers themselves can prevent responsible online purchases. According to this study, consumers tend to attribute their irresponsible spending mostly to online stores: pricing of responsible products, information about responsibility issues and availability of responsible products. In addition, consumers recognize their own responsibility and the influence of personal factors on practicing responsible behavior while shopping online.

As previous research has indicated (e.g., Demarque et al., 2015), opting for responsible choices often entails trade-offs and various costs for consumers. According to this study, consumers tend to perceive such trade-offs and costs particularly in terms of **price**. The study highlighted that pricing and perceptions related to pricing are the primary factors that hinder responsible online shopping. Consumers tend to view responsible products as costly or more expensive than other products, which limits their willingness to purchase them. Previous research has also emphasized the crucial role of price in responsible consumption (e.g., Kemppainen et al., 2021). Given that pricing is (still) a significant obstacle to responsible behavior, further investigation is necessary to understand why consumers perceive responsible products as expensive and what can be done to the negative price perceptions. Future studies should delve deeper into the (lower) pricing of responsible products and explore ways to enhance consumers' price perception and motivation to purchase responsible options.

In line with previous studies (e.g., Song et al., 2020; Kemppainen et al., 2021), the findings underscore the significance of the responsibility information provided by online stores. Online retailers do not provide comprehensive information about the social and environmental impacts of their products. Lack of transparency and information about products' sourcing, production processes and their impact makes responsible shopping challenging. The responsibility information – and the inadequacy of it – is also linked to another obstacle identified in this stydy: consumers' trust. According to the findings, consumers exhibit a degree of skepticism and suspect that companies engage in greenwashing. Such perceptions hinder responsible buying and may negatively impact online stores and other companies that genuinely prioritize responsibility themes. Future research should examine how issues related to responsibility could be communicated more effectively to buyers. Clarifying the communication of responsible practices could enhance consumers' understanding of responsible products and promote their purchasing behavior. Another critical aspect to explore is how to build consumer trust in the information provided. Consumers are becoming increasingly aware of the ethical and environmental implications of their purchases and are seeking more information to make informed choices. By understanding these issues, online services can be developed to promote responsible consumption and better cater to consumers' needs in this regard. Previous studies have noted that practices such as feedback concerning the carbon footprint of a shopping basket (Kanay et al. 2021) can promote responsible online purchasing. Hence, future studies should delve deeper into other solutions and online store characteristics that could help solving the well-identifies information gap.

The findings also indicate that the availability of responsible products is an obvious challenge to shop responsibly. Consistent with these results, prior research has demonstrated that sustainable consumption choices are impeded by limited opportunities (Tong et al., 2023) and inadequate availability (Vermeir & Verbeke, 2006). As responsible product availability has been recognized as a challenge for quite some time, it prompts a question of why it continues to present a major hurdle. It is worth exploring the reasons behind the perceived inadequacy of the supply and identifying strategies to make responsible alternatives more accessible to consumers.

Finally, the study underscored the influence of consumer attributes and convenience-seeking behavior – self-indulgence – on responsible online purchases. Amidst the business of daily life, responsible products or the associated purchasing procedures may not seem appealing enough. The act of responsible online purchasing is often viewed as unpleasant, excessively challenging and requiring significant amounts of time – the tradeoff is perceived as excessively large (Olson, 2013). Hence, sustainable consumption decisions are hindered by lack of motivation to consume sustainably (Tong et al., 2023). Future research should delve deeper into ways to impact the convenience of responsible shopping, such as exploring how online store design and characteristics can be utilized to enhance the ease of responsible shopping.

To summarize, this study identified factors that prevent responsible online purchasing based on survey responses. The identified obstacles are largely in line with previous research related to responsible consumption in different (online/offline) contexts. It is therefore worth asking, why these obstacles have persisted in a similar fashion, year after year. The obstacles of responsible online shopping should be investigated more comprehensively and through various methodologies to gain a deeper understanding and solutions regarding these issues.

References

Antonides, G., & Welvaarts, M. (2020). Effects of default option and lateral presentation on consumer choice of the sustainable option in an online choice task. Sustainability, 12(13), 5484.

Armstrong, G., Kotler, P., & Opresnik, M. (2019). Marketing: An Introduction (14th ed.). Pearson Education Limited.

Berger, M., Müller, C., & Nüske, N. (2020). Digital nudging in online grocery stores – Towards ecologically sustainable nutrition. In Proceedings of the 41st International Conference on Information Systems. Atlanta, GA: AIS.

Carter, K., Jayachandran, S., & Murdock, M. R. (2021). Building A Sustainable Shelf: The Role of Firm Sustainability Reputation. Journal of Retailing, 97(4), 507–522.

De Canio, F., Martinelli, E., & Endrighi, E. (2021). Enhancing consumers' pro-environmental purchase intentions: the moderating role of environmental concern. International Journal of Retail & Distribution Management, 49(9), 1312-1329.

Demarque, C., Charalambides, L., Hilton, D. J., & Waroquier, L. (2015). Nudging sustainable consumption: The use of descriptive norms to promote a minority behavior in a realistic online shopping environment. Journal of Environmental Psychology, 43, 166–174.

Follows, S. B., & Jobber, D. (2000). Environmentally responsible purchase behaviour: A test of a consumer model. European Journal of Marketing, 34(5/6), 723–746.

Gossen, M., Jäger, S., Hoffmann, M. L., Bießmann, F., Korenke, R., & Santarius, T. (2022). Nudging sustainable consumption: A large-scale data analysis of sustainability labels for fashion in German online retail. Frontiers in Sustainability, 3, 922984.

Grimmer, M., & Bingham, T. (2013). Company environmental performance and consumer purchase intentions. Journal of Business Research, 66(10), 1945–1953.

Hollaus, M., & Schantl, J. (2022). Incentivizing consumers towards a more sustainable online shopping behavior: A study on nudging strategies in B2C e-commerce. In Proceedings of the 13th International Conference on E-Education, E-Business, E-Management, and E-Learning (pp. 372–376). New York, NY: ACM.

Jain, V. K., Dahiya, A., Tyagi, V., & Sharma, P. (2022). Development and validation of scale to measure responsible consumption. Asia-Pacific Journal of Business Administration, Ahead-of-print.

Kanay, A., Hilton, D., Charalambides, L., Corrégé, J. B., Inaudi, E., Waroquier, L., & Cézéra, S. (2021). Making the carbon basket count: Goal setting promotes sustainable consumption in a simulated online supermarket. Journal of Economic Psychology, 83, 102348.

Kemppainen, T., Frank, L., & Luhtanen, V. (2022). What is meaningful for responsible shoppers in online fashion retail? In Proceedings of the 8th International Workshop on Socio-Technical Perspective in IS Development.

Kemppainen, T., Frank, L., Makkonen, M., & Hyvönen, O.-I. (2021). Barriers to responsible consumption in e-commerce: Evidence from fashion shoppers. In A. Pucihar, M. Kljajić Borštnar, R. Bons, H. Cripps, A. Sheombar & D. Vidmar (Eds.), Proceedings of the 34th Bled eConference (pp. 323–335). Maribor, Slovenia: University of Maribor Press.

Kilbourne, W. E., & Pickett, G. M. (2008). How materialism affects environmental beliefs, concern, and environmentally responsible behavior. Journal of Business Research, 61(9), 885-893.

Lehner, M., Mont, O., & Heiskanen, E. (2016). Nudging – A promising tool for sustainable consumption behaviour? Journal of Cleaner Production, 134(A), 166–177.

Michels, L., Ochmann, J., Günther, S. A., Laumer, S., & Tiefenbeck, V. (2022). Empowering consumers to make environmentally sustainable online shopping decisions: A digital nudging approach. In Proceedings of the 55th Hawaii International Conference on System Sciences (pp. 4707–4716). Honolulu, HI: University of Hawai'i at Mānoa.

Olson, E. L. (2013). It's not easy being green: The effects of attribute tradeoffs on green product preference and choice. Journal of the Academy of Marketing Science, 41(2), 171–184.

Park, H. J., & Lin, L. M. (2020). Exploring attitude–behavior gap in sustainable consumption: Comparison of recycled and upcycled fashion products. Journal of Business Research, 117, 623–628.

Schumacher, K., Peters, L., & Feste, J. (2022). Please mind the stress: The influence of technostress on mindset-driven sustainable consumption in an online shopping context. In Proceedings of the 55th Hawaii International Conference on System Sciences (pp. 4378–4387). Honolulu, HI: University of Hawai'i at Mānoa.

Song, W., Zhu, Y., & Zhao, Q. (2020). Analyzing barriers for adopting sustainable online consumption: A rough hierarchical DEMATEL method. Computers & Industrial Engineering, 140, 106279.

Su, M., Fang, M., Kim, J., & Park, K. S. (2022). Sustainable marketing innovation and consumption: Evidence from cold chain food online retail. Journal of Cleaner Production, 340, 130806.

Thaler, R. H., & Sunstein, C. R. (2008). Nudge: Improving Decisions About Health, Wealth, and Happiness. New Haven, CT: Yale University Press.

Tiwari, S., & Singh, P. (2011). E-Commerce: Prospect or Threat for Environment. International Journal of Environmental Science and Development, 211–217.

Tong, L., Toppinen, A., Lei, W., & Berghäll, S. (2023). How motivation, opportunity, and ability impact sustainable consumption behaviour of fresh berry products. Journal of Cleaner Production, 401, 136698.

Vermeir, I., & Verbeke, W. (2006). Sustainable food consumption: Exploring the consumer "attitude-behavioral intention" gap. Journal of Agricultural and Environmental Ethics, 19(2), 169-194.

Yang, S., Li, L., & Zhang, J. (2018). Understanding consumers' sustainable consumption intention at China's Double-11 online shopping festival: An extended theory of planned behavior model. Sustainability, 10(6), 1801.

Zhang, M. (2023). Sustainability Transitions in E-commerce Research—Academic Achievements and Impediments. Circular Economy and Sustainability, 1-22.

Ethical Considerations of Augmented Reality in High-Tech Manufacturing

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The use of Augmented Reality (AR) in industry is growing rapidly, driven by benefits such as efficiency gains and ability to overcome physical boundaries. Existing studies stress the need to take stakeholder values into account in the design process. In this study the impact of AR on stakeholders' values is investigated by conducting focus groups and interviews, using value sensitive design as a framework. Significant impacts were found on the values of safety, accuracy, privacy, helpfulness and autonomy. Twenty practical design choices to mitigate potential negative impact emerged from the study.

Keywords:
augmented reality, mixed reality, OHMD, human values, value sensitive design, industry 4.0

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1 Introduction

Driven by the travel restrictions caused by the Covid-19 outbreak, industrial companies that need to perform complex maintenance tasks sought out possibilities for overcoming the issue of not being able to have their engineers on site. These companies began to quickly adopt augmented reality technology that enabled senior engineers to instruct less experienced staff on site[1].The vast number of professional and academic publications that mention Covid-19 and Augmented Reality (AR) keywords indicates that this not only happened in the industrial sector but also in other sectors such as healthcare. The use of AR might provide an effective solution for overcoming travel restrictions (Lamberti et al., 2014), but an important question is whether companies are ready to use these technologies in an effective and sustainable way and whether they understand the possible implications.

Challenges and success factors for implementing AR are of technological, organizational and/or environmental type (Egger & Masood, 2020). Masood & Egger (2019) show that though academic research focuses more on the *technological* aspects, professionals are more concerned with the *organizational* consequences. All but one of the success factors professionals labeled as most relevant were user-centric: user acceptance, visibility of information, ergonomics, and usability of the user interface. Other research shows that, if human values are not incorporated effectively enough, companies may not be able to leverage all of AR's potential (Burleigh et al., 2020; Hofmann et al., 2017; Rousi, 2016).

This study addresses ethical aspects of using AR technology in an Industry 4.0 context. The main research question for this study is: How can the application of AR technology in the high-tech semiconductor industry take human values into account to positively influence the impact on its stakeholders? Examples of stakeholders are the users of AR glasses, but also their managers, group leads and customers. These stakeholders all have different stakes in regard to the use of AR technology.

The key concepts investigated in this study are stakeholders and their values. These concepts are studied within the context of specific AR use cases in the semi-

[1] See for instance https://www.smartindustry.com/tools-of-transformation/augmented-reality/article/11414929/how-covid-19-boosted-augmented-reality-and-virtual-reality-in-manufacturing).

conductor industry, to stimulate discussion of values in more detail. AR technology might impact the personal values of stakeholders in a positive or negative way. Based on insights into these impacts on stakeholder values, designs can be adapted to foster the positive impact and limit the negative impact, resulting in a design that is in balance with the values of the different stakeholders.

In section 2 we discuss the theoretical background to our study, followed by a description of our research method in section 3. Section 4 presents the results, which are discussed in section 5. The paper ends with conclusions in section 6.

2 Theoretical background

Within the high-tech industry the concepts of industry 4.0 and 5.0 are often mentioned. Industry 4.0 represents the 4th industrial revolution with high levels of mechanization, automation, digitalization and miniaturization (Lasi et al., 2014). While in the smart manufacturing paradigm of Industry 4.0 the role of human workers has become increasingly smaller, Industry 5.0 is bringing human workers back into the picture (Longo et al., 2020). The 5th Industrial Revolution combines human and machine, creating synergy between the two (Nahavandi, 2019). It is expected that the use of AR technology will significantly increase with Industry 5.0 concepts as new technical improvements are introduced (Fernández del Amo et al., 2018). Technical obstacles seem to become less inhibitory in large-scale usage and AR appears to be effective in both transferring knowledge *to* users and discovering and capturing knowledge *from* users (Fernández del Amo et al., 2018). Future factories will combine different technologies such as Big Data, AI and AR (Shi et al., 2020), enabling individualized human-machine interaction (Xu, 2021).

Though Industry 5.0 is purported to be human-centric instead of technology-driven (Xu, 2021), Longo et al. (2020) raise ethical concerns as the new technologies of the factories of the future are expected to have great impact on human values. They argue that more attention must be paid to the means by which technologies in Industry 5.0 systems can be designed for human values rather than treating these values as a side issue. This is the more relevant when the boundaries between human and technological capabilities are blurred, as is the case with AR technology. Regarding AR outside the context of Industry 4.0, Pase (2012) argues that AR is a persuasive technology, having the potential to intentionally influence or modify behaviors, values or attitudes, and as such raises ethical concerns. The main impacted values he discusses are manipulation of people, privacy and physical safety. Slater et al. (2020) explains the concept of physical vs. psychological realism. They discuss ethical issues that may arise when it becomes more difficult to differentiate the real from the virtual world. A third example of research regarding ethical considerations in AR is by Hofmann et al. (2017), who found a variety of ethical issues related to privacy, safety, justice, change in human agency, accountability, responsibility, social interaction, power and ideology.

3 Research Method

This study uses the Value Sensitive Design (VSD) approach. VSD is a theoretically based approach that takes human values into account in technical design. In VSD human value is defined as "What is important to people in their lives, with a focus on ethics and morality" (Friedman & Hendry, 2019, p. 24). VSD distinguishes between three types of investigations into stakeholder values: conceptual (general knowledge from literature or experts), empirical (eliciting actual values and norms from stakeholders) and technical (translating values into technical affordances). These investigations are intended to be iterative, feeding each other and allowing the designer to continuously modify the design (Friedman & Hendry, 2019).

In this study, first, values that might be impacted by technology design were distilled from existing academic literature (conceptual investigation). Next, these values were validated by a focus group (Bell et al., 2019) existing of four AR specialists who were involved with AR initiatives in the same high tech industry company: 1) a business leader 2) a business process specialist and expert in AR 3) a business solutions architect and 4) a systems architect. The focus group also identified two relevant scenarios of AR technology use in high tech industry as well as the stakeholders that might be impacted in these use cases.

The scenarios and value list were input for semi-structured interviews with representatives from the stakeholder groups that were identified (empirical investigation). These stakeholders were part of the same company but worked mainly at customer sites (other companies) or were associated with them. In total, 13 employees with different roles (engineers, project leads, site managers and team leads) and work locations in Northern America, Europe and Asia were interviewed.

During the interviews the participants were asked how they are involved in and affected by this technology, what values they think are most important in this context, how these values are impacted and how they think the impact can be influenced. The two scenarios from the focus group were discussed. The first consisted of Guided Work Instructions (GWI), where an engineer wears AR glasses to view step-by-step work instructions for a specific task in the form of text, holograms, audio and video. The second scenario was GWI+ where GWI is extended with more interaction between engineer and technology, because AI can "observe" the environment and work of the engineer and interact more with the engineer based on these observations. Interviewees were also asked to rank human values in order of importance to them in the context of the two given scenarios. The data gathering phase of this study took place in the summer and fall of 2021.

A thematic analysis was performed across the interviews to identify themes and search for patterns involving repetitions, similarities and differences. This was accomplished by using the code groups: harms, benefits, constraints, do's, don'ts, enablers, values, value tensions and mitigating measures. During the coding, at first the inductive method was used to code all content, while the grouping of codes used a more deductive approach (Linneberg, 2019). Relations between items and code groups were identified. Benefits, harms, do's and don'ts were linked to values in cases where there was a clear and strong relationship. Two kinds of relationships were used: relationships that indicate a positive contribution to the value and relationships that indicate a negative impact on the value. Creating this structure allowed further analyses of the raw interview data and helped find patterns and draw conclusions.

Subsequently, a formula was used to calculate the overall value ranking based on all interviews. One point was given to a value if it was selected in third place, 2 points if it was rated as second, and 3 points were given to values chosen as most important. These scores were added up, leading to a ranking with overall scores per value. In addition to the scores, two other variables are used to compare the outcome of the value ranking: groundedness and density. Groundedness refers to the number of quotations associated with a code, and density refers to the number of codes linked with a value.

After the interviews a second focus group session was conducted with the aim of validating and complementing the mitigation measures that emerged from the interviews (technological investigation).

4 Results

In the interviews the following values emerged in descending order of priority: *safety, accuracy, privacy, helpfulness, autonomy*, care, comfort, self-control, trust, independence, power, efficiency, security, accountability, pride, social interaction, cleanliness, professionalism, health, knowledge, quality, accessibility, change in human agency, reliability, effectiveness, ergonomics, responsibility as displayed in figure 1 (note that the scales of the four dimensions scenario 1, scenario 2, groundedness and density are different; dimensions can thus be compared between values but not within one and the same value).

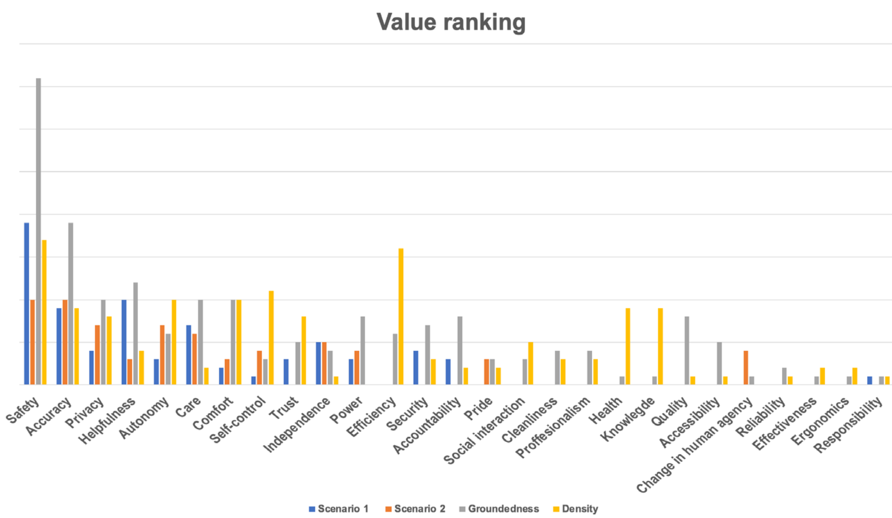

Figure 1: Value Ranking

The five values with highest priority (in italic above) are discussed in the following paragraphs, as well as the mitigating measures (numbered below) that were suggested by the participants to prevent potential negative impact on these values.

Many times, the phrase "safety first" was mentioned. Stakeholders identified several issues regarding *safety*. The wearer of an AR device is more vulnerable to falling, hitting something with their head or arms or when controlling a heavy moving object. Persons who work with lasers were cautious about open-beam hazards since a safety glass was not integrated in the AR headset. Safety sensors on the device that warn about potential safety hazards were seen as a significant improvement (1). Incorporation of safety glasses that protect the eyes from laser beams (2) was also suggested as a mitigating measure. The focus group indicated that safety regulations (3) and work instructions accompanied by safety tips (4) were the most feasible and effective measures to improve safety. Improvements in the viewing angle (5) were also mentioned. A narrator function could help prevent text objects from appearing in the field of sight (6). Advanced object recognition and safety hazard detection (7) are further possible future solutions.

Accuracy was the second most important value mentioned. The use of AR technology potentially enables the participants to do their jobs more accurately with fewer errors, and requiring less interpretation compared to the existing method of working. Accuracy can be considered an industry value in the semiconductor industry. Performing their jobs more accurately was important to the participants, but the accuracy of the AR technology itself is also important. Several measures for improvement were given such as: more accurate work instructions (8), and higher resolutions and less screen jitter (9). More accurate control of the device (10) was also often mentioned.

Privacy became an important value in the second scenario that contained more intelligent interaction between user and technology, which requires an AI function that observes the environment as well as the person. In this scenario participants became more sensitive about their privacy, and they began to raise concerns about being evaluated using AR and AI technology. Some mentioned that people behave differently when someone is wearing an AR device because others might think they are being recorded. The most significant measures to ensure privacy were to adhere to privacy laws (11), anonymize personal data (12), prevent storage of personal information (13) and not share the data with management (14). Privacy-ensuring measures such as blurring faces (15) and transparent privacy controls such as a blinking light when the device is recording (16) were also mentioned by participants.

Helpfulness was rated as the fourth important value for the stakeholders; the interviewees stated that if AR was not helpful to them, they were not going to use it. AR technology is considered a potentially helpful technology, but if it is not helpful on the spot, there is no time to make it so. Others mentioned that they need more help in using the tool to make it more helpful to them. The focus group suggested getting context-aware help in the form of projected suggestions (17). Additionally, reducing the administrative burden for engineers was proposed through intelligently assessing the components used during the assembly or maintenance task (18) and making the license portal accessible via the headset (19).

It became clear during the interviews that *autonomy* is a two-sided topic; autonomy is influenced in both positive and negative ways according to the interviewed stakeholders. They indicated a positive influence because an engineer can do more work autonomously as the information to do the task is at hand in a clear and easy to understand way. On the negative side stakeholders indicated that AR can also take away autonomy. Work instructions can become more prescriptive and rigid, leaving less room for the creativity of the engineer. The engineer becomes more dependent on the technology itself to do the job. Stakeholders expressed that if the technology, specifically in the form of work instructions, is too strict, workers would start feeling like robots or puppets, making them feel less appreciated as professionals. There appears to be a tension between working as an independent professional, and ensuring efficiency and quality by providing uniform detailed instruction; we will return to this topic later in this section. The focus group suggested giving the engineers more control and providing them with the space to make decisions as part of the work instructions by applying a state-based design principle (20).

Besides the individual values, the VSD concepts of value dams (features that some stakeholders strongly object to), value flows (features that many stakeholders support) and value tensions (values contradicting each other) were identified. The most significant value dam mentioned during the interviews involved security, more specifically the lack of intellectual property (IP) protection in the current design. Value dams are explained as design options to which even a small percentage of stakeholders strongly object (Friedman & Hendry, 2019). For companies in the semiconductor industry, protecting their IP is a major concern. IP is often considered one of the most valuable assets of a company working in this domain. Companies in the semiconductor industry often do not allow devices from suppliers that they do not control in their cleanroom as these can potentially be used to observe and steal IP-sensitive information. Thus, the technology is not easily accessible to the end user because lengthy approval processes and security controls build a metaphorical dam that hinders fostering other values such as autonomy, efficiency and helpfulness. A solution to overcome this value dam mentioned by the focus group was the capability to blur specific objects based on object recognition or virtual curtains placed on specific coordinates.

A value tension was identified between efficiency and autonomy or independence. Efficiency can be reached in the area of doing work faster by reducing execution, learning and travelling time, making fewer mistakes and having the right information at hand, leading to higher productivity. This higher productivity can be attained by building AR technology that provides more consistent work instructions, understands the context and how the activities are performed by the user, and can even correct users. Potentially, this could lead to more prescriptive and rigid ways of instructing users. Increasing autonomy means providing individuals with more freedom to determine their working procedures and task scheduling (Niessen & Volmer, 2010). This tension shows the importance of finding a proper balance between AR technology and its capabilities to instruct engineers and the level of freedom given to the engineers. Especially as autonomy is a critical aspect of both justice and wellbeing (Calvo et al., 2020). Lu et al. (2022) describes this phenomenon as empathic machines or empathic robot control where empathy skills generate human-robot shared actions based on understanding of the human state and situational circumstances.

5 Discussion

Comparing the values mentioned by the participants with existing research about Industry 4.0/5.0 and AR values, it seems that the values mentioned are more related to the AR technology itself than to the context of the semi-conductor industry. However, context does influence some of the values in terms of prioritization. Safety, privacy, comfort and accountability seem to be tightly related to the technology itself. Accuracy, care, helpfulness, and autonomy seem to have a stronger relation to the semiconductor industry.

As mentioned in the result section safety stood out as the most significant value. This relates to research by Lu et al. (2022) which positions Safety as a ground level value in their Industrial Human Needs Pyramid (Lu, 2022). The first aspect that must be ensured in a manufacturing environment is safety which can also be concluded from our study in the area of AR technology usages. Once safety is ensured other values become more important.

During the interviews two scenarios (GWI and GWI+) were described to the interviewees. In the second scenario other values emerged from the interviews. The values autonomy and privacy were considered more important in Scenario 2. The stakeholders worried that if artificially intelligent technology becomes too prescriptive, they may lose their autonomy. AR technology opens new opportunities to measure the performance of employees by using cameras and sensors. Performance monitoring of employees has been a topic of study for many years. Hawk (1994) investigated the effects of computerized performance monitoring, concluding that it can result in health problems, stress and the perception of unfairness. He urges organizations to be selective in which tasks are to be measured by computerized monitors. In 2017 an empirical study on the effects of employee surveillance showed that it leads to reduced sense of privacy and self-esteem and increased uncertainty, employee vulnerability and changes in behavior (Indiparambil, 2017). There seems to be a very thin line between using observation technology and AI for the good of the employees and using it in such a way that individuals change their behaviors for the bad, resulting in undesired behaviors and lack of intentional benefits.

Although the value of trust was not selected in the top five values during the interviews, it was mentioned quite a few times that positive outcomes on certain values such as helpfulness, privacy, autonomy, and security will build trust in AR technology, which leads to more usage and broader adoption. Since experience with AR is limited, and the technology is immature in many ways, building trust in the technology is important (Mcknight et al., 2011). Humanity's trust in technology has always been somewhat problematic, however (Taddeo, 2010). Considering the overall importance of trust in technology, the growing maturity level of AR, the potential negative outcomes and value dams and the high level of human-computer interaction (HCI) that this technology brings (Dünser et al., 2007), trust should play an important role in the further design and development of this technology.

6 Conclusion

The stakeholders of AR can be impacted by this technology in a positive but also in a negative way. This study revealed that the values stakeholders are most concerned with are safety, accuracy, privacy, helpfulness and autonomy. Twenty appropriate measures that can be embedded in the design to reduce potential negative impact on these values, were formulated during the value discussions. In addition to these five values, the importance of building trust in AR technology frequently emerged. The most significant value tension that this study disclosed was between autonomy and efficiency. Important design questions need to be answered for AR applications that provide work instructions. How much freedom will an engineer have in using GWI and will they be able to develop a personal way of working? Will GWI take existing experience into account? Will it adapt the instructions based on the level of details an engineer needs? How will mistakes or faulty executions of the work instructions by the engineer be reported?

A limitation to this study is that is performed in the context of only one company in the semiconductor industry. However, although the persons interviewed were employees of this company, they often executed their work as engineer at other major semiconductor companies. Therefore, they were able to some extent to share perspectives from those companies.

Situational factors such as local culture might influence stakeholder values and how they perceive the impact that AR has on those values. Situational factors are taken into account in this study by considering multiple stakeholders and stakeholders from different regions in the world. Interviews were held with stakeholders from three different regions (US, EU, APAC) to represent the whole population of the stakeholder group. Since the interviewees from the US, Taiwan, Japan, Korea and the Netherlands represented the global footprint of the semiconductor industry (Semiconductor Industry Association, 2020) this research provides reliable results on a global level by ruling out local influences.

The use of AR technology in the semiconductor industry is a novelty. Some interviewees had more extensive experience with AR, but overall, the experience was limited. As a minimum requirement the stakeholders selected for the interviews needed to have experimental experience with AR. Ideally, when using VSD, all participants can experience the technology extensively, including new design improvements. That was not the case in this research. Envisioned scenarios were presented that required some imagination and interpretation by the participants. We recommend to continue using VSD to validate future development.

Valuable future research could be performed in developing working instructions for AR devices. There is still a great deal to explore in developing personalized, effective work instructions. Many work instructions consist of step-by-step guides that do not take the existing skills, learning curves and personal preferences of the users into account. Since AR technology will significantly drive human computer interaction, and users need to work more and more in symbiosis with the technology, this area will be an important area for future research.

We argue that the further development of AR technology needs to profoundly take human values into account. AR technology will further mature over time, experience new iterative design cycles, and new applications will be combined with other technologies like AI. Embedding a value-sensitive design approach may prevent harm and balance value tensions in future designs.

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References

Bell, E., Bryman, A., & Harley, B. (2019). Business research methods (Fifth edition ed.). Oxford University Press.

Burleigh, C., Kroposki, M., Magabo, M., & Bailey, L. (2020). Ethical Considerations in Designing Virtual and Augmented Reality Products--Virtual and Augmented Reality Design with Students in Mind: Designers' Perceptions. Journal of Educational Technology Systems, 49(2), 219-238. https://hu.on.worldcat.org/oclc/8686785393

Calvo, R. A., Peters, D., Vold, K., & Ryan, R. M. (2020). Supporting human autonomy in AI systems: A framework for ethical enquiry. Ethics of digital well-being: A multidisciplinary approach, 31-54.

Dünser, A., Grasset, R., Seichter, H., & Billinghurst, M. (2007). Applying HCI principles to AR systems design.

Egger, J., & Masood, T. (2020). Augmented reality in support of intelligent manufacturing - A systematic literature review. Computers & Industrial Engineering, 14010.1016/j.cie.2019.106195

Fernández del Amo, I., Erkoyuncu, J. A., Roy, R., Palmarini, R., & Onoufriou, D. (2018). A systematic review of Augmented Reality content-related techniques for knowledge transfer in maintenance applications. Computers in Industry, 103, 47-71. 10.1016/j.compind.2018.08.007

Friedman, B., & Hendry, D. G. (2019). value sensitive design. MIT Press. https://doi.org/10.7551/mitpress/7585.001.0001

Hawk, S. R. (1994). The effects of computerized performance monitoring: An ethical perspective. Journal of Business Ethics, 13(12), 949-957.

Hofmann, B., Haustein, D., & Landeweerd, L. (2017). Smart-Glasses: Exposing and Elucidating the Ethical Issues. Science and Engineering Ethics, 23(3), 701-721. 10.1007/s11948-016-9792-z

Indiparambil, J. J. (2017). An empirical study on the detrimental effects of employee surveillance in India. International Journal of Research in Computer Application & Management, 7(12), 48-51.

Lamberti, F., Manuri, F., Sanna, A., Paravati, G., Pezzolla, P., & Montuschi, P. (2014). Challenges, opportunities, and future trends of emerging techniques for augmented reality-based maintenance. IEEE Transactions on Emerging Topics in Computing, 2(4), 411-421.

Lasi, H. D., Fettke, P. P. D., Kemper, H. P. D., Feld, T. D., & Hoffmann, M. D. (2014). Industrie 4.0. Wirtschaftsinformatik, 56(4), 261-264. 10.1007/s11576-014-0424-4

Linneberg, M. S., & Korsgaard, S. (2019). Coding qualitative data: A synthesis guiding the novice. Qualitative research journal, 19(3), 259-270.

Longo, F., Padovano, A., & Umbrello, S. (2020). Value-Oriented and Ethical Technology Engineering in Industry 5.0: A Human-Centric Perspective for the Design of the Factory of the Future. Applied Sciences, 10(12), 4182. 10.3390/app10124182

Lu, Y., Zheng, H., Chand, S., Xia, W., Liu, Z., Xu, X., Wang, L., Qin, Z. & Bao, J. (2022). Outlook on human-centric manufacturing towards Industry 5.0. Journal of Manufacturing Systems, 62, 612-627.

Masood, T., & Egger, J. (2019). Augmented reality in support of Industry 4.0—Implementation challenges and success factors. Robotics and Computer Integrated Manufacturing, 58, 181-195. 10.1016/j.rcim.2019.02.003

Mcknight, D. H., Carter, M., Thatcher, J. B., & Clay, P. F. (2011). Trust in a specific technology: An investigation of its components and measures. ACM Transactions on Management Information Systems (TMIS), 2(2), 1-25.

Nahavandi S. (2019). Industry 5.0 - A Human-Centric Solution. Sustainability, 11(16)

Niessen, C., & Volmer, J. (2010). Adaptation to increased work autonomy: The role of task reflection. European Journal of Work and Organizational Psychology, 19(4), 442-460.

Pase, S. (2012). Ethical considerations in augmented reality applications. Paper presented at the Proceedings of the International Conference on E-Learning, E-Business, Enterprise Information Systems, and E-Government (EEE), 1.

Rousi, R. (2016). Using human-values as a guide for understanding worthy design directions in augmented reality. AcademicMindtrek 2016 - Proceedings of the 20th International Academic Mindtrek Conference, , 243-252. 10.1145/2994310.2994322

Semiconductor Industry Association. (2020). 2020 STATE OF THE U.S. SEMICONDUCTOR INDUSTRY. https://www.semiconductors.org/wp-content/uploads/2020/06/2020-SIA-State-of-the-Industry-Report.pdf

Shi, Z., Xie, Y., Xue, W., Chen, Y., Fu, L., & Xu, X. (2020). Smart factory in Industry 4.0. Systems Research and Behavioral Science, 37(4), 607-617. 10.1002/sres.2704

Slater, M. (2020). The Ethics of Realism in Virtual and Augmented Reality. Frontiers in Virtual Reality, 1

Taddeo, M. (2010). Trust in Technology: A Distinctive and a Problematic Relation. Knowledge, Technology Policy : Knowledge, Techology Policy (Untill 2011), 23(3-4), 283-286.

Xu, X. (2021). Industry 4.0 and Industry 5.0 Inception, conception and perception. Journal of Manufacturing Systems, 61, 530-535.

THE EFFECT OF E-LEADERSHIP ON DIGITAL TRANSFORMATION IN THE DUTCH PUBLIC SECTOR

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A public sector that adequately makes use of information technology can provide improved government services that not only stimulates business development it also intensifies citizen participation and economic growth. However, the effectiveness of IT and its governance at both national as well as on municipality level leaves much to be desired. It is often stated that this is due to a lack of digital skills needed to manage the IT function and alignment with business. Therefore, the aim of this study is to determine the effect that digital leadership competences and IT capabilities have on digital transformation readiness within Dutch municipalities. Based on an analyses of survey data from 178 respondents we recommend municipalities to implement a range of activities that all are related to realize the ability to constantly apply strategic thinking and organizational leadership to exploit the capability of Information Technology to improve the business.

Keywords:
public sector, municipalities, digital leadership, IT capabilities, digital transformation

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1 Introduction

The change toward a public sector that adequately makes use of the advantages that information technology has to offer to optimize processes and services has been going on for many years. Dunleavy at al. (2006) already stated that a shift is needed toward "digital-era governance" that is realized by '*reintegrating functions into the governmental sphere, adopting holistic and needs-oriented structures, and progressing digitalization of administrative processes*' (Dunleavy et al., 2006). In recent years, the Dutch government has been investing more effort in digital transformation to improve its services that are vital towards society (Blacquière et al., 2021). Several studies show that improved government services through digitization not only stimulate business development it also intensifies citizen participation and economic growth (Alvarenga et al., 2020, Alnuaimi et al., 2022). Other benefits that are often mentioned are: better transparency and accountability, improved access to government data, increased support for innovation, a more responsive supply chain, and support for environmental initiatives (Alnuaimi et al., 2022). However, the effectiveness of IT and its governance at both the national as well as on municipality level leaves much to be desired (Elias et al., 2015). Within the public sector implementation of management of information systems causes issues regarding coordination between organisational units and achieving organisational goals (Broadbent et al., 1989). The IT function of an organisation needs to be managed and aligned between business and technology focused IT departments as it is regularly the missing link between the often artificial boundaries within government organisations (Njanka et al., 2021). However, for successful digital transformation, it is also necessary for managers and employees to have the required digital competences. Ravesteyn & Ongena (2019) stated that e-leadership competences derived from the European e-competence framework (e-CF) have a positive significant effect on digital transformation. Furthermore, Nwankpa & Roumani (2016) found that IT capabilities have a positive effect on digital transformation. Based on this the objective of the study described in this paper is to determine the effect that digital leadership competences and IT capabilities have on digital transformation readiness within Dutch municipalities.

The remainder of this paper is structured as follows, after an overview of the theoretical background in the next section we describe the research approach (section 3) and the results of our analyses in section 4. Practical recommendations that can be implemented by municipalities are discussed in section 5 and the paper ends with conclusions in section 6.

2 Theoretical background and conceptual model

Digital transformation in municipalities is not just about digitising paper-based work processes but about a change of methods and communication that will improve the efficiency and service quality of the organization by improving transparency, lead times and reducing the phenomenon of being 'pushed from pillar to post' (Layne & Lee, 2001; Lindgren et al., 2019). Digital transformation involves the use of digital capabilities and technologies to influence different aspects of the organisation to create value. It is important to understand specifically how different types of digital technologies, in combination with capability, influence certain aspects of the organisation (Morakanyane et al., 2017). In addition, digital transformation is an evolutionary process whereby digital technologies and skills are deployed to add value to business models, operational processes and to customer experiences (Morakanyane et al., 2017). Due to a lack of shared strategic vision, empowerment, and innovation the strategic contribution of the IT-function to its business counterpart is less effective within the ecosystems of municipalities (Elias et al., 2015). IT is not merely instrumental in cost reduction, but it is a business enabler that adds value to the organisation (Njanka et al., 2021). Working towards digital transformation there is a shortage of administrative skills, data availability, a lack of resources, a lack of technological capabilities (Alnuaimi et al, 2022) and a lack of competences (Elias et al., 2015; Hüsing, 2013). In a survey among Dutch public administrations, Tangi et al. (2021) provide insight into their transformation efforts and find that the public bodies that were studies only act on exogenous input and that there is no sense of urgency other than sufficient external pressure.

The European Union recognised the lack in IT related competences and therefore in the Malmö (European Union, 2009) and Tallinn (European Union, 2017) declarations 32 participating countries unanimously adopted an e-Governance initiative to develop digital leadership skills for civil servants at all levels. However, there is no common understanding on what entails digital leadership. Klein (2020) defined characteristics of digital leadership catagorized into three groups: digital business, social attitude, and general mindset. Though, none of the listed characteristics seem to be related to technical skills. In contrast, McCarthy, Sammon

& Alhassan (2021) identified eight digital transformation leadership characteristics that contain both business oriented (digital strategist, digital culturalist, customer centrist, organisational agilist, business process optimizer, and digital workplace landscaper) as well as more technical (digital architect, and data advocatte) characteristics. Looking at the European e-Competence Framework standard (e-CF, 2019; NEN, 2018) we find 30 generic roles and 41 competences that are defined which contribute to uniform development and common principles for competence development for ICT professionals. Ravesteyn and Ongena (2019) used the e-CF competences of the Digital Transformational Leader Role to examine the effect on IT Capabilities and Digital Transformation readiness within organizations. These competences, with business and technical orientation, are Business Plan Development (A3), Architecture Design (A5), Innovating (A9), Business Change Management (E7), Information Systems Governance (E9)[1]. Given the fact that the e-CF standard is adopted by Dutch government we have selected this role and corresponding competences for this study.

That IT Capabilities have a positive effect on digital transformation readiness is shown in earlier research by Lu and Ramamurthy (2011), and Nwankpa and Roumani (2016). Lu and Ramamurthy (2011) conceptualise IT capabilities as a latent construct that is reflected in three dimensions. First, IT infrastructure; the ability of an organisation to deploy IT-based managed data services, its architecture and network services in addition to managing the application portfolio and services delivered. Second, IT business spanning; the ability of an organisation's management to leverage IT infrastructure in support of business objectives (Lu & Ramamurthy, 2011; Mao et al., 2015). And finally, proactive stance, the ability of an organisation to actively explore ways to embrace IT innovations that contribute to its business objectives (Lu and Ramamurthy, 2011). As earlier studies have found positive relations but didn't explicitly do research in the context of government organizations this study focuses on municipalities to help them better prepare for digital transformation.

Derived from the literature our conceptual model (figure 1) has three reflective exogenous latent constructs related to IT Capabilities: 1) IT Proactive Stance, 2) IT Infrastructure, and 3) IT Business Spanning. Furthermore, digital leadership consists

[1] The code between brackets refers to the competence label in the e-CF framework.

of five formative exogenous latent constructs: 1) Innovating, 2) Architecture Design, 3) Business Plan Development, 4) Business Change Management, and 5) Information Systems Governance. Finally, the endogenous construct is Digital Transformation.

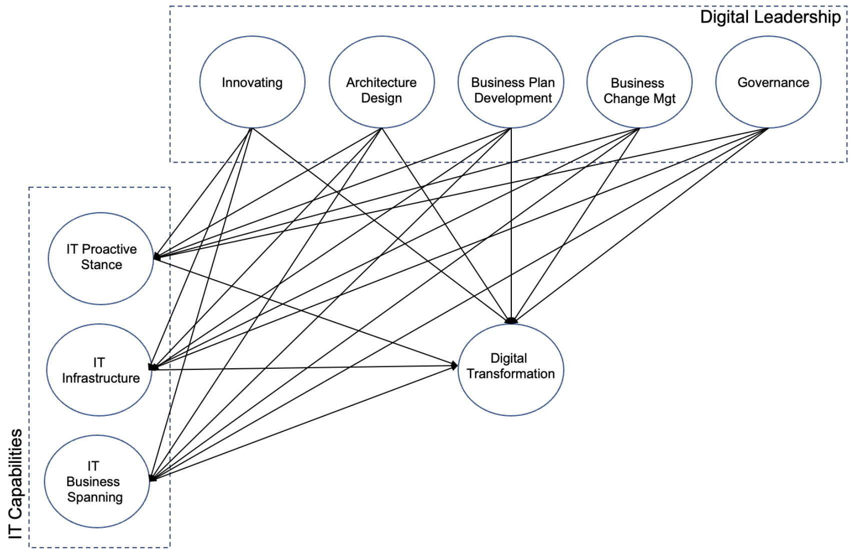

Figure 1: Conceptual Model

As the objective of our research is to determine the effect that digital leadership competences and IT capabilities have on digital transformation readiness within Dutch municipalities the following hypotheses were formulated in line with the conceptual model:

H_1: Digital leadership competences have a positive effect on digital transformation.

H_2: IT capabilities have a positive effect on an organization's digital transformation.

3 Research Method

To investigate the influence of the e-leader towards the relationship between IT capabilities and digital transformation a quantitative research method was used that emphasises the quantification of the data collection and provides for analysis at the ordinal level. In the operationalization of this research, the existing e-competence framework has been used for collecting data in Dutch municipalities. The questionnaire, sent to over 1800 civil servants, contained all the constructs of the conceptual model which are measured using multiple items. As there were seven respondents with too many missing values and one that scored 1 on each question, the number of usable respondents after cleaning the dataset was 178. Respondents worked across different sizes of municipalities based on the number of employed persons (table 1). The period of data collection was between February 14th, 2022, and May 30th, 2022.

Table 1: Municipality size

	Sample (N=178)	**Proportion** (%)
Municipality size (number of employees)		
Less than 250	42	23.6%
250-999	90	50.6%
1000-4999	35	19.63%
Above 5000	11	6.17%

For this study, both business stakeholders and ICT stakeholders were invited to participate. Unfortunately, the municipal government has no uniformity regarding job titles, distribution of work and mandate (De Tuya et al., 2020). Therefore, to determine the target group, the most common job roles that are responsible and/or bear co-responsibility for digital transformation-related subjects were sought in the immediate vicinity of the researchers. From an inventory within 8 municipal organisations, 18 roles were frequently encountered. Participation requests were therefore sent to the following job roles: IT director, ICT manager, manager I&A, IV manager, CIO, alderman IT/IS, functional manager, technical manager, Information consultant, ICT director, Service Level Manager, CISO, Tiso (technical information security officer), data protection officer, municipal secretary, IT director, transition manager. The initial low response rate was partly mitigated by requesting some of the respondents to forward the request for participation within their own organisation towards the target group. This means that a request for snowball sampling was also used for approximately 25% of the invitations (Baarda et al., 2021).

In regard to the survey (containing 47 questions in total), questions on digital transformation and IT capabilities are taken from Nwankpa & Roumani (2016) who derived them from different studies: 4 on Infrastructure (Bharadwaj et al., 2000; Ross et al. 1996; Weill et al., 2002), 4 on Business Spanning (Bharadwaj et al., 2000; Mata et al., 1995), 4 on Proactive Stance (Lu & Ramamurthy, 2011; Weill et al., 2002), and 9 related to Digital Transformation (Aral & Weill, 2007). Questions (21) regarding Digital Leadership competencies have been reused from Ravesteyn and Ongena (2019). Besides this five general questions were posed to determine size of the organization (#employees and population), funtion of the respondent, and worklevel (strategic, tactic, operational).

The questions were presented via a 7-point Likert scale (Taherdoost, 2019). Across the entire data set (after cleaning) there were 60 missing values and as there was no more than 5% missing in any individual question we opted for the option 'mean replacement' during analysis in SmartPLS (Hair et al., 2021).

4 Results

4.1 Evaluation of Measurement Model

Given that it places less of a burden on the measurements and normal distribution (Gefen, et al., 2000; Hair, et al., 2011), partial least squares (PLS) is employed to evaluate the model (Chin, 1998). To evaluate the statistical significance of the loadings and the path coefficients, a bootstrap approach was performed (Hair et al., 2021). A non-parametric method of estimation called 'bootstrapping' involves resampling the original data with replacement in order to estimate each parameter in the PLS model (Chin, 2001). Prior to evaluating the structural model and testing the hypotheses, the measurement model is assessed to determine its reliability and validity using the software SmartPLS (Ringle et al., 2015).

4.1.1 Reflective Constructs

As shown in Table 2, Cronbach's alpha, Composite reliability and Average variance extracted (AVE) show that the internal consistency and convergent validity requirements are met. Also, the outer loadings are between 0.785 and 9.41 so meet the rule of thumb >0.7 hence all items can be retained.

Table 2: Construct reliability and validity

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Digital Transformation	0.942	0.943	0.963	0.897
IT Business Spanning	0.917	0.922	0.942	0.802
IT Infrastructure	0.831	0.838	0.887	0.662
IT Proactive Stance	0.919	0.921	0.943	0.805

The Fornell-Larcker criteria to assess discriminant validity is met (Fornell & Larcker, 1981) and this is also true for the assessment of cross-loadings. Finally, we used the heterotraitmonotrait ratio (HTMT) to accurately assess discriminant validity as there is discussion about whether the first two methods are effective in empirical applications (Franke & Sarstedt, 2019; Henseler, Ringle, & Sarstedt, 2015).

Based on Bootstrapping with 10,000 samples and a 0.05 significance level (one-sided) table 3 shows that discriminant validity is established as HTMT ratios are less than 0.90 and even below the more conservative threshold of 0.85 (Henseler, Ringle, & Sarstedt, 2015) therefore we conclude that the reflective measures are valid and can be used as a basis for further analysis.

Table 3: Heterotrait-monotrait ratios

		BS	INF	PS	DT
BS	Business Spanning				
INF	Infrastructure	0.772			
PS	Proactive stance	0.684	0.654		
DT	Digital Transformation	0.553	0.584	0.744	

4.1.2 Formative Constructs

To evaluate our formative measurement model (i.e. the constructs for digital leadership), we first test for possible collinearity issues. For this, we use the variance inflation factor (VIF) for which values of 5 or higher indicate significant collinearity issues (Hair, Risher, et al. 2019). We found that all VIF values are below the threshold of 5 therefore we conclude that there are no critical levels of collinearity. Subsequently, we used bootstrapping to test the significance and relevance of the outer weights of our model. All the weights present satisfactory significance levels except two. Items A5_2 of the Architecture Design construct and E7_2 of the Business Change Management construct are marked non-significant. However, when an indicator's weight is not significant, but the corresponding item loading is relatively high (>=0.50), or statistically significant, the item can be retained (Hair, Hult, Ringle, & Sarstedt, 2021). Since the loadings of A5_2 and E7_2 are respectively 0.847 and 0.800 both with p-value 0.000 we decided not to remove these items from the model.

4.2 Evaluation of Structural Model

We examined the significance and relevance of the structural model relationships. Here we not only discuss the significant direct effects but also any indirect effects on the endogenous construct of Digital Transformation (see figure 2) as the goal of our study is to advise municipalities on how to improve their readiness for digital transformation.

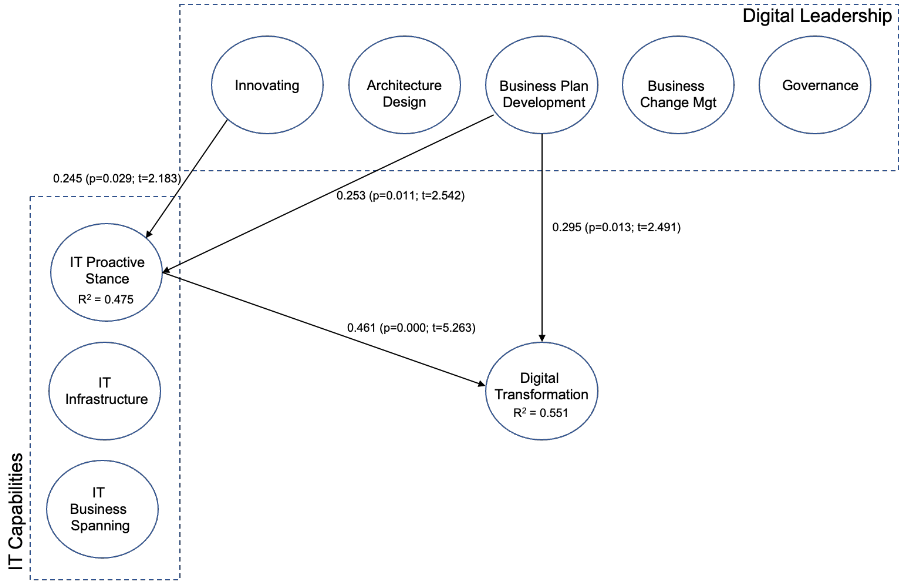

Figure 2: Estimated relationships of structural model

If we look at the relevance of the constructs, we find that from the digital leadership constructs Business Plan Development ($\beta = 0.295$, $t = 2.491$, $p < 0.013$) is significant while for the IT capability constructs the IT Proactive Stance path ($\beta = 0.461$, $t = 5.263$, $p < 0.000$) has a significant relation with Digital Transformation. However, since the IT capability constructs also act as a mediator on the key target variable Digital Transformation, we also need to look at the total effect. We then see that Business Plan Development ($\beta = 0.428$, $t = 3.412$, $p < 0.001$) has a much larger total effect on digital transformation (see table 4). Furthermore, we find that there is also a significant indirect effect of the Digital Leadership competence Innovating on Digital Transformation via Proactive Stance ($\beta = 0.245$, $t = 2.183$, $p < 0.029$).

Table 4: Total and Indirect Effects

	Original sample (O)	Standard deviation	*t*-value	*p*-values
Total Effects				
Businessplan dev.\DT	0.428	0.125	3.412	0.001
Innovating\IT Proactive Stance	0.245	0.112	2.183	0.029
Specific Indirect Effects				
Businessplan dev.\IT Proactive Stance\DT	0. 117	0.051	2.284	0.022
Innovating\IT Proactive Stance\DT	0.113	0.055	2.055	0.040

The explanatory power of our structural model (figure 2) is determined by examining the R^2 value of the endogenous latent variable Digital Transformation which with R^2=0.551 explains 55.1% of the variance and is considered moderate (Hair, Risher, Sarstedt, & Ringle., 2019). The effect sizes for Business Plan Development and IT Proactive Stance are respectively f^2=0.064 and f^2=0.218.

R^2 however only indicates the model's in-sample explanatory power (Shmueli 2010). To assess the model's out-of-sample predictive power. Shmueli et al. (2016) developed a holdout-sample-based procedure that generates case-level predictions on an item or a construct level to reap the benefits of predictive model assessment in PLS-SEM. To assess the predictive power of the model we executed a *k*-fold cross-validation with PLSpredict. The first step is to check whether Q^2 values are above zero which indicates that the model outperforms the most naïve predicted benchmark (Shmueli, Sarstedt, et al. 2019). This is the case for all the indicators in the dataset used in our study. The second step then is to compare the root mean squared error (RMSE) against the naïve linear regression model (LM) benchmark. An increasingly higher number of indicators that yields lower prediction errors in terms of RMSE when comparing the PLS-SEM analysis to the naïve LM benchmark shows a higher predictive power (Shmueli, Sarstedt, et al. 2019). Concerning the dependent variable Digital Transformation two PLS-SEM RMSE's values are higher than LM RMSE's (indicators DT_1 and DT_2). This indicates that the model has a low predictive power (Shmueli, Sarstedt, et al. 2019). Comparing RMSE's with regard to IT Proactive Stance, IT Business Spanning and IT Infrastructure shows that *all* indicators yield a lower prediction error in the PLS-SEM analysis. This indicates that the model has a high predictive power (Shmueli, Sarstedt, et al. 2019). Based on these analyses we conclude that the overall model has high predictive power and can therefore be used as a foundation for our recommendations to municipalities.

5 Recommendations and Discussion

To provide clear guidelines to municipalities that want to improve the way they use digital technologies to improve services we need to look at the underlying weights of the items in the constructs that we found to have a significant effect. For Business plan development we find that item A3_3 (0.481) scores highest compared to A3_1 (0.306) and A3_2 (0.355). Therefore, we recommend that municipalities should '*constantly apply strategic thinking and organizational leadership to exploit the capability of Information Technology to improve the business'* (A3_3). This confirms the attention for strategy found by McCarthy et al. (2021) who state: "prioritizing digital transformation as a strategic objective by influencing top management to put it top of their agenda" (p.10).

Similarly, for Proactive Stance the item weights are respectively ITCPS_1 (0.280), ITCPS_2 (0.277), ITCPS_3 (0.261) and ITCPS_4 (0.297). Although the items are more evenly weighted, ITCPS_4 '*We constantly seek new ways to enhance the effectiveness of IT use*' is rated highest and should therefore be a process that municipalities internalize. Furthermore, the importance of a focus on innovation (ITCPS_1) '*To constantly keep current with new information technology innovations'* supports the notion by Klein (2020) who found that "the most distinguished leadership characteristic in the era of digital transformation [..] is to be innovative visionary" (p.895). Another capability that municipalities should emphasize is to make sure to '*have people that are capable of and continue to experiment with new IT as necessary*' (ITCPS_2), which coincides with the "digital talent scout" characteristic mentioned by Klein (2020). Also important is the need to '*Create a climate that is supportive of trying out new ways of using IT*' (ITCPS_3), and this corresponds with the "digital culturalist" characteristic of digital transformation leadership found by McCarthy et al. (2021). Lastly, we also found a significant indirect effect of the Innovating competence on Digital Transformation via Proactive Stance. Looking at the underlying items we find that A9_1 (0.599) has the highest score compared to A9_2 (0.463). Even though the Innovating competence seems to be less important in this study (compared to Klein (2020)) it is worth mentioning as the underlying items are clearly in support of A3_3 and ITCPS_4 as the related principles that municipalities should adopt are '*to constantly apply independent thinking and technology awareness to lead the integration of disparate concepts for the provision of unique solutions*' (A9_1), and '*to constantly challenge the status quo and provide strategic leadership for the introduction of revolutionary concepts*' (A9_2).

Finally, what we didn't find in this study is an effect of the architecture design competence even though in the literature study by McCarthy et al. (2021) the "digital architect" characteristic was the second most found characteristic after "digital strategist".

6 Conclusion

With this study, we tried to determine the effect that digital leadership competences and IT capabilities have on digital transformation readiness within Dutch municipalities. We found that from the digital leadership competences only Business Plan Development had a direct effect on Digital Transformation while Innovating had an indirect effect via the IT Proactive Stance capability, which by itself also has a direct effect on Digital Transformation. Based on this we can state that the hypotheses we formulated are accepted for only some of the underlying constructs. While we advise municipalities to implement a range of activities that should enable them to 'constantly apply strategic thinking and organizational leadership to exploit the capability of Information Technology to improve the business', some final words of caution are necessary. Specifically, the number of respondents from large municipalities was limited so the difference between organization sizes has not been analyzed and might go unnoticed. Furthermore, the sample of respondents contains employees with a wide range of roles, which we haven't analyzed to determine if there are different views amongst specific groups that have traits in common. Similarly, cultural aspects might play a role during digital transformations so the outcomes in other countries might be different. Future studies are needed to provide more contextual insights into how Digital Leadership competences, IT Capabilities and Digital Transformation interact.

References

Alnuaimi, B. K., Sing, K. S., Ren, S., Budhwar, P., & Vorobyev, D. (2022). Mastering digital transformation: The nexus between leadership, agility, and digital strategy. Journal of Business Research 145, 636-648.

Alvarenga, A., Matos, F., Godina, R., & C. O. Matias, J. (2020). Digital Transformation and Knowledge Management in the Public Sector. Sustainability, 12(14), 5824. https://doi.org/10.3390/su12145824

Aral, S., & Weill, P. (2007). IT assets, organizational capabilities, and firm performance: How resource allocations and organizational differences explain performance variation. Organization science, 18(5), 763-780.

Baarda,B., Bakker, E., T.Fischer,T., Julsing & Vianen. (2021). Basisboek Methoden en Technieken Kwantitatief praktijkgericht onderzoek op wetenschappelijke basis: Vol. Zevende druk (Nummer Sociale methoden en technieken). Noordhoff Uitgevers BV. https://web-p-ebscohost- com.hu.idm.oclc.org/ehost/detail/detail?vid=0&sid=66738126-89fe-453e-9ffc-7d6aa815e62d%40redis&bdata=JnNpdGU9ZWhvc3QtbGl2ZSZzY29wZT1zaXRl#

Bharadwaj, A.S. (2000). A Resource-Based Perspective on Information Technology Capability and Firm Performance: An Empirical Investigation. MIS Quarterly, 24(1), 169-196. https://doi.org/10.2307/3250983

Blacquière, R., de Groot, M., & Serruys, M. (2021). I-strategie Rijk 2021 – 2025: Doorpakken op digitale transformatie. https://www.digitaleoverheid.nl/document/i-strategie-rijk-2021-2025/

Broadbent, M., Hansell, A., Dampney, N.G., Gilmour, P., Hardy, G. (March 1989) Business Strategic Orientation, Information Systems Strategic Orientation, and Strategic Alignment. International Journal of Information Management

Chin, W.W. (1998). The partial least squares approach to structural equation modeling. In Modern Methods for Business Research, edited by G.A Marcoulides, 1295–1336. Mahwah, N.J: Lawrence Erlbaum Associates.

Chin, W.W. (2001). PLS-Graph user's guide. CT Bauer College of Business, University of Houston, USA, 15, 1-16.

De Tuya, M., Cook, M., Sutherland, M., & Luna-Reyes, L.F. (2020). The leading role of the government CIO at the local level: Strategic opportunities and challenges. Government Information Quarterly, 37(3). https://doi.org/10.1016/j.giq.2017.01.002

Dunleavy, P., Margetts, H., Bastow, S., & Tinkler, J. (2006). New public management is dead: long live digital-era governance. Journal of Public Administration Research and Theory 16, 467-494

E-Competence Framework (e-CF) (2019). A common European Framework for ICT Professionals in all sectors—NEN- EN 16234-1:2019.

European Union (2009). Ministerial Declaration on eGovernment (2009). Accessed on July 20, 2022: https://administracionelectronica.gob.es/pae_Home/pae_Estrategias/pae_lineas_ccoperacion/pae_Cooperacion_Internacional/pae_estrategias_de_administracion_electronica/pae_Ambito_Europeo_- _Las_Declaraciones_Ministeriales.html?idioma=en#.YtfBZy-Qn0o

European Union (2017). Tallinn Declaration on eGovernment at the Ministerial Meeting during Estonian Presidency of the Council of the EU (2017). Accessed on April 15, 2022. https://digital-strategy.ec.europa.eu/en/news/ministerial-declaration-egovernment-tallinn-declaration

Elias, T., Ulenbelt, P., Fokke, M., Bruins Slot, H., & Van Meenen, P. (2015). Parlementair onderzoek naar ICT-projecten bij de overheid. 's Gravenhage: Tweede Kamer. Accessed June 10th 2022:

https://www.tweedekamer.nl/sites/default/files/field_uploads/33326-5-Eindrapport_tcm181-239826.pdf

Fornell, C., & Larcker, D.F. (1981). Evaluating structural equation models with unobservable variables and measurement error. Journal of marketing research, 18(1), 39-50.

Franke, G., & Sarstedt, M. (2019). Heuristics versus statistics in discriminant validity testing: a comparison of four procedures. Internet Research.

Gefen, D., Straub, D.W., & Boudreau, M. (2000). Structural equation modeling techniques and regression: Guidelines for research practice. Communications of AIS 4 (7): 1-77.

Hair, J.F., Hult, G.T.M., Ringle, C.M., & Sarstedt, M. (2021). A primer on partial least squares structural equation modeling (PLS-SEM). Sage publications.

Hair, J.F, Ringle, C.M, & Sarstedt, M. (2011). PLS-SEM: Indeed a silver bullet. Journal of Marketing Theory and Practice 19 (2): 139-152.

Hair, J.F, Risher, J.J., Sarstedt, M., & Ringle, C.M. (2019). When to use and how to report the results of PLS-SEM. European Business Review 31(1), 2-24.

Henseler, J., Ringle, C.M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. Journal of the Academy of Marketing Science 43 (1): 115-135

Hüsing, T., Korte, W. B., Fonstad, N., Lanvin, B., Cattaneo, G., Kolding, M., Lifonti, R., & van Welsum, D. (2013). e- Leadership: E-Skills for Competitiveness and Innovation Vision, Roadmap and Foresight Scenarios Final Report. 180.

Klein, M. (2020). Leadership Characteristics in the Era of Digital Transformation. Business & Management Studies: An International Journal, 8(1), 883–902.

Layne, K., & Lee, J. (2001). Developing fully functional E-government: A four stage model. Government Information Quarterly, 18(2), 122–136. https://doi.org/10.1016/ S0740-624X(01)00066-1

Lindgren, I., Madsen, C.Ø., Hofmann, S., & Melin, U. (2019). Close encounters of the digital kind: a research agenda fort he digitalization of public services. Government Information Quarterly, 36, 427-436.

Lu, Y., & Ramamurthy, K. (2011). Understanding the Link Between Information Technology Capability and Organizational Agility: An Empirical Examination. MIS Quarterly, 35(4), 931-954. https://doi.org/10.2307/41409967

Mao, H., Liu, S., Zhang, J., & Deng, Z. (2016). Information technology resource, knowledge management capability, and competitive advantage: The moderating role of resource commitment. International Journal of Information Management, 36(6), 1062–1074. https://doi.org/10.1016/j.ijinfomgt.2016.07.001

Mata, F. J., Fuerst, W. L., & Barney, J. B. (1995). Information technology and sustained competitive advantage: A resource-based analysis. MIS quarterly, 19(4), 487-505.

McCarthy, P., Sammon, D., & Alhassan, I. (2021): Digital Transformation Leadership Characteristics: A Literature Analysis, Journal of Decision Systems, DOI: 10.1080/12460125.2021.1908934

Morakanyane, R., Grace, A., & O'Reilly, P. (2017). Conceptualizing Digital Transformation in Business Organizations: A Systematic Review of Literature. Digital Transformation – From Connecting Things to Transforming Our Lives, 427–443. https://doi.org/10.18690/978-961-286-043-1.30

NEN (2018). European ICT professionals role profiles – Part 1 – CWA 16458-1. https://www.nen.nl/cwa-16458-1- 2018-en-250293

Njanka, S. Q., Sandula, G., & Colomo-Palacios, R. (2021). IT-Business Alignment: A Systematic Literature Review. Procedia Computer Science, 181, 333–340. https://doi.org/10.1016/j.procs.2021.01.154

Nwankpa, J., & Roumani, Y. (2016). IT Capability and Digital Transformation: A Firm Performance Perspective. ICIS 2016 Proceedings. https://aisel.aisnet.org/icis2016/ISStrategy/Presentations/4

Ravesteyn, P., & Ongena, G. (2019). The Role of e-Leadership in Relation to IT Capabilities and Digital Transformation. 12th IADIS International Conference Information Systems 2019, 171–179. https://doi.org/10.33965/is2019_201905L022

Ringle, C.M, Wende, S., & Becker, J.-M. (2015). SmartPLS 3. Boenningstedt: SmartPLS GmbH. http://www.smartpls.com.

Ross, J.W., Beath, C.M., & Goodhue, D. L. (1996). Develop long-term competitiveness through IT assets. MIT Sloan Management Review.

Shmueli, G. (2010). To explain or to predict? Statistical Science 25 (3): 289-310.

Shmueli, G., Hair, J.F., Sarstedt, M., Cheah, J.-H., Ting, H., Vaithilingam, S., & Ringle, C.M. (2019). Predictive model assessment in PLS-SEM: guidelines for using PLSpredict. European Journal of Marketing 53 (11): 2322-2347.

Shmueli, G., Ray, S., Velasquez Estrada, J.M., & Shatla, S.B. (2016). The elephant in the room: Evaluating the predictive performance of PLS models. Journal of Business Research 69 (10): 4552-4564

Taherdoost, H. (2019). What Is the Best Response Scale for Survey and Questionnaire Design; Review of Different Lengths of Rating Scale / Attitude Scale / Likert Scale; International Journal of Academic Research in Management.

Tangi, L., Janssen, M., Benedettie, M., & Noci Guiliano (2021). Digital government transformation: a structural equation modeling analysis of driving and impeding factors. International Journal of Information Management 60. https://doi.org/10.1016/j.ijinfomgt.2021.102356

Weill, P., Subramani, M., & Broadbent, M. (2002). IT infrastructure for strategic agility. Available at http://dx.doi.org/10.2139/ssrn.317307

The Impact of Innovation Objectives on Industry-Academia Collaboration. A Look Towards Sustainability

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The literature on innovation has been very prolific in highlighting the importance of companies developing new products, processes or business models in order to be more competitive in the marketplace. Empirical studies have shown that this innovative activity has translated into superior results for companies that have engaged in innovation. However, most of these initiatives have been studied mainly from the company's point of view without considering the contribution that academia can make to these innovation processes. This paper explores precisely how it is possible to achieve better results in innovation objectives through industry-academia collaboration (IAC). To this end, a sample of 7638 Spanish companies is analysed, distinguishing between those that have linked their innovation objectives to collaboration between the company and higher education centres. The results reveal that this IAC helps reinforce innovation objectives, demonstrating that the union of the academic and business worlds improves the results of business innovation processes. This has important theoretical implications as it offers new insights into the analysis of innovation processes and business implications as it proves that there is a need to develop platforms that encourage IAC.

Keywords: Industry-Academy collaboration; innovation objectives; business model innovation; economic, social, and environmental levels, sustainable BMI

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1 Introduction

In the last few years, Business Model Innovation (BMI) has gained significant interest among academics and professionals as an avenue for business development and for achieving above-average performance (Ghinoi & Di Toma, 2022). Its implementation is essential in order to foster long-term sustainable competitive advantage and to recognize new techniques to business organization (Kraus et al., 2020). Despite the growing literature in this research field, there are still many issues regarding BMI that remain limited (Foss & Saebi, 2017). The relationship between BMI and industry-academia collaboration (IAC) is one of them.

The engagement between university and industry or multi-stakeholder collaboration has the potential to generate synergies both for industry and academia (Haug, 2018) and results in higher levels of innovation and advances in knowledge, technological enhancements, and industry objectives (Arshed et al., 2022). Universities provide workforce that can be useful to firms, and are the source of innovative ideas to set up new business ventures (Ahmed et al., 2022). Based on this, when industry require research in unknown areas where they do not have access yet, they look for academia. Besides, this educational institution has the knowledge expertise and the research methods to designed solutions which are valid and relevant, so that industries should benefit from its collaboration (Burova et al., 2021). Several topics regarding IAC and innovation have been addressed in the literature, specially related to technology transfer (Blundi et al., 2019; Ravi & Janodia, 2022). To the best of our knowledge, there is no research that assesses the relationship between BMI objectives and IAC.

We consider that BMI objectives may lead a company to decide to collaborate with research institutions as a means to achieve them. To fill this gap, this research has a twofold objective: on the one hand, to determine whether the importance that firms give to BMI objectives is higher when they collaborate with universities; and, on the other hand, to identify which of these innovation objectives contribute to IAC. On this purpose, data was drawn from the Spanish (Eurostat) Community Survey (CIS) for 2014-2016 in order to evaluate if there is an influence of BMI objectives on the collaboration between industry and university. In addition, through hierarchical logistic regression a set of seven BMI objectives, classified with the Triple Layered

Business Model Canvas (TLBMC), have been identified which contribute to collaboration between companies and universities.

The remaining paper is structured as follow. First, we provide a review of the salient literature on BMI and Industry-Academia Collaboration. Next, the methodology to collect data from 7,638 Spanish organizations is detailed. Then, the results of the empirical analysis are discussed. Finally, conclusions are summarized in section five.

2 Business Model Innovation Objectives and Industry-Academia Collaboration: Literature review

The term business model was introduced for the first time by Bellman et al. (1957) (Groesser & Jovy, 2016), yet it was the arrival of internet and the expansion of information and communication technologies (ICT) that prompted it to be explored to a greater extend in the 1990s (DaSilva & Trkman, 2014). Despite the fact that there is a large number of definitions provided regarding the concept; many contributions to the literature agree with the notion of business model as "the logic the firm follows to operate its resources and to create and capture value for external and internal stakeholders" (Ammar & Chereau, 2018, p. 2). A business model is built on the three main value dimensions of a business: the creation, delivery, and value capture (Clauss et al., 2020). Value creation occurs when a firm matches the customer's demands with a re-organisation of its resources which lead to enhanced efficient (Kraus et al., 2020); value delivery explains the mechanisms how to bring the created value to the customers (Dahan et al., 2010; Spieth et al., 2021), and the value capture indicates how a firm will obtain money from developing its activity (Osterwalder & Pigneur, 2010).

In this context, innovation constitutes one of the cornerstones of business model (Budler et al., 2021). BMI is essential for business sustainability (Breier et al., 2021) and represents a source of a firm's competitive advantage (Latifi et al., 2021; Pieroni et al., 2019). Although there is no consensus on its definition, we follow Foss & Saebi, (2017, p. 201) who state that it can be understood as "designed, novel, nontrivial changes to the key elements of a firm's business model and/or the architecture linking these elements". While business model objectives refer to the overall business objective that a company seeks to achieve in developing or shaping its business model (Molina-Castillo et al., 2019); innovation objectives comprises a firm's distinguishable aims that depict intentions and strategies that involve innovation efforts (OECD & European Comission, 2018). Based on this, we refer to BMI objectives as those that involve innovation efforts and imply novel, trivial and designed modifications in a firm's business model. Thus, these innovation objectives may lead to innovation activities and performance (Meroño-Cerdan & López-Nicolas, 2013).

Literature on BMI has pointed out several tools and path to design and assist it (Heikkila et al., 2016). Nowadays, businesses are required to innovate their business models by creating sustainable value on its economic, social, and environmental levels (López-Nicolás et al., 2021). The TLBMC thus constitutes a tool which provides a full understanding of the business model of a company, includes the three levels previously mentioned and that support sustainability-oriented BMI (Joyce & Paquin, 2016). More specifically, the economic layer consists of the Business Model Canvas proposed by Osterwalder & Pigneur (2010), which distinguish nine modules which are interrelated with each other, being these: customer value proposition, segments, customer relationships, distribution channels, key resources, key activities, partners, costs and revenues. Moreover, Joyce & Paquin (2016) describe the aim and composition of the aforementioned two other layers of the business model, the environmental and the social. These authors state that the former has as its main purpose to assess how a firm can produce further environmental benefits than environmental effects and encompasses functional value, materials, production, supplies and outsourcing, distribution, use phase end-of-life and environmental impacts and benefits; the latter attempts to capture what are the key social impacts of the organization that derive from its relationships; and its components are social value, employee, governance, communities, societal culture, scale of outreach, end-users and social impacts and benefits.

We consider that there are several BMI objectives that not only do focus on specific areas of the business model, but they also drive firms to collaborate with other stakeholders. The IAC may be a way for achieving BMI and for generating synergies both for industry and for academia (Arshed et al., 2022). In fact, among the main benefits resulting from this collaboration, we can remark the emergence of general solutions to issues related to products or service offering, which encourages innovation in the business model (Sjöö & Hellström, 2021). For achieving this, (Vico et al., 2015) find as the main reasons to start a collaboration the following: assistance in problem solving, provision of specialized services, patent generation and introducing innovations (e.g., new products, processes, findings from research, etc.).

In this research, several BMI objectives have been classified within the different layers of the TLBMC to determine which of them encourage the company to collaborate with universities or IAC. Specifically, Table 1 shows to which business model dimension and layer the analyzed BMI objectives would correspond – remarking that most of the objectives are linked to the dimension of value creation.

Table 1: Integration of dimensions layers of business model and business model innovation objectives

Dimension	Layer	BMI Objective
Value creation	Economic	Expand the grade of good and services
		Replace obsolete products or processes
		Improve quality of goods or services
		Improve flexibility for producing goods or delivering services
		Increase the capacity of producing goods or delivering services
	Environmental	Reduce material per unit of output
		Reduce energy per unit of output
		Reduce negative environmental impacts/ deliver environmental benefits
		Improve public health, safety or security
		Comply with mandatory regulations
	Social	Total employment growth
		Increase in qualified employment
		Maintenance of employment
Value delivery	Economic	Enter new markets
		Increase market share
Value capture	Economic	Reduce labour costs per unit of output
	Environmental	Reduce energy per unit of output
		Reduce negative environmental impacts/ deliver environmental benefits
		Improve public health, safety or security
		Comply with mandatory regulations

Source: Own ellaboration based on Joyce & Paquin, (2016) and OECD & European Comission, (2018)

3 Methodology

Our dataset comes from Spanish Community Innovation Survey (CIS). The CIS questionnaire is extensively used in most European countries, especially in the UK, France, Spain, and Italy (e.g., Aronica et al., 2022; Evangelista & Vezzani, 2010; Ganter & Hecker, 2013; Hervas-Oliver et al., 2014, 2015; Lubacha & Wendler, 2021; Wei et al., 2022) but also considered the most influential innovation questionnaire even in non-EU countries (Wei et a., 2022). It has become an interesting source of research data to study complementarities between different forms of innovation (Ballot et al., 2015). This survey, conducted by the Spanish National Statistics Institute, provides information about the innovation process, its structure, the relationships between that process and firms' technological strategy, the factors affecting their capability to innovate and companies' performance. The respondent units (companies) are sent a letter of presentation of the survey, which includes the user and password for online completion. Since 2013, access to web completion is carried out via the secure protocol page https://iria.ine.es. Once this letter has been received, companies have a period of 15 days to complete and send the questionnaire. The Statistics Institute establishes an initial telephone contact with the company to check that the questionnaire has been received. If the completed questionnaire has not been received by the deadline, the necessary telephone and written complaints will be made. The monitoring of the data collection schedule and the quality control of the information has been carried out by Statistics Institute's Central Services. The response rate was 93,17 percent.

The 2016 survey addressed innovation activity for the period 2014-2016. The sample for that period consisted of 7,638 companies with a minimum size of 10 employees operating in different sectors (agriculture, construction, industry, commerce, and services). When using CIS data, a potential bias may arise related to the sample selection problem. Because of the CIS questionnaire structure, some variables regarding innovation are available only for firms which have introduced at least one process or one product innovation. This may create a selection bias if the econometric analysis is limited to that sub-sample of companies which is likely to be not randomly drawn from the larger population. This type of bias may distort coefficients. As in other studies (Evangelista & Vezzani, 2010), the choice of variables used here and our estimation strategy allows us to include all the firms present in the CIS sample, avoiding the selection bias problem mentioned.

A description of variables included in the analysis is given in Table 2. All of them comes from Oslo Manual (OECD & European Comission, 2018; OECD & Eurostat, 2005).

Table 2: Variable in the analysis

Variable	Scale
Dependent variable: Industry-Academia Collaboration (in the 2014-2016 period)	Dummy variable (1=collaboration, 0=non-collaboration)
Independent variables: Importance of business model innovation objectives	Continuous variables from 1 (noimportance) to 4 (high importance)
Economic objectives: - Wider range of goods or services (OBJ_1) - Substitution of outdated products or processes (OBJ_2) - Penetration into new markets (OBJ_3) - Increased market share (OBJ_4) - Higher quality of goods or services (OBJ_5) - Greater flexibility in production or service provision (OBJ_6) - Greater production capacity or provision of services (OBJ_7) - Lower labour costs per unit produced (OBJ_8) - Less materials per unit produced (OBJ_9) - Less energy per unit produced (OBJ_10) Specifically, objectives 1 to 5 refer to "product innovation" and objectives 6 to 10 refer to "innovation in process".	1-4 interval
Environmental objectives: - Less environmental impact (OBJ_11) - Improved health and safety (OBJ_12) - Compliance with Environmental, Health or Safety Regulatory Requirements (OBJ_13)	1-4 interval
Social objectives:	1-4 interval

- Increase in total employment (OBJ_14) - Increase in qualified employment (OBJ_15) - Maintenance of employment (OBJ_16)	
Control variables	
Firm year	Dummy variable: 0= mature company (more than 10 years); and 1= young company (up to 10 years).
Firm sector	Continuous variable that takes the values: 0=Agriculture, 1=Industry, 2=Construction, 3=Commerce and 4=Services)

4 Results

Before stimating the regression model, ANOVA tests were carried out. Although not presented here due to extension limits, ANOVA results show the importance that companies give to BMI objectives depending on whether or not they collaborate with universities in the 2014-2016 period. In general, the means obtained in each objective are higher when the company collaborates with a higher education institution. In addition, these means are especially high regarding economic objectives –both those referring to product innovation and to process innovation. Going further, the differences in means are statistically significant in all objectives. This allows us to affirm that the importance that companies give to innovation (economic, environmental, and social) objectives are greater when the organization collaborates with the university compared to those firms which do not collaborate with higher education institution.

Table 3 shows the results of the hierarchical logistic regression. The dependent variable in all the models is the company-university collaboration, while the independent and control variables vary depending on the model; in particular, Model 1 includes the constant and firm age; Model 2 adds the sector; and Model 3 adds economic, environmental, and social objectives. Focusing on Model 3 (which is the one that includes BMI objectives as independent variables), we obtain that the seven objectives that statistically contribute to collaboration between companies and universities are: (i) wider range of goods or services; (ii) penetration into new markets, (iii) increased market share; (iv) less environmental impact; (v) improved health and safety; (vi) increase in total employment; and (vii) increase in qualified employment. Among them, we appreciate how three are economic objectives (all of them related to product innovation), two are environmental objectives, and the remaining two are social objectives.

Table 3: Hierarchical Logistic Regression

	Collaboration with universities		
	Model 1	Model 2	Model 3
Wider range of goods or services (OBJ_1)			0.170***
Substitution of outdated products or processes (OBJ_2)			-0.058
Penetration into new markets (OBJ_3)			0.186***
Increased market share (OBJ_4)			-0.154**
Higher quality of goods or services (OBJ_5)			0.085
Greater flexibility in production or service provision (OBJ_6)			0.000
Greater production capacity or provision of services (OBJ_7)			-0.017
Lower labour costs per unit produced (OBJ_8)			-0.023
Less materials per unit produced (OBJ_9)			-0.040
Less energy per unit produced (OBJ_10)			0.111
Less environmental impact (OBJ_11)			0.379*
Improved health and safety (OBJ_12)			-0.063***
Compliance with environmental, health or safety regulatory requirements (OBJ_13)			-0.034
Increase in total employment (OBJ_14)			-0.250***
Increase in qualified employment (OBJ_15)			0.467***
Maintenance of employment (OBJ_16)			0.103
Firm year	0.520	0.500	0.598
Constant	-1.436***	-1.429***	-3.761***
Sector Control	No	Yes	Yes
Chi-squared (model)	2.114	47.778***	433.795***
R-squared	0.001	0.017	0.146

5 Conclusions

As highlighted at the beginning of this paper, the study of IAC requires further analysis to discover how to improve the innovation processes that can be developed. The results show that there are essential benefits at a business level when the company actively collaborates with the academic world, demonstrating how unity is a strength and allows better results to be achieved than when this collaboration is not carried out (Yi et al., 2022). There is no doubt that the company has a deep understanding of the needs of its customers as it has developed its products precisely to meet those needs (Keiningham et al., 2020). But academia also has much to offer to complement this activity as it is responsible for analyzing in detail the cognitive processes by which customers decide to purchase one product rather than another from among those available in the set under consideration (Wijekoon et al., 2021). In the academic world, this is usually carried out with experimental studies with subjects and nowadays it is very common to analyze aspects of neuromarketing applied to the marketing of new products (Kansra et al., 2022).

In this vein, we observe how IAC is fundamental when it comes to achieving innovation objectives related to the development and launch of new products on the market (Liu et al., 2022). Analogously, we see how the study results demonstrate that IAC is very useful for penetrating new markets and increasing market share (Canabal & White, 2008). Companies collaborating with universities have probably benefited from all the predictive models of new product adoption that have long been developed in academia (Rogers, 2003). Researchers devote significant effort to understanding how a new product can reach the market earlier and better than the product with which it competes (Suarez et al., 2015). In fact, the modelling of consumer adoption processes developed by academics is becoming increasingly complex.

We also see how the results clearly demonstrate the impact on employment aspects through IAC. In this way, objectives related to improving employment and job quality are actively promoted when a business collaborates with academia (Mohammadi et al., 2017). This is undoubtedly a fundamental fact that should be actively considered from a governmental policy point of view. Companies require a skilled workforce but at the same time a workforce that matches the specific skills demanded by these organisations (Schweisfurth & Raasch, 2018). The academic world must try to adapt its teaching processes, learning methodologies and contents to the business reality. Our results show that this IAC could have significant social implications in this sense.

However, we also find that other innovation objectives have not shown significant results from IAC. It is, therefore essential to further explore how to improve IAC to better design collaborative business models that allow for fewer materials per unit produced or greater flexibility in production or service provision (Heirati & Siahtiri, 2019). In the same way, longitudinal studies on these collaborative processes could shed light on the barriers that may exist in these types of collaborations that are difficult to analyze in cross-sectional studies (Bitetti & Gibbert, 2022). To this end, it is essential to support initiatives at the European level to develop platforms that favour IAC. A clear example of this is the venture alliances platform (https://www.venturealliances.eu) that, for the last year has been helping companies and academics to find the right partner so that they can achieve innovation objectives that to date, have been studied in isolation between industry and academia. This work also reveals the need to replicate this work in other countries to verify the benefits of collaboration and how it contributes to improving the development of new products, processes, and innovative and sustainable business models.

References

Ahmed, F., Fattani, M. T., Ali, S. R., & Enam, R. N. (2022). Strengthening the Bridge Between Academic and the Industry Through the Academia-Industry Collaboration Plan Design Model. Frontiers in Psychology, 13, 875940. https://doi.org/10.3389/fpsyg.2022.875940

Ammar, O., & Chereau, P. (2018). Business model innovation from the strategic posture perspective An exploration in manufacturing SMEs. European Business Review, 30(1), 38-65. https://doi.org/10.1108/EBR-09-2016-0119

Aronica, M., Fazio, G., & Piacentino, D. (2022). A micro-founded approach to regional innovation in Italy. Technological Forecasting and Social Change, 176, 121494. https://doi.org/10.1016/j.techfore.2022.121494

Arshed, N., Ahmad, W., & Hanif, U. (2022). A Spatial Temporal Exploration of Factors Motivating Academia-Industry Collaboration. Journal of the Knowledge Economy, 13(1), 521-540. https://doi.org/10.1007/s13132-021-00729-6

Ballot, G., Fakhfakh, F., Galia, F., & Salter, A. (2015). The fateful triangle: Complementarities in performance between product, process and organizational innovation in France and the UK. Research Policy, 44(1), 217-232. https://doi.org/10.1016/j.respol.2014.07.003

Bellman, R., Clark, C., Malcom, D., Craft, C., & Ricciardi, F. (1957). On the construction of a multi-stage, multi-person business game. Operations Research, 5(4), 469-503.

Bitetti, L., & Gibbert, M. (2022). The ROAD to continuous business model innovation: A longitudinal study unveiling patterns of cognitive sensing dynamic capabilities. Creativity and Innovation Management, 31(1), 123-140. https://doi.org/10.1111/caim.12477

Blundi, D., Nonato, A. C., Medeiros, S., Filgueiras, J., Veiga, F., Travassos, G., & Oring, V. (2019). Technology Appropiation and Technology Transfer in the Brazilian Mining Sector.

Breier, M., Kallmuenzer, A., Clauss, T., Gast, J., Kraus, S., & Tiberius, V. (2021). The role of business model innovation in the hospitality industry during the COVID-19 crisis. International Journal of Hospitality Management, 92, 102723. https://doi.org/10.1016/j.ijhm.2020.102723

Budler, M., Župič, I., & Trkman, P. (2021). The development of business model research: A bibliometric review. Journal of Business Research, 135, 480-495. https://doi.org/10.1016/j.jbusres.2021.06.045

Burova, A., Heinonen, H., Becerril Palma, P., Keskinen, T., Hakulinen, J., Opas, V., Mäkelä, J., Ronkainen, K., Siltanen, S., Raisamo, R., & Turunen, M. (2021). Toward Efficient Academia-Industry Collaboration: A Case Study of Joint VR System Development. Academic Mindtrek 2021, 176-185. https://doi.org/10.1145/3464327.3464367

Canabal, A., & White, G. O. (2008). Entry mode research: Past and future. International Business Review, 17(3), 267-284. https://doi.org/10.1016/j.ibusrev.2008.01.003

Clauss, T., Bouncken, R. B., Laudien, S., & Kraus, S. (2020). Business model reconfiguration and innovation in SMEs: A mixed-method analysis from the electronics industry. International Journal of Innovation Management, 24(2). https://doi.org/10.1142/S1363919620500152

Dahan, N., Doh, J., Oetzel, J., & Yaziji, M. (2010). Corporate-NGO collaboration: Co-creating new business models for developing markets. Long Range Planning, 43(2-3), 326-342.

DaSilva, C. M., & Trkman, P. (2014). Business Model: What It Is and What It Is Not. Long Range Planning, 47(6), 379-389. https://doi.org/10.1016/j.lrp.2013.08.004

Evangelista, R., & Vezzani, A. (2010). The economic impact of technological and organizational innovations. A firm-level analysis. Research Policy, 39(10), 1253-1263. https://doi.org/10.1016/j.respol.2010.08.004

Foss, N. J., & Saebi, T. (2017). Fifteen Years of Research on Business Model Innovation: How Far Have We Come, and Where Should We Go? Journal of Management, 43(1), 200-227. https://doi.org/10.1177/0149206316675927

Ganter, A., & Hecker, A. (2013). Deciphering antecedents of organizational innovation. Journal of Business Research, 66(5), 575-584. https://doi.org/10.1016/j.jbusres.2012.02.040

Ghinoi, S., & Di Toma, P. (2022). Conceptualising business model innovation: Evidence from the managers' advice network. Innovation, 24(2), 251-271. https://doi.org/10.1080/14479338.2021.1885298

Groesser, S. N., & Jovy, N. (2016). Business model analysis using computational modeling: A strategy tool for exploration and decision-making. Journal of Management Control, 27(1), 61-88. https://doi.org/10.1007/s00187-015-0222-1

Haug, G. (2018). Universidades y empresas: Apuntes para crear sinergias con sentido.

Heikkila, M., Bouwman, H., Heikkila, J., Haaker, T., Lopez-Nicolas, C., & Riedl, A. (2016, junio 19). Business Model Innovation Paths and Tools. 29th Bled eConference Digital Economy, Bled, Slovenia.

Heirati, N., & Siahtiri, V. (2019). Driving service innovativeness via collaboration with customers and suppliers: Evidence from business-to-business services. Industrial Marketing Management, 78, 6-16. https://doi.org/10.1016/j.indmarman.2017.09.008

Hervas-Oliver, J.-L., Sempere-Ripoll, F., & Arribas, I. (2015). Asymmetric modeling of organizational innovation. Journal of Business Research, 68(12), 2654-2662. https://doi.org/10.1016/j.jbusres.2015.04.005

Hervas-Oliver, J.-L., Sempere-Ripoll, F., & Boronat-Moll, C. (2014). Process innovation strategy in SMEs, organizational innovation and performance: A misleading debate? Small Business Economics, 43(4), 873-886. https://doi.org/10.1007/s11187-014-9567-3

Joyce, A., & Paquin, R. L. (2016). The triple layered business model canvas: A tool to design more sustainable business models. Journal of Cleaner Production, 135, 1474-1486. https://doi.org/10.1016/j.jclepro.2016.06.067

Kansra, P., Oberoi, S., Gupta, S. L., & Singh, N. (2022). Factors limiting the application of consumer neuroscience: A systematic review. Journal of Consumer Behaviour, cb.2131. https://doi.org/10.1002/cb.2131

Keiningham, T., Aksoy, L., Bruce, H. L., Cadet, F., Clennell, N., Hodgkinson, I. R., & Kearney, T. (2020). Customer experience driven business model innovation. JOURNAL OF BUSINESS RESEARCH, 116, 431-440. https://doi.org/10.1016/j.jbusres.2019.08.003

Kraus, S., Filser, M., Puumalainen, K., Kailer, N., & Thurner, S. (2020). Business Model Innovation: A Systematic Literature Review. International Journal of Innovation and Technology Management, 17(06), 2050043. https://doi.org/10.1142/S0219877020500431

Latifi, M.-A., Nikou, S., & Bouwman, H. (2021). Business model innovation and firm performance: Exploring causal mechanisms in SMEs. Technovation, 107. https://doi.org/10.1016/j.technovation.2021.102274

Liu, A., Gu, J., & Liu, H. (2022). The fit between firm capability and business model for SME growth: A resource orchestration perspective. R&D Management, 52(4), 670-684. https://doi.org/10.1111/radm.12513

López-Nicolás, C., Ruiz-Nicolás, J., & Mateo-Ortuño, E. (2021). Towards Sustainable Innovative Business Models. Sustainability, 13(11), 5804. https://doi.org/10.3390/su13115804

Lubacha, J., & Wendler, T. (2021). Do European firms obey the rules? Environmental innovativeness in light of institutional frameworks. Industry and Innovation, 28(9), 1196-1223. https://doi.org/10.1080/13662716.2021.1929869

Meroño-Cerdan, A. L., & López-Nicolas, C. (2013). Understanding the drivers of organizational innovations. The Service Industries Journal, 33(13-14), 1312-1325. https://doi.org/10.1080/02642069.2013.815736

Mohammadi, A., Broström, A., & Franzoni, C. (2017). Workforce Composition and Innovation: How Diversity in Employees' Ethnic and Educational Backgrounds Facilitates Firm-Level Innovativeness: WORKFORCE COMPOSITION AND INNOVATION. Journal of Product Innovation Management, 34(4), 406-426. https://doi.org/10.1111/jpim.12388

Molina-Castillo, F.-J., Meroño-Cerdan, A.-L., & López-Nicolás, C. (2019). Impact of business model objectives on marketing innovation activities: A comparison between manufacturing and service firms. European Journal of Innovation Management, 23(1), 177-195. https://doi.org/10.1108/EJIM-12-2018-0259

OECD, & European Comission (Eds.). (2018). Oslo manual 2018: Guidelines for collecting, reporting and using data on innovation (4th edition). OECD Publishing. https://doi.org/10.1787/9789264304604-en

OECD, & Eurostat. (2005). Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data. (Third Edition).

Osterwalder, A., & Pigneur, Y. (2010). Business model generation. (Self published). Deuto.

Pieroni, M. P. P., McAloone, T. C., & Pigosso, D. C. A. (2019). Configuring New Business Models for Circular Economy through Product-Service Systems. Sustainability, 11(13). https://doi.org/10.3390/su11133727

Ravi, R., & Janodia, M. D. (2022). Factors Affecting Technology Transfer and Commercialization of University Research in India: A Cross-sectional Study. Journal of the Knowledge Economy, 13(1), 787-803. https://doi.org/10.1007/s13132-021-00747-4

Rogers, E. M. (2003). Diffusion of innovations (5th ed). Free Press.

Schweisfurth, T. G., & Raasch, C. (2018). Absorptive capacity for need knowledge: Antecedents and effects for employee innovativeness. Research Policy, 47(4), 687-699. https://doi.org/10.1016/j.respol.2018.01.017

Sjöö, K., & Hellström, T. (2021). The two sides of the coin: Joint project leader interaction in university-industry collaboration projects. R&D Management, 51(5), 484-493. https://doi.org/10.1111/radm.12452

Spieth, P., Laudien, S. M., & Meissner, S. (2021). Business model innovation in strategic alliances: A multi-layer perspective. R&D Management, 51(1), 24-39. https://doi.org/10.1111/radm.12410

Suarez, F. F., Grodal, S., & Gotsopoulos, A. (2015). Perfect timing? Dominant category, dominant design, and the window of opportunity for firm entry: Perfect Timing? Dominant Category and Window of Entry. Strategic Management Journal, 36(3), 437-448. https://doi.org/10.1002/smj.2225

Vico, M. L., Nina, M. R., & Torres, J. V. (2015). ¿Qué quieren las empresas de las universidades? Oportunidades de colaboración para desarrollar innovaciones. Forum Empresarial. Centro de Investigaciones Comerciales e Iniciativas Académicas., 3(1.1), 1-11.

Wei, J., Li, Y., Liu, X., & Du, Y. (2022). Enterprise characteristics and external influencing factors of sustainable innovation: Based on China's innovation survey. Journal of Cleaner Production, 372, 133461. https://doi.org/10.1016/j.jclepro.2022.133461

Wijekoon, A., Salunke, S., & Athaide, G. A. (2021). Customer heterogeneity and innovation-based competitive strategy: A review, synthesis, and research agenda. Journal of Product Innovation Management, 38(3), 315-333. https://doi.org/10.1111/jpim.12576

Yi, Y., Chen, Y., & Li, D. (2022). Stakeholder ties, organizational learning, and business model innovation: A business ecosystem perspective. Technovation, 114, 102445. https://doi.org/10.1016/j.technovation.2021.102445

YOUNG ADULTS' ATTITUDE TOWARDS DIGITAL PAYMENT METHODS AND FINANCIAL RESPONSIBILITY

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There are numerous online payment methods when shopping online. This paper presents the evolution of payment methods through the years and investigates which payment methods young adults prefer and investigates if and how modern payment methods affect financial responsibility among young adults. The study was conducted through a survey and follow-up interviews with Swedish young adults. 75% claimed they make online purchases 1-3 times a week or more, of which 35% always check their bank account before paying. The study suggests that direct payment using their smart device (Swish) is the most preferred payment method. The research suggests that it is the combination of the different payment methods available that is impacting financial responsibility among young adults rather than the payment method itself.

Keywords:
payment methods, financial responsibility, finance, purchase behaviour, Bled eConference

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1 Introduction

Traditionally money (cash) was handled banks. When you wanted to use the money, you had to walk to the bank so the teller could hand it over to you. Then you had to take the money to the store if you wanted to buy something (Eriksson, & Sandhill, 2019). In the early 60s, debit cards were launched as the first step toward digitalizing payments (Leblebici, 2012; Lauer, 2020). The debit card was similar to the check, but its infrastructure and payment guarantee to the seller eventually outcompeted checks and cash (Wisehn, 2019). About 10 years later, Michael Aldrich invented a system that came to be the foundation of e-commerce (Aldrich, 2011). The breakthrough for online payments and e-commerce happened in the early 90s and big tech companies such as PayPal and Amazon worked hard to lead the market forward (Ferrera & Kessedjian, 2019). In 2005, The National Federation coined the term "Cyber Monday", due to the high number of online transactions carried out during Thanksgiving that year (McFerrin, 2021). For 30 years, online payments and e-commerce have constantly developed. Since almost all payments and transactions are something that can be done by yourself without interaction with another human party, the teller in the bank, is now no longer needed. The list of different ways of paying on the internet is long, but all of them have one thing in common, they strive toward making the experience for the customers as easy as possible (van der Cruijsen, & Plooij, 2018; Page, 2021).

2 Research Objectives

With the rise of the cashless society and the ephemeral nature of digitalization payments means that young people have grown up in an environment where payments are more straightforward, accessible, and frictionless (Senali et al., 2022; Tatum, 2022). The digitalization of payment methods and the rise of "buy now pay later" schemes have seen increasing numbers of young people experiencing debt and financial distress (Coffey et al., 2023). This paper aims to understand young adult's approach to finance in the context of how different payment methods can affect financial responsibility among young adults. To answer this, the following research questions have been formulated:

1. Which online payment methods do young adults use and prefer today?
2. How do online payment methods affect young adult's level of financial responsibility?

3 Literature Review

The following section will introduce some key concepts of this study.

3.1 Financial responsibility

Financial responsibility is a term that is used when talking about the process of handling money and assets in a way that is considered productive and in the best interest of the individual. Financial responsibility is about having a mindset where you can look beyond the wants of today to be able to provide the needs of tomorrow (Senali et al., 2022; Tatum, 2022).

3.2 BankID

BankID is a Swedish digital ID launched in 2002. It is an electronic ID document that can be compared with a national ID card and is based on the Swedish personal number that is unique for each citizen. BankID makes it possible for companies, banks, authorities, and other organizations to identify and enter into agreements with private persons via the internet. BankID has become an effective addition to the individual security device that many banks provide (BankId, n.d.-a). Today, 12 of Sweden's biggest banks use BankID as an identification service which means that when paying online with third-party payment methods, such as Klarna and Swish, the identification will be handled through BankID. The identifying process, when paying online, only consists of reading through the information about the purchase (amount of money and receiver) and confirming with either a code consisting of digits or any other smartphone unique verification procedure, such as fingerprint or facial recognition (BankID, n.d.-b).

3.3 Digital Payment Methods

The following section describes five different payment methods that will be covered in this study. The payment methods are commonly used in Sweden, and some only operate in Sweden (Arvidsson, 2019; Insight Intelligence, 2020).

1) *Klarna:* Klarna is a global leading payment and shopping service that currently provides 150 million active customers with a flexible and smart purchase experience. In Sweden, Klarna offers three different ways of paying – (1) Direct payment, which means that the money is drawn from the account straight away, (2) Pay after delivery with "Klarna – Pay in 30 days" ("Klarna – Få först. Betala sen" in Swedish), which means that the customer do not have to pay until receiving the goods, and (3) Instalment plans where the customer can spread the cost of their purchase over up to 36 months. All the payments and purchases can be handled in Klarna's mobile app or website (Klarna, 2022).

2) *Swish:* Swish is a Swedish mobile-based payment method where the user can send money through an app that is directly connected to their bank account (Arvidsson, 2019). It was launched in 2012 as a service for payments between private users. In 2014, Swish expanded to companies and organizations (Swish, n.d.). As of 2022, Swish has over 8.3 million private users and over 300,000 connected companies, and during June 2022 around 40 billion SEK was sent via Swish (Arvidsson, 2019; Swish, 2022).

3) *Apple Pay:* Apple Pay is a way of handling payments, both in physical stores and online. The bank card is connected to Apple Pay through a unique device number and a unique transaction code. This means that the personal card number is never stored directly on the device and runs less chance of getting hijacked. When paying online with Apple Pay no confirmation with an external verification service is needed. Depending on the device the confirmation can be done with either Face ID, Touch ID, or passcode (Apple, n.d.).

4) *Invoice:* An invoice is a physical or electronic document that contains a payment claim. It can be sent from one company to another company or to a private person. All online banks work differently, but paying an invoice is often carried out similarly (Hansson, 2022).

5) *Card payment:* Card payment is when the payment is done directly by using a bank card. To complete the purchase, the card number, the card's validity period, and the CVC code need to be entered. Often the purchase will have to be confirmed via a third-party security service, such as BankId (Swedbank, n.d.).

4 Method

The study was carried out by using a survey with follow-up interviews. The survey was created with the tool Typeform and was sent out via Facebook and Slack. The target group of the study is young adults, which are defined as men and women between 18-25 years old. The respondents were selected from Umeå University and We Know It, a consultant firm for students. The reason behind the choice was for the respondents to preferably be young adults and somehow be experienced with digital payment methods.

4.1 Survey questions

The first part of the study aimed to collect demographic data about the user. Questions such as age, gender, and daily occupation were asked. The second part of the survey consisted of questions regarding which payment method the respondent prefers and most frequently uses. Questions such as "Which payment method do you prefer?" and "Rank the following payment methods according to which you are most likely to use" were asked. The last part of the survey consisted of questions regarding how the respondents view their own financial responsibility. Questions such as "Do you know how much money you have in your bank account right now?" and "Do you check your bank account before you make a purchase?" were asked. At the end of the survey, the respondents were asked to enter their e-mail addresses to participate in follow-up interviews. After the answers were analyzed, four people were contacted for interviews. Based on their answers in the survey, questions regarding their payment habits and financial responsibility were asked. The study only investigates payment methods that are used in Sweden. All questions were written in Swedish but were translated into English in the result section of this paper. Another limitation is that most of the participants were Swedish young adults studying at the university and may therefore not give a correct representation of the whole target group.

5 Results

5.1 Demographic data

A total of 57 respondents within the target group (18-25 years old) answered the survey (63% male and 37% female). Due to the target group and the choice for distributing the survey, 95% of the population were students and only 5% were employed.

5.2 Payment methods

The data collected through the survey showed that most of the participants prefer Swish as a payment method when shopping online (Figure 1). When asked about the factors that influenced their choice of payment method, most part of the participants cited simplicity and flexibility as the main reasons for preferring Swish. The second most popular payment method was card payment. Respondents supported their choice of card payment due to the ability to save your card details in your browser, which makes it simple and easy or feeling of familiar and not knowing any other payment option. The third most popular payment method, with 21%, was "Klarna – Pay in 30 days. One factor that made them choose this payment was that they want to receive the item before they pay of it. Another factor was that they do not want to pay for something they may want to return. Invoice and Klarna instalment plan were also included as alternatives in the question, but these options were by any of the respondents as their preferred payment method.

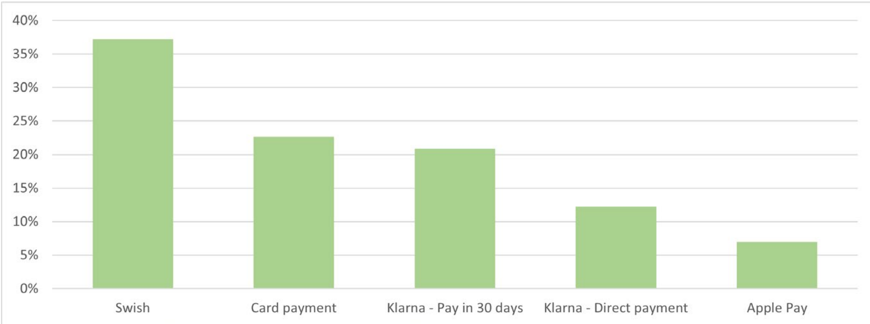

Figure 1: Which payment method do you prefer when shopping online?

The respondents were also asked to rank the payment methods according to which they are most likely to use. The answers agreed with the previous results, with Swish ranked in first place. Of the respondents 54% have tried the "Klarna – Pay in 30 days" function as part of the ranking. When asked why they tried it, 14% of respondents were motivated by not having enough money for the purchase. However, the most common reason for using it was the ability to see the item before paying. For 30% of the respondents the most common reason for using invoices was that there was no other payment method available and for 17% they used invoices when they wanted to buy something but did not have the money for it. 11% stated they use invoices when the purchase was made on behalf of someone else or for their employer, and three said they only use them when buying expensive items. Finally, 51% of the respondents claimed that there has been at least one occasion that they have not fulfilled a purchase due to limited payment methods (Figure 2).

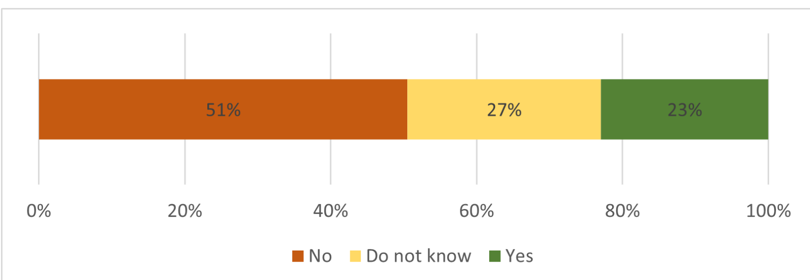

Figure 2: Has it happened that you have not fulfilled a purchase due to limited payment methods?

5.3 Financial responsibility

The part of the survey regarding financial responsibility consisted of seven questions. The first three questions asked about the respondent's online purchase behaviour. 61% of the respondents make online purchases 1-3 times a month, and 23% make online purchases a couple of times per year. Only one person never makes online purchases and only one person makes online purchases a couple of times per week. 37% of the respondents always checked their bank account balance before they make the purchase (Figure 3).

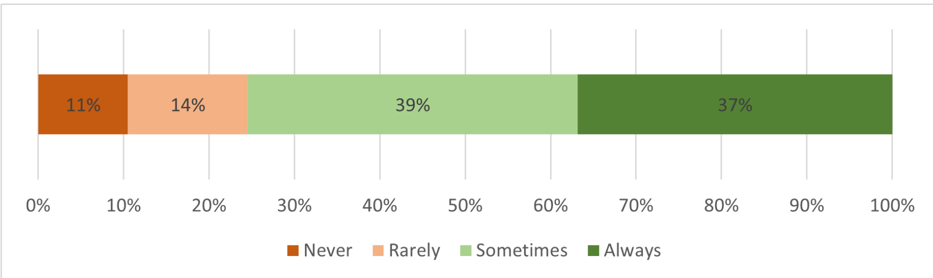

Figure 3: Do you check your balance before making an online purchase?

Respondents were asked if they borrow money from friends and family. Only one person answered that they do it often, approximately 16% answered that it can happen, but rarely, and the remaining 82% claimed that it never happens. The 18% of the people who say they borrow money from friends and family still claim to have a buffer with easily accessible money, of more than 500 USD (5,000 SEK). In total, 79% of the respondents have a buffer of over 500 USD with 18% have a buffer of under 500 USD and only 3% answered that they do not have a buffer at all.

In the final question the respondents ranked their financial responsibility from 1-10. The mean answer was 7.2 (Figure 4). Comparing to the previous answers of the respondents who considered themselves less financially responsible (3 or lower), none of them uses "Klarna – Pay in 30 days" or Invoice due to not having enough money at the time of purchase. Only one person that answered that they never or rarely check their bank account before purchase (Figure 3) also answered that they are less financially responsible (3 or lower).

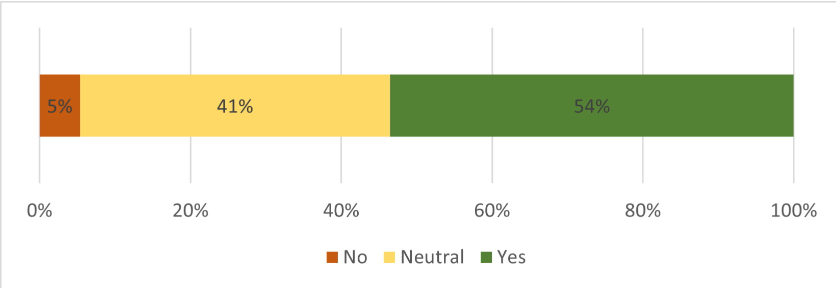

Figure 4: Do you consider yourself as financial responsible?

5.5 Follow up interviews

Of the respondents 14 participants chose to enter their email addresses and therefore volunteered to be a part of the follow up interviews. After analysing their results, four people who were representative of the range of survey respondents were contacted and asked to attend an interview. A semi-structured interview was conducted where the questions were adapted to the participants' previous answers. Some of the questions that were asked were:

- How often do you make impulse purchases?
- Develop further what makes you prefer Klarna/Swish/Card Payment.
- "Klarna – Pay in 30 days" and invoice work basically the same way. What makes you prefer "Klarna – Pay in 30 days"?
- How do you keep track of when it is time to pay for your purchase?
- How do you keep track of your purchases?
- Tell more about the situation where you did not proceed with your purchase due to limited payment methods.

The common findings from the interviews, which corroborates the results of the survey, was that people prefer to use Swish since it is easy, feels safe and the money is drawn from the account straight away. The major reason for preferring "Klarna – Pay in 30 days" was the shortage of money at the time for the purchase and the possibility of receiving the item before payment was required. One respondent stated that it is easier to decide whether you want the item since you can see and feel it before paying. But the same person also highlighted that they often forget to return items or, decide to keep them, even though they might not need or want them, due to the effort required to return the item.

One respondent expressed that he easily loses track of how much he spends as it is so easy to purchase with Klarna. He said that he often buys takeaway food with Klarna since it is the fastest way of paying when you are on the go, and sometimes they only offer "Klarna – Pay in 30 days", not direct payment. Another person preferred "Klarna – Pay in 30 days" over invoice since Klarna does not charge any extra cost and you pay for your purchase through the app or website directly, without filling in any invoice details. The same person also mentioned the difficulties of keeping track of when the pay date expires on an invoice as a reason for using "Klarna – Pay in 30 days" and appreciated the notices from Klarna as he considered them crucial to remember to complete the payment. All four participants expressed strain of keeping track of purchases and getting an accurate overview of their finances since purchases can be spread out over different platforms and payment services.

6 Discussion

When analysing the results, Swish is currently the most popular payment method among young adults in Sweden. Swish was chosen due to its simplicity, flexibility, and the fact that the money is drawn from the account immediately. Card Payment is the second most popular payment method because of reliance and simplicity, with the addition that it is mainly preferred if the user already has the card details saved in the browser. The third most popular payment method is "Klarna – Pay in 30 days" and it was chosen due to the flexibility when making returns and not needing the money at the time of the purchase (Senali, et al., 2022; Kumar et al., 2023). However, it needs to be taken into consideration that almost all the respondents were students. Students may be less likely to make as many online purchases as someone who works, but at the same time, students may be more versed in using digital payment methods with is consident with previous research (Yuk et al., 2021; An et al., 2023). Students also may be more aware of their private economy since they are on a strict budget. To answer these questions and make a more accurate study, the number of respondents would need to increase, but also expanded with a greater variation in occupation. This could be done by not only spreading the survey to university students but also reaching out to young adults working. Common to the three preferred payment methods mentioned is that they all use the third-party BankID to complete the payment this is consistent with previous research that has identified security as a key determent of the use of digital payments (Patil et al., 2017; van der Cruijsen and Plooij, 2018; Senali, et al., 2022). BankID is an important part of the payment process since it handles security in a much more efficient and fast way than using e.g., a specific security device. One could therefore argue that it is not the paying method itself that needs to be considered in the paper, but the whole purchase and payment process.

Regarding the second research question, there is not enough evidence to conclude whether these payment methods can affect financial responsibility among young adults. To investigate this matter further, additional questions regarding purchase behaviour and financial responsibility need to be included in further research. Another obstacle when gathering information for the second research question is that the respondent's idea of how financially responsible, they are, does not always align with the reality of how they act as found by Garbinsky et al., (2021).

Regardless, one interesting finding was that the motivation to complete a purchase decreased if the choice of payment methods was limited (van der Cruijsen and Plooij, 2018; Senali, et al., 2022). If the respondent never completed the purchase, this could suggest that the payment methods that are not as fast and flexible may make the customer more thoughtful when making a purchase (Coffey et al., 2023). However there is a point where the purchase is so important that this over rides any difficulties with the payment method. If this is some sense of financial responsibility by deferring discretionary purchases, or just laziness, it is hard to tell. Since no follow-up questions were asked about the situation, this is a subject for further research.

Another interesting finding was the struggle of getting an overview of purchases when they are spread out over different types of platforms and payment methods. Further research is required to determine if it is not the payment method itself that affects the financial responsibility among young adults, it is the situation and combination of different payment methods available at the time of purchased (Senali, et al., 2022). As this insight is drawn from the four people during the follow-up interviews it would be necessary to interview more people and add questions about the matter to any future survey. One conclusion that can be made is that "Klarna – Pay in 30 days", which was the third most popular payment method, creates a way to temporarily avoid financial responsibility. By being able to buy things for money that you do not have, you avoid the fundamental idea of financial responsibility, which is about giving up today's desires to be able to provide for the needs of tomorrow.

7 Conclusion

This paper aims to investigate which payment method young adults prefer and use today and if the payment method has any impact on their financial responsibility. This study shows that Swish is currently the most preferred payment method among young adults in Sweden. Whether the payment method affects financial responsibility among young adults cannot be entirely determined by the result of the study. Still, the results show that an individual's choice of payment method can play a role in their financial responsibility. Some respondents highlighted that "Klarna – Pay in 30 days" has a (negative) impact on their financial responsibility since it is easy to use money that they do not have. The findings of the study also implicate that it can be the combination of different payment methods that affect young adults' financial responsibility.

References

Aldrich, M. (2011). Online Shopping in the 1980s. Annals of the History of Computing, 33(4), 57–61.

An, Q., Hong, W. C. H., Xu, X., et al. (2023). How education level influences internet security knowledge, behaviour, and attitude: a comparison among undergraduates, postgraduates and working graduates. International Journal of Information Security, 22, 305–317. https://doi.org/10.1007/s10207-022-00637-z

Apple. (n.d.). Apple Pay. Available: https://www.apple.com/apple-pay/

Arvidsson, N. (2019). Building a Cashless Society: The Swedish Route to the Future of Cash Payments. Springer.

BankID. (n.d.-a). Mobilt BankID, Available: https://support.bankid.com/sv/bankid/mobilt-bankid

BankID. (n.d.-b). Vad är BankID?. Available: https://support.bankid.com/sv/bankid/vad-aer-bankid

Coffey, J., Senior, K., Haro, A., et al. (2023). Embodying debt: youth, consumer credit and its impacts for wellbeing. Journal of Youth Studies. https://doi.org/10.1080/13676261.2022.2162376

Eriksson, B., & Sandhill, U. (2019). Cashless: A dead end for Sweden?. In A. Larsson & R. Teigland (Eds.), Digital Transformation and Public Services (pp. 235–242). Routledge.

Ferrera, C., & Kessedjian, E. (2019). Evolution of E-commerce and Global Marketing. International Journal of Technology for Business, 1(1), 33-38.

Garbinsky, E. N., Mead, N. L., & Gregg, D. (2021). Popping the positive illusion of financial responsibility can increase personal savings: Applications in emerging and western markets. Journal of Marketing, 85(3), 97-112.

Hansson, A., (2022). Betala räkning – Hur betalar man en faktura? Available: https://buffert.se/betala-rakningar-fakturor/

Insight Intelligence. (2020). Sverige betalar 2020. Available:

https://www.svenskhandel.se/globalassets/dokument/aktuellt-och-opinion/rapporter-och-foldrar/betalfragor/sverige-betalar-2020.pdf

Klarna. (2022). About Klarna. Available: https://www.klarna.com/international/about-us/

Kumar, S., Prashar, S., & Shah, A. (2023). Creating brand love for payment apps through emotions. Marketing Intelligence & Planning, 41(3), 279–292. https://doi.org/10.1108/MIP-07-2022-0314

Lauer, J. (2020). Plastic surveillance: Payment cards and the history of transactional data, 1888 to present. Big Data & Society, 7(1), 1–14. https://doi.org/10.1177/2053951720907632

Leblebici, H. (2012). The evolution of alternative business models and the legitimization of universal credit card industry: Exploring the contested terrain where history and strategy meet. In S. J. Kahl, B. S. Silverman, & M. A. Cusumano (Eds.) History and Strategy (Advances in Strategic Management, Vol. 29) (pp. 117–151). Emerald Group Publishing Limited. https://doi.org/10.1108/S0742-3322(2012)0000029009

McFerrin, J. (2021). The history of ecommerce: from its origins to modern day. Available: https://www.iwdagency.com/blogs/news/the-history-of-ecommerce-how-did-it-all-begin

Page, G., (2021). Focus: Evolution of payment methods. Available: https://cigp.com/insights/evolution-of-payment-methods

Patil, P.P., Dwivedi, Y.K., Rana, N.P. (2017). Digital Payments Adoption: An Analysis of Literature. In: Digital Nations – Smart Cities, Innovation, and Sustainability, I3E 2017. Lecture Notes in Computer Science, vol 10595. Springer. https://doi.org/10.1007/978-3-319-68557-1_7.

Senali, M. G., Cripps, H., Meek, S., & Ryan, M. M. (2022). A comparison of Australians, Chinese and Sri Lankans' payment preference at point-of-sale. Marketing Intelligence & Planning, 40(1), 18–32.

Swedbank, (n.d.). Handla på nätet med kort. Available: https://www.swedbank.se/privat/kort/sa-anvander-du-ditt-kort/handla-med-kort-pa-natet.html

Swish (n.d.). About Swish. Available: https://www.swish.nu/about-swish

Swish. (2022, June). Swich statistics – June 2022. Available: https://assets.ctfassets.net/zrqoyh8r449h/4oohpQ2xPiUFJFWZLwifZ/fd1be4bfd8d10dd65c20c64157f38b6f/Swish_statistics___downtime_june_2022.pdf

Tatum, M., (2022). What is financial responsibility? Available: https://www.smartcapitalmind.com/what-is-financial- responsibility.htm

van der Cruijsen, C., & Plooij, M. (2018). Drivers of payment patterns at the point of sale: stable or not?", Contemporary Economic Policy, 36(2), 363–380. https://doi.org/10.1111/coep.12245

Wisehn, I., (2019). Sveriges första kreditkort, Available: https://www.foretagskallan.se/foretagskallan-nyheter/lektionsmaterial/sveriges-forsta-kreditkort/

Yuk, M. T., Ka, Y. C., Luchen, H., Yun, K. I., & Wan, Y. (2021). Financial innovation in digital payment with wechat towards electronic business success. Journal of Theoretical and Applied Electronic Commerce Research, 16(5), 1844–1861. https://doi.org/10.3390/jtaer16050103

Digital Coaching Motivating Towards Physical Activity in Japan During the COVID-19 Pandemic

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COVID-19 influenced peoples lives enormously and its impact was also seen in physical activity and exercising. This mixed methods intervention study highlights some of the impact the pandemic had on the physical activity and exercising behaviors of 10 Japanese information systems employees and students. This study also focuses on the influence that using sport and wellness technology digital coaching had on peoples' physical activity, exercise motivation and exercise self-efficacy during the pandemic. Based on the findings digital coaching can have motivational elements to support people towards a more physically active lifestyle for example by making users more aware of their own physical activity. However, digital coaching is not enough if users do not have initial motivation which may be understandable in the challenging times of the COVID-19 pandemic. The findings highlight that digital coaching could be further developed to better support its users. This study and the results bring insight for digital coaching developers and users as well as people working in health care field.

Keywords:
digital coaching,
exercise self-efficacy,
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1 Introduction

Japan was the second country outside of China to have an identified case of COVID-19, in early 2020. Japan's response was considered to be fairly rapid and organized. There was no formal lockdown, as the Japanese government has no power to force businesses to close and people to stay inside. However, local States of Emergency were declared to encourage businesses to close and people to stay home (BBC, 2020). The government encouraged citizens to avoid "the 3Cs": closed spaces, crowded places, and close-contact settings. Despite there being no actual punishment for not following these guidelines, it was recognized that the Japanese populace were generally following them, and thus, crowds of many forms were significantly reduced for much of 2020 (Sayeed & Hossain, 2020). Understandably, these kinds of recommendations could have had a significant impact on sport and exercise participation. In Japan many people use smartwatches and activity trackers to track and measure their daily lives and various activities (Yoshida et al., 2018). Based on the article of IT Media Mobile (2022) 38% of the Japanese population aged between 20-69 have a smart watch. Interestingly, 41.3% of those smart watch owners bought them in 2020. Health management was the top reason for buying a smart watch (IT Media Mobile, 2022). This can be interpreted as showing that the effect of COVID-19 changed people's mind about health management since 29.6% of those who have a smart watch bought it for health management reasons (IT Media Mobile, 2022).

This article focuses on exploring the usage and effects of sport and wellness technology digital coaching in Tokyo, Japan during spring 2020. The aim is to see how the start of the COVID-19 pandemic influenced the exercise behavior of 10 Japanese information systems (IS) field employees and students, how these participants were able to adapt and use sport and wellness technology digital coach into their lives and how the usage of a digital coach influenced their exercise self-efficacy and motivated them toward physical activity and exercise during the beginning of the pandemic. This study brings insight for digital coaching developers, digital coaching users and for people working in health care field. However, because of the limited number of participants due to the restrictions of the pandemic, the purpose of this article is more to highlight interesting aspects of digital coaching usage during the time of the pandemic and suggest potential areas for future studies. This study is unique because it was done in a culturally different environment compared to other studies of the same topic, as well as being conducted during a pandemic.

2 Theoretical background

2.1 Sport and wellness technology digital coaching

The maturing of the consumer market for sport and wellness technology has meant that there are more lower-cost devices of high-quality available, which has also created an opportunity to do human-centered research in this area (James, 2017). Sport and wellness technology has been shown to increase levels of physical activity in part by the information it can provide a user on their own physical activity and exercising habits (e.g. Larset et al., 2019; Romo et al., 2019). This enhanced awareness of one's own physical activity and exercising habits has the added benefit of being a motivating factor for some users (e.g. Chan et al., 2004; Faghri et al., 2008). Sport and wellness technology can also contribute to the goal setting process (e.g. Gordon et al., 2008), both by setting goals and providing feedback on the progress towards those goals, both of which make users more goal-oriented (e.g. Kari et al., 2016). There is, however, not necessarily always a connect between increased awareness of a user's own physical activity and sustained use of a sport and wellness technology device (Miyamoto et al., 2016). Typical sport and wellness technology that has already been available tend to focus only on providing information and data about previous performances, rather than giving meaningful feedback or guidance on what to do next. Without meaningful or personalized data, a person would need specialized knowledge or professional help to make appropriate decisions in relation to their future exercise plans (Duking et al., 2016).

One solution for this demand is digital coaching. Sport and wellness technology digital coaching refers to a "service on a technological device that not only gives feedback but also offers advice, suggestions and future steps for a user to follow in the pursuit of their wellness and fitness goals" (Kettunen & Kari, 2018 p.3). Typically sport and wellness technology devices and applications give only performance data and feedback. In addition to this, a digital coach creates a personalised training plan which is continually updated based on the user's actions (Schmidt et al., 2015). It is important to acknowledge that digital coaching does not refer to the use of digital tools by human coaches, rather, it refers to a device or a solution which in itself is the coach and functions independently without human interaction. The potential of sport and wellness technology digital coach has been recognized in previous IS research (e.g. Kranz et al., 2013; Kettunen et al. 2021) and interest toward more instructional and personalized interaction has become more popular (Boulos & Yang, 2020; Mezei et al., 2020). However, commercial sport and wellness technology digital coaching devices and applications are still relatively new and therefore only a few studies have focused on studying the usage experience and the motivational influence of the use of digital coach. Previous studies have suggested that the most suitable processes for digital coaching are related to behavior change techniques, goal setting persuasion, evaluation, interaction and co-creation Chatterjee et al. (2021) whereas the key element influencing adherence and usability was personalization (Lentferink et al., 2017; Chatterjee et al. 2021). Users seem to be more engaged with digital coaches that take into account the psychological needs related to motivation (Sundar, 2012; Chang et al. 2016).

2.2 Exercise Self-efficacy

The quantitative part of this study is based on the theory of self-efficacy by Albert Bandura (1977). The concept of self-efficacy refers to a person's own beliefs about their own capacity related to performing a specific task. It is important to recognize that a person's self-efficacy does not necessarily correlate to his/her actual capacity to perform a specific task. A person with high levels of self-efficacy is more likely to view a difficult task as an opportunity and a challenge whereas a person with low self-efficacy easily tends to avoid difficult tasks (Bandura 1997). Therefore, it is understandable that self-efficacy can also affect a person's motivation by impacting the amount of effort they are willing to give to overcome a specific task. According to Bandura (1998) there are four main sources of information that affect person's self-efficacy: vicarious experiences, performance accomplishment, verbal persuasion, and physiological states.

Since in this study the topic is physical activity and exercise, the theory of self-efficacy is applied to exercise and physical activity and therefore is called exercise self-efficacy. Self-efficacy plays an important role in exercise since it has been shown to have a high influence in the adoption of physical activity habits (McAuley & Blissmer, 2000). The importance of self-efficacy tends to be even more important in the phase when physical activity has not yet become a habit (Bandura, 1986). Self-efficacy has also been associated with maintaining long-term physical activity (McAuley et al., 2011). People with high levels of self-efficacy may work harder and participate in physical activity more frequently (Bandura, 1986). Self-efficacy is one of the most researched concepts in the field of physical activity and exercise (Kroll et al., 2007), and is a well-known theory when studying motivation and self-confidence in the field of sport performance (Feltz, 1988). In this paper, exercise self-efficacy is studied from the perspective of sport and wellness technology digital coaching and the aim is to see whether the use of a digital coach can influence the users' exercise self-efficacy during the COVID-19 pandemic and despite the issues and restrictions the pandemic caused related to physical activity and exercising.

3 Methodology

3.1 The Digital Coach Used in the Study

The digital coach used for this study was the Suunto 3 Fitness sports watch, created by Finnish company Suunto OY (Suunto, 2019). The device is designed as a training watch for exercisers and is particularly tuned for aerobic exercising such as walking, running or cycling. The watch has features related to exercise timing, wrist-based heart rate monitoring, sleep monitoring, GPS, and 24/7 activity, stress and recovery tracking. The features that make the watch a digital coach is its "adaptive training guidance" and "real time feedback". The watch creates a personalised weekly training plan based on the goal user has set. An estimation of the user's fitness level is made using the existing training data. On a training day, the watch provides the workout goals such as the time and the intensity. The digital coach provides real-time guidance during the recommended workout. The guidance is primarily related to staying in a particular heart rate zone. The watch also provides instructions through audio and visual indicators to help the user to keep up with the set goal. After the workout the device provides information about the workout. The training guidance will adapt if a person misses or modifies a workout.

3.2 Research approach, data collection and analysis

The study was a mixed methods intervention study that took place in Tokyo, Japan, at the start of the COVID-19 pandemic from February to April 2020. The intervention lasted three months and included eight male and two female participants, ages 22-67, who were students or employees working in IS field. The volunteers were recruited from the National Institute of Advanced Industrial Science and Technology and from Tokyo University of Agriculture and Technology. The participants had different types of physical activity backgrounds. The physical activity background was not a selection criterion. Participants did not have previous experience related to digital coaching although some of them had previous experience on of sport and wellness technology.

In the beginning of the intervention all participants were given quantitative paper questionnaires related to exercise self-efficacy and attitude towards sport and wellness technology digital coaching. After answering the questionnaire all participants were given a sport and wellness technology digital coach to use for the duration of the study. The participants were asked to use the digital coach as they felt most suitable for them. In the end of the intervention period the participants were asked to answer again the same questionnaires they answered in the beginning of the intervention. In this second round the questionnaire was an online questionnaire due to the COVID-19 restrictions. The purpose of this quantitative data was to see if there were any changes in their answers due to the intervention. After the intervention the participants were also interviewed about their experiences related to physical activity during COVID-19 and their usage of the digital coach to support their physical activity and exercising. Due to COVID-19 restrictions the qualitative data was collected via online and email interviews in the end of the intervention in early May 2020. The interviews were semi-structured interviews which are the most used interview type in IS qualitative research (Myers & Newman, 2007), consisting of themes related to exercise background, COVID-19 pandemic, adaptation of digital coach, digital coach's influence on physical activity and exercise and ideal digital coach. Interviews done over email followed a more structured format.

The quantitative data was analyzed using Excel. Due to the low number of participants the purpose of the quantitative data analysis was not to provide statistically significant information but instead, by analyzing averages on an item by item basis, to highlight possible trends and areas worth researching more deeply. The qualitative data was analyzed using thematic analysis method which is meant for "analyzing, identifying and reporting patterns within data" (Braun and Clarke, 2006, p. 79) and is widely used in qualitative research (Guest et al., 2012). The analysis process of the studies began with transcribing the relevant parts of the interviews and becoming familiar with the data. The interview themes were already divided into smaller sections in the interview phase During the analysis the answers of the individual participants were compiled into an Excel spreadsheet. This made it easier to see the occurring themes and compare the data. The most highlighted issues and topics were presented in the result section.

4 Findings

4.1 Quantitative findings related to exercise self-efficacy and attitude

Exercise self-efficacy was measured using a scale by Kroll et al. (2007). The scale, presented in table 2 below, included statements regarding personal abilities related to physical activity. The self-efficacy was measured on the scale from 1-4 where 1=not true at all, 2= seldom true, 3=somewhat true and 4= completely true. As seen from the table 2 there was no significant changes when comparing the means of the questionnaires before and after the intervention. One statement that seemed to have the biggest change between the two data points was related to exercising when feeling depressed. It seemed that after the intervention the participants were less certain that they are capable of being physically active and exercise when feeling depressed.

The second part of the questionnaire, presented in table 3 below, focused on self-efficacy related to the participants' overall opinions about their exercising and improving their own fitness. This part included 13 statements, of which six were related to the role of sport and wellness technology. The statements were measured on a scale of 1-7 where 1 represented "strongly disagree" and 7 represented "strongly agree". Based on the results participants seemed less confident at the end of the intervention that they are able to train independently without any guidance or coaching. However, they also found it less hard after the intervention to find out how to improve or analyze their own aerobic fitness. Also the belief of the truthfulness of the information provided by sport and wellness technology was increased during the intervention.

Table 1: Changes in exercise self-efficacy

Statement	**Start (Mean)**	**End (Mean)**
I can overcome barriers and challenges with regard to PA and exercise if I try hard enough	3,1	3,3
I can find means and ways to be physically active and exercise	3,4	3,5
I can accomplish my PA and exercise goals that I set	3,1	3,4
When I am confronted with a barrier to PA or exercise, I can find several solutions to overcome this barrier	2,8	3,0
I can be physically active or exercise even when I am tired	2,4	2,2
I can be physically active or exercise even when I am feeling depressed	**2,7**	**1,9**
I can be physically active or exercise even without the support of my family or friends	3,1	3,0
I can be physically active or exercise without the help of a therapist or trainer	3,3	3,4
I can motivate myself to start being physically active or exercising again after I've stopped for a while	3,1	3,0
I can be physically active or exercise even if I had no access to a gym, exercise, or rehabilitation facility	2,7	3,2

Attitudes towards using a digital coach was measured by five statements shown in table 4 below. The statements focused on the overall attitude (bad vs. good), the experimental aspect (unpleasant vs. pleasant and uncomfortable vs. comfortable), and the instrumental aspect (useless vs. useful and foolish vs. sensible). As can be seen from the means, participants' attitudes towards digital coaching remained relatively similar. However, after the intervention the participants considered using digital coaching more uncomfortable than before.

Table 2: Changes related to improving fitness, and sport and wellness technology

Statement	Start (Mean)	End (Mean)
I know how to create myself an exercising program	4,0	4,3
I need help in creating myself a suitable exercising program	4,1	4,3
I am able to train independently without any guidance or coaching	**5,1**	**4,0**
Sport and wellness technology has an important role in my exercising	4,7	4,6
Sport and wellness technology provides me with important information that I can use in my exercising	5,3	5,6
I am able to improve my fitness with the help of sport and wellness technology	5,3	5,5
I believe that sport and wellness technology provides me with reliable information regarding my own exercising	5,5	5,9
I believe that sport and wellness technology provides me with accurate information regarding my own exercising	5,3	5,6
I believe that sport and wellness technology provides me with truthful information regarding my own exercising	**5,1**	**5,9**
It is hard for me to find out how to improve my aerobic fitness	**4,9**	**4,1**
I do not know how to increase the level of my aerobic fitness	4,3	4,2
It is hard for me to analyze my aerobic fitness	**5,0**	**4,0**
I know how to improve my aerobic fitness	**4,1**	**4,6**

Table 3: Changes in attitude towards using a digital coach

Statement	Start (Mean)	End (Mean)
I know how to create myself an exercising program The thought of using a digital coach as a support for my training sounds: bad (1) vs. good (7)	5,5	5,7
The thought of using a digital coach as a support for my training sounds: useless (1) vs. useful (7)	5,7	5,7
The thought of using a digital coach as a support for my training sounds: foolish (1) vs. sensible (7)	6,0	5,7
The thought of using a digital coach as a support for my training sounds: unpleasant (1) vs. pleasant (7)	5,7	5,4
The thought of using a digital coach as a support for my training sounds: uncomfortable (1) vs. comfortable (7)	**5,6**	**4,9**

4.2 Qualitative findings

4.2.1 COVID-19 influencing exercise behavior

The exercise background of the participants varied. Four participants had walking and commuting to work/school as their only exercise and other participants reported also having exercise related hobbies such as strength training, dancing, running or team sports. During the COVID-19 pandemic their exercise behavior changed significantly due to the restrictions. Exercise related hobbies that were held in public places such as gyms and exercise arenas were cancelled causing a decrease in physical activity level for many participants. Since people worked from home, so the amount of walking decreased from the elimination of commuting. Some participants continued or started running during the pandemic but even running was considered more difficult due to big crowds outside. As one participant stated "I avoided people jams. For instance I started running around the park near home at midnight". In general participants reported that COVID-19 had a negative influence on their physical activity as well as on their exercise motivation: "I have no motivation to go out anymore"(Male, 25 years), "The frequency of training has decreased"(Male, 24 years). Despite the restrictions and limitations, some participants found a way to remain physically active: "I decided to do longer walk exercises as my commuting activity disappeared" (Female, 46 years), "I became more motivated to exercise since I felt stressed at home. Exercise became my new routine." (Male 22).

4.2.2 Adaptation and usage of the digital coach

None of the participants had used a sport and wellness technology digital coach before but a couple of them had used a pedometer or a running application. Most participants had either no expectations or high expectations towards digital coaching hoping that it would guide and encourage them to exercise. Participants felt that starting to use the digital coach was relatively easy. Most wore the digital coach every day during the intervention although some participants felt uncomfortable wearing it overnight. Few participants wore the digital coach only during exercising. The lock down and working remotely affected some participants' usage of the digital coach: "I used the digital coach all day before I started working from home. After that I wore it occasionally when I went to sleep or for a walk" (Female, 46 years). The feature participants used the most were heart rate, step counting, sleep tracking and exercise tracking. Only a few participants followed the training program offered by the adaptive training guidance since participants thought it was hard to understand or that they would have liked to schedule their training themselves. As some participants noted: "I did not use the adaptive training guidance. It looked rational but I would have liked to schedule the training myself" (Male, 24 years), "I did use it at first but it was a little too hard to understand" (Male, 24 years) The real time feedback feature was perceived somewhat more useful since half of the participants used it. The usage of the digital coach changed as the pandemic continued. Some participants decreased the usage since their exercise levels decreased.

4.2.3 Motivational influence of the digital coach

After the intervention most participants reported becoming more aware about their physical activity or lack of physical activity. Most participants had also learned something new about their own physical activity, such as their heart rate levels. As one participant stated: "I realized my heart rate is quite high. I also realized how much I walk every day, I walk more than I thought" (Male, 28 years). Because people were working more from home, some participants found more time to exercise. A few participants started running and felt that having a digital coach along their exercising increased motivation and made running more regular and consistent.

Participants also perceived seeing their exercise progress as well as seeing their daily activities motivational. According to one participant: "Using the digital coach has improved my health since it gives me numbers and I can set goals. This increases my motivation which will improve my health" (Male, 22 years). COVID-19 decreased the exercise motivation for some participants, and the use of a digital coach was not a good enough motivator to start increasing their exercise levels. According to one participant: "Being unable to exercise outside reduced my motivation" (Male, 22 years).

Using the digital coach encouraged some of the participants to make some changes to their exercise and wellbeing. Some participants reported having made changes to their training and health management due to the usage of the digital coach: " I learned that I exercised too hard, so I reviewed my training plan" (Male, 24 years), " Because of using the digital coach, I am now trying to keep an ultra slow pace in early stage of running" (Male 67 years),"Before I thought I slept more but after using the watch I tried to go to bed earlier and have better sleep quality by calming down before going to bed" (Male, 22 years). In general participants found it motivational to receive exercise and health related data as well as being able to compare the progress. As one participant noted: "Digital coach assists on exercising but the responsibility is on the person. That makes it easy to start with the digital coach" (Male, 28 years). For some participants tracking exercise became fun and easy: "By making it appear numerically, the exercise became fun and easy" (Female, 60). For some participants the purpose of using a digital coach changed during the intervention: "Digital coach usage has changed from exercise management to life management such as sleep management" (Male, 22 years).

4.2.4 Ideal digital coach

Participants were also asked how to develop digital coaching to make it more motivational and suitable for them. Some participants felt the coach should be more encouraging, more clear, and more straight forward. The data should be more accurate and the device itself could be more comfortable. In general participants wanted their ideal digital coach to include features related to weight training, and calorie consumption. It should also connect more effectively with other technologically. In general, participants felt that digital coaching is suitable for different types of people but especially for people who want to increase their exercise level and learn more about their own physical activity and health. One participant stated: “Digital coach is for people who want to increase their exercise level and do not know a lot about exercising.” (Male, 22 years). When comparing a human coach to a digital coach, participants felt that a human coach can be more flexible, provide more detailed instructions and give more personal advice. A human coach would also possibly earn more respect and as a result motivate the client to work harder. One participant felt that: “With a human coach you have to show respect and work harder and do exercise” (Male, 25 years). The benefits of a digital coach were flexibility, cheaper price, ease of use and rich personal information. As one participant said: “You have more freedom to do things your way. It creates less stress. No schedules are needed and the response is fast” (Male, 28 years).

5 Discussion

This study focused on exploring the usage, effect on exercise self-efficacy and the motivational influence of sport and wellness technology digital coaching during the COVID-19 pandemic in Japan. Based on the findings it seems that the overall attitude towards physical activity and exercising also affected the usage of digital coach during COVID-19. The motivational influence of digital coaching seemed inconclusive. Whereas for some participants digital coach brought extra motivation, for others the COVID-19 restrictions decreased the exercise motivation such that the usage of digital coaching could not bring back the motivation. This result is consistent with previous research (Kettunen et al. 2021) suggesting that motivational elements of the digital coach are not enough if the user themselves are not initially motivated to exercise. The quantitative findings highlight that digital coach usage can make people more confident about training without outside support and being more in charge of their own fitness development. This finding is also consistent with previous studies (Kettunen et al., 2019; Kettunen et al., 2021). However, it seems that the atmosphere created by COVID-19 has made people less confident that they can train when feeling depressed. The trust in the truthfulness of the data provided by the digital coach increased during the intervention. This finding is opposite to previous similar studies (Kettunen et al. 2019; Kettunen et al., 2020) done in Finland. The attitude towards digital coaching was relatively high already in the beginning of the study and remained about the same throughout the intervention. An exception to this was that people perceived using a digital coach as less comfortable after the intervention.

According to the findings the digital coach was perceived as interesting and useful in helping people learn about their physical activity as well as increased the exercise motivation. Digital coaching also makes the training more visible and exciting to some participants by giving numbers and setting goals. Thus, a digital coach has potential in influencing exercise motivation even during difficult times such as during the COVID-19 pandemic. However, digital coaching could be developed much further to increase its motivational influence. For example, enhancing communication between the user and the device was highlighted. It is notable that most technology related to health improvement reaches only those who are already health-conscious, sporty, and active, so the problem seems to be rather how to reach those who do not care about their health. There does not appear to be a good solution for this. Based on this study digital coaching has potential and therefore might be the key to solve that problem, so it would be useful to conduct more studies with different target groups and using different types of digital coaches. It is also important to recognize that technology such as a digital coach may not be able to overcome the individual traits that guide a person's behavior during extraordinary events like the COVID-19 pandemic was. Thus, the impact of a digital coach on a person's exercise behavior might have been somewhat different in an otherwise more normal time period.

6 Limitations and suggestions for future research

The results of the study are based on a relatively small and homogenous target group and the usage of one particular digital coaching device. Due to the pandemic and the limited number of digital coaches it was not possible to extend the number of participants. It is also important to note that the participants were all working or studying in the information systems field which might have influenced the adoption of new technology. Since the quantitative data is based on a small numer of participants the quantitative results serve as highlighting possible trends and areas worth researching more deeply. Doing research on a unique time such as during a pandemic made the topic more interesting but at the same time made analysis harder as it is hard to know for sure whether some results were more related to the usage of the digital coach or to the change in lives due to COVID-19. Future studies could focus on the influence that digital coaching usage has on exercise motivation and self-efficacy especially. The usage of sport and wellness technology digital coaching in Japan could also be studied more broadly, since to our knowledge this study is among the few studies, if not the only one, conducted in Japan about the topic.

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References

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. Psychological Review 84 (2), 191-215.

Bandura A. (1986). Social Foundations of Thought and Action: A Social Cognitive Theory. Englewood Cliffs, NJ: Prentice Hall.

Bandura, A. (1998). Health promotion from the perspective of social cognitive theory. Psychology and Health 13 (4), 623–649.

Boulos, M. N. K., & Yang, S. P. (2021). Mobile physical activity planning and tracking: a brief overview of current options and desiderata for future solutions. Mhealth, 7.

Braun, V., and V. Clarke (2006). "Using thematic analysis in psychology," Qualitative research in Psychology 3 (2), 77-101.

BBC. (2020). Coronavirus: State of emergency lifted in most of Japan. BBC News. Retrieved September 29, 2022, URL: https://www.bbc.com/news/world-asia-52658551

Chan, C. B., Ryan, D. A., & Tudor-Locke, C. (2004). Health benefits of a pedometer-based physical activity intervention in sedentary workers. Preventive Medicine, 39(6), 1215-1222.

Chang, R. C. S., Lu, H. P., Yang, P., & Luarn, P. (2016). Reciprocal reinforcement between wearable activity trackers and social network services in influencing physical activity behaviors. JMIR mHealth and uHealth, 4(3), e5637.

Chatterjee A, Gerdes M, Prinz A, Martinez S. 2021. Human Coaching Methodologies for Automatic Electronic Coaching (eCoaching) as Behavioral Interventions With Information and Communication Technology: Systematic Review J Med Internet Res, 23(3):e23533

Faghri, P. D., Omokaro, C., Parker, C., Nichols, E., Gustavesen, S., & Blozie, E. (2008). E-technology and pedometer walking program to increase physical activity at work. The Journal of Primary Prevention, 29(1), 73-91.

Feltz, D. (1988) "Self-confidence and sports performance." Exercise and Sport Sciences Reviews 16 (1), 423-458.

Finnish Sports Federation. (2011). Kansallinen liikuntatutkimus 2009–2010: Aikuis- ja senioriliikunta. [National Sports Study 2009-2010: Adult and Elderly Physical Activity (Report), Helsinki: Finnish Sports Federation.

Gordon, M., Althoff, T., & Leskovec, J. (2019). Goal-setting and achievement in activity tracking apps: a case study of MyFitnessPal. The World Wide Web Conference, USA, 571-582.

Guest, G., MacQueen, K. M. and E. E. Namey (2012). Applied Thematic Analysis. Los Angeles: SAGE.

IT Media Mobile. (2022) Smart watch ownership rate is 38.0%, top reason for purchase is "health management". URL: https://www.itmedia.co.jp/mobile/articles/2102/09/news086.html

James, D. (2017). Wearable Technology in sport, a convergence of trends. Journal of Advanced Sport Technology, 1(1), 1-4.

Kari, T., Koivunen, S., Frank, L., Makkonen, M., & Moilanen, P. (2016). Critical Experiences During the Implementation of a Self-tracking Technology. PACIS 2016: Proceedings of the 20th Pacific Asia Conference on Information Systems, Taiwan, 129.

Kettunen, Eeva (2021) Using Digital Coaching to Promote Physical Activity to University Students with Low Levels of Physical Activity: A Qualitative Intervention Study. In Proceedings of the 54th Hawaii International Conference on System Sciences, University of Hawai'i.

Kettunen, E., and Kari, T. (2018). "Can Sport and Wellness Technology be My Personal Trainer?: Teenagers and Digital Coaching." in Proceedings of the 31st Bled eConference. Digital Transformation: Meeting the Challenges", Bled, Slovenia, pp. 463-476

Kettunen, E., Kari, T., Makkonen, M., Critchley, W., & Sell, A. (2019) Digital Coaching among Physically Inactive University Students: A Quantitative Intervention Study on Exercise Self-efficacy. In Proceedings of the 32th Bled eConference. Humanizing Technology for a Sustainable Society.

Kettunen, E., Kari, T., Makkonen, M., Frank, L. & Critchley, W. (2020). Young Elderly and Digital Coaching: A Quantitative Intervention Study on Exercise Self-Efficacy. In the proceedings of the 33rd Bled eConference : Enabling technology for a sustainable society. Maribor: University of Maribor, 469-484

Kranz, M., A. Möller, N. Hammerla, S. Diewald, L. Roalter, T. Ploetz and P. Olivier (2013). "The Mobile Fitness Coach: Towards Individualized Skill Assessment Using Personalized Mobile Devices" Pervasive and Mobile Computing 9, 2013, pp. 203-215.

Kroll, T., Kehn, M., Ho, P. S., & Groah, S. (2007). The SCI Exercise Self-Efficacy Scale (ESES): development and psychometric properties. The international journal of behavioral nutrition and physical activity, 4, (34).

Larsen, R. T., Christensen, J., Juhl, C. B., Andersen, H. B., & Langberg, H. (2019). Physical activity monitors to enhance amount of physical activity in older adults–a systematic review and meta-analysis. European Review of Aging and Physical Activity, 16(1), 1-13.

Lentferink, A. J., Oldenhuis, H. K., de Groot, M., Polstra, L., Velthuijsen, H., & van Gemert-Pijnen, J. E. (2017). Key components in eHealth interventions combining self-tracking and persuasive eCoaching to promote a healthier lifestyle: a scoping review. Journal of medical Internet research, 19(8), e7288.

McAuley E. & Blissmer B. (2000). Self-efficacy determinants and consequences of physical activity. Exercise and Sport Sciences Reviews, 28, 85–88.

McAuley, E., Szabo, A., Gothe, N., & Olson, E. A. (2011). Self-efficacy: Implications for Physical Activity, Function, and Functional Limitations in Older Adults. American journal of lifestyle medicine, 5(4),

Mezei, J., Sell, A., & Walden, P. (2020). Digital coaching-an exploratory study on potential motivators. Proceedings of the 53rd Hawaii International Conference on System Sciences, USA.

Miyamoto, S. W., Henderson, S., Young, H. M., Pande, A., & Han, J. J. (2016). Tracking health data is not enough: a qualitative exploration of the role of healthcare partnerships and mHealth technology to promote physical activity and to sustain behavior change. JMIR mHealth and uHealth, 4(1), Article e5.

Romeo, A., Edney, S., Plotnikoff, R., Curtis, R., Ryan, J., Sanders, I., Crozier, A., & Maher, C. (2019). Can smartphone apps increase physical activity? Systematic review and meta-analysis. Journal of Medical Internet Research, 21(3), Article e12053. https://doi.org/10.2196/12053

Sayeed, U. B., & Hossain, A. (2020). How Japan managed to curb the pandemic early on: Lessons learned from the first eight months of COVID-19. Journal of global health, 10(2), 020390. URL: https://doi.org/10.7189/jogh.10.020390

Sundar, S. S., Bellur, S., & Jia, H. (2012, June). Motivational technologies: a theoretical framework for designing preventive health applications. In International conference on persuasive technology (pp. 112-122). Springer, Berlin, Heidelberg.

Suunto, 2022 URL: https://www.suunto.com/en-gb/Support/Product-support/suunto_3/suunto_3/

Yoshida, Y., Nishimura, T., Jokinen, K. (2018). Biomechanics for understanding movements in daily activities. LREC Workshop "Language and Body in Real Life & Multimodal Corpora" (REAL-MM), 7-12 May 2018, Miyazaki, Japan. http://lrec-conf.org/workshops/lrec2018/W20/index.html

Appendix 1: Participant information

Age	Gender	Employment Status	Activity Level
22	Man	Student	Health enhancing participant
22	Man	Student	Health enhancing participant
24	Man	Student	Health enhancing participant
24	Man	Student	Fitness participant
25	Man	Student	Casual participant
28	Man	Employed	Inactive or sedentary
46	Woman	Employed	Inactive or sedentary
52	Man	Employed	Competition athlete
60	Woman	Employed	Health enhancing participant
67	Man	Employed	Fitness participant

The Appendix 1. above shows more detailed information of the participants. The activity level categorization was collected using a categorization based on the Finnish National Sport Survey (Finnish Sports Federation, 2011), which classifies people into seven categories based on their PA level. These categories, presented in order from the most to least active, were: competition athletes, fitness athletes, fitness participants, physically active for health, active in commuting and non-exercise, occasionally active, and inactive or sedentary.

Mobile Clinical Decision Support Systems: A Pathway from Design to Commercialization

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A smartphone-based clinical decision support system (CDSS) has been designed for perioperative patient management in cancer care. A systematic design approach to ensure fit-for-purpose of such mobile CDSSs is lacking. This study attempts to fill that void by reporting on the pathway we took from design to commercialization. Our pathway is governed by the design science research methodology and the theory of task technology fit. Our experiences are generalizable and can provide guidance to many mobile clinical decision support solutions in healthcare.

Keywords:
clinical decision support systems, commercialization, design science research methodology, perioperative, surgery, task technology fit, smartphone

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1 Introduction

Clinical decision making is a complex and cognitively demanding process. It involves the interplay between tacit and explicit knowledge and includes observation, information, knowledge, experience, caring, and incidental learning (Banning, 2008). Medical errors could result from shortcomings in clinical decision making (Makary & Daniel, 2016) and manifest as adverse health and cost implications. As such, effective and accurate clinical decision making becomes essential for quality healthcare delivery.

Technology has been introduced to healthcare over the years to support clinical decision making. Clinical decision support systems (CDSSs) has been one such use of technology. CDSSs have advanced over the years. Starting from paper-based systems they have evolved to legacy-based computer systems (Skyttberg, et. al., 2016), and then more recently to handheld mobile device-based systems (Chahal, et. al., 2020). Latest technology advancements such as Industry 4.0 and Healthcare 4.0 have enabled this evolution. Following this backdrop, designing a Smartphone-based CDSS is the focus of this study.

The introduction of mobile CDSSs to healthcare is not simple. A recent scoping review (Ulapane & Wickramasinghe, 2021) has listed some of the major issues encountered in the past five years in attempts to introduce mobile technologies to healthcare as follows: complexity and performance-related issues in the used technologies; difficulty to validate the efficacy of the introduced technologies; costs involved in introducing new technologies; lack of quality of data (when it comes to the use of Artificial Intelligence (AI)); lack of generalizability of certain techniques and technologies used, lack of expandability and scalability of the introduced technologies; lack of streamlining of the technologies with the clinical workflows; privacy and cyber security-related issues; surveillance capitalism; risks and accountability; policy and legislative challenges; slow adoption of certain technologies in healthcare; perceptions and biases of technology users and potential users; and competence (or lack of it) in technology usage among clinicians. The call for better standardization of mobile technologies in healthcare has also emerged (Lee, et. al., 2018).

The prevalence of diverse issues as noted above, indicates a void in this field. This void comes due to the lack of a systematic approach for the design and development of mobile CDSSs. Motivated by that void, this study attempts to answer the following research question: "How can mobile CDSSs be designed and developed to be of superior fit-for-purpose?"

By answering the aforesaid research question this study makes a twofold contribution: A contribution to theory and a contribution to practice. The contribution to theory comes as a systematic design approach for mobile CDSSs. Our approach extends towards validation and commercialization. Our approach combines the theory of Task Technology Fit (TTF) (Goodhue & Thompson, 1995), the Design Science Research Methodology (DSRM) (Hevner & Chatterjee, 2010), and the input from a commercial software development partner. The contribution to practice is a designed and validated mobile CDSS. It includes a smartphone application and a web-based data analytics platform. This CDSS assists clinicians, specifically doctors, and nurses, to manage surgery patients during perioperative care (i.e., pre-operative and post-operative stages). The CDSS supports with decisions like management of anticoagulant drugs. The specific health focus is prevention of thromboembolism. Thromboembolism is a condition of undesired blood clotting. It is a leading cause of death and complication in surgery patients (Chahal, et. al., 2020). This CDSS has been designed for a leading cancer hospital in Australia.

This paper is arranged as follows: Review of related works; relevant theories; methodology; results; discussion, and conclusions.

2 Review of Related Work

A literature search was carried out surrounding Smartphone-based CDSSs in perioperative care. The following keyword search was done: ("perioperative" OR "surgery") AND "smartphone". The keyword search was done in the Google Scholar database. Google Scholar is accessible to the public free of charge. Almost all academic databases are enlisted in Google Scholar. The search was done between May 1st and May 5th of 2022. The search was limited to items written in English. The items that included the keywords within the item's title were considered. Works published since 2021 were considered to capture the latest results. Twelve articles got retrieved matching the search criteria. Our search is deliberately restrictive and thus may be incomplete. Our purpose here was to scan the latest literature within the previous year or so for a snapshot of the latest works.

The aims and objectives of the retrieved works were reviewed. We noticed that none of the retrieved works had focused on proposing a systematic design approach. As such, our study contrasts those works. The works (Ahmad, et. al., 2022), (Awaludin, et. al., 2022), (Boaro, et. al., 2021), (Panda, et. al., 2022), (Soangra & Lockhart, 2021), (van den Berg, et. al., 2022), (Voglis, et. al., 2022), and (Wu, et. al., 2022) have all reported some degree of design and development. Their primary focus is the technology solution rather than the design approach. As such, their design approaches are specific for their solutions. Such design approaches can be improved and generalized by grounding on theory. Therefore, our study offers an increment to current thinking as we propose a systematic design approach grounded on theory. Our approach can be replicated irrespective of the health or technology context.

The works (Jones, et. al., 2021), (Kabbani & Kabbani, 2021), and (Lesher, et. al., 2021) were review articles. The need for a systematic design approach is further emphasized in them. Jones, et. al., (2021) concludes a lack of certification, validation and peer review of applications designed for plastic surgery in the UK. Kabbani & Kabbani, (2021) highlights the importance of codesign and cocreation of applications through collaboration with healthcare professionals. Moreover, Lesher, et. al., (2021) has discussed institutional and regulatory barriers to the adoption of mobile health (i.e., mHealth) applications. Such points complement our argument and reemphasize the need for a systematic design approach so that persistent barriers can be overcome and thereby enable smooth and seamless introduction of digital health solutions to healthcare contexts.

3 Relevant Theories

Our attempt is to maximize the fit-for-purpose of mobile CDSSs. A well-known theory to assess fit-for-purpose is the theory of Task Technology Fit (TTF) (Goodhue & Thompson, 1995). We have adopted TTF in this work. Furthermore, our study involves designing an artifact through codesign. Therefore, the Design Science Research Methodology (DSRM) (Hevner & Chatterjee, 2010) is also followed. These theories are summarized in the following subsections.

3.1 The Theory of Task Technology Fit (TTF)

Stated in TTF is that Information Technology (IT) systems are likely to be more usable, desirable, and impactful, if the system's capabilities match the tasks the user must perform (Goodhue & Thompson, 1995). Goodhue & Thompson, (1995) presented a list of factors to measure the influence of TTF on user performance. We have constructed the questionnaire in (TTF Questionnaire, 2022) based on that list. It is tailored for the users of mobile CDSSs. This questionnaire is used for validation of our artifact through user feedback.

3.2 Design Science Research Methodology (DSRM)

DSRM (Hevner & Chatterjee, 2010) is a process for systematically creating an artifact so that the artifact's desirability can be maximized by meeting stakeholder needs. The process includes six steps: (1) Problem identification and motivation; (2) Defining the objectives for a solution; (3) Design and development; (4) Demonstration, (5) Evaluation, and (6) Communication. Research can be integrated at every or any one of the first five steps. Research can target understanding and solving any issues to maximize the artifact's desirability. The landmark publications (Hevner & Chatterjee, 2010), (Hevner & Wickramasinghe, 2018), and (Peffers, et. al., 2007) are useful for more details.

4 Methodology

The DSRM inspired design process we followed is depicted in Figure 1. The participants of the codesign process are listed in Table 1. The various stages of the design process are described in the subsections that follow.

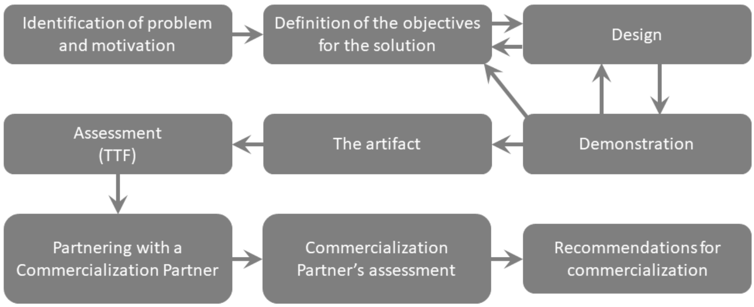

Figure 1: The design process followed

Table 1: Details of the research team

Researcher's code	Description about the participant	Role in the project
C1	Senior Hematologist	Project Lead
C2	Senior Anesthetist	Clinician Facilitator
C3	Senior Anesthetist	Clinician Facilitator
A1	Professor in Digital Health	Principal Investigator
A2	Professor in Behavioral Science	Chief Investigator
A3	Professor in Computer Science	Chief Investigator
R1	Senior Research Fellow in Computer Science	Associate Investigator
R2	Junior researcher in Digital Health	Junior Investigator

4.1 Identification of problem and motivation

This step was conducted between January and June 2020 with the participation of C1, A1, A2 and A3. This step was carried out through drafting and reviewing a proposal for this project. The primary aim came out as to design and develop a mobile CDSS for the target health context (i.e., optimization of perioperative patients to reduce the incidence of thromboembolism). A secondary aim was to commercialize this CDSS, extending it to become a gold-standard for all surgical procedures. A project proposal document was the outcome of this phase.

4.2 Definition of the objectives for a solution

The specific objectives were identified between May and October 2020. These were identified through 1-hour semi-structured virtual meetings that were arranged once a month. Participants C1, A1, A2, A3, R1, and R2 were regular participants and attended all the meetings. Participants C2 and C3 were invited occasionally by the regular participants to obtain specific clinical expertise. Detailed minutes of each meeting were documented. After each meeting the minutes were shared among all participants for consensus. At this stage, the clinician participants C1, C2, and C3, shared with the team the relevant clinical rules to be implemented as the CDSS. The following were defined with consensus as the objectives and deliverables expected from the design phase: (a) A smartphone based CDSS; (b) A database to capture usage data of the CDSS (usage data include data entered to the CDSS and recommendations displayed by the CDSS); (c) A web-based dashboard to enable data display and analytics (this was expected to be a prototype to inspire further developments, specific analytics requirements were not defined at this stage), and (d) Updating certain clinical rules about anticoagulant drug management.

4.3 Design and Demonstration

The Design and Demonstration phases occurred in tandem between October 2020 and October 2021. Participants R1 and R2 led the design and implementation. Participant R2 as one of the first activities translated the clinical rules to editable flowcharts. Examples are available in (CLOTS Dashboard Demo, 2022) and (Ulapane, et. al., 2023). This was done to map clinical rules onto a data structure that is accessible to both clinicians and computer scientists. In our experience, this translation was helpful for liaison between the clinicians and the rest. It also helped in programming the clinical rules into an application. We suggest that translating clinical rules into such more widely accessible data structures is an important intermediate step that helps software implementations of clinical rules. These flowcharts were then shared with participants C1, C2, and C3 to update any clinical rules. Those clinician participants reached consensus among themselves and responded with updates to the clinical rules.

After obtaining the updated clinical rules, the development activities followed. Participant R1 led the software implementation. First, the mobile application was built enabling the app usage data being recorded in a backend database. Secondly, a web-based front-end was developed to enable data display and analytics. The mobile application with data capture facility and the web-based front end combined is the artifact produced by this study. Snapshots of the artifact are available in the Results section. The layouts for the mobile application and the web-interface were deliberately kept simple. Non-cluttered interfaces, preference for push buttons, and using colors of the partnering client hospital's logo were taken as the key design considerations for the mobile application and the web interface. The rationale behind these design considerations was to enhanced user-friendliness through decluttering and adequate functionality. Fancified aesthetics was not prioritized.

Demonstration was done through 1-hour virtual meetings arranged once a month. These meetings were conducted as semi-structured codesign workshops. Incremental progress was demonstrated, and the clinician participants were given the opportunity to provide feedback and express any 'would-like-to-have' sort of wishes. As indicated in Figure 1, opportunity was given for participants to reconsider the original objectives and propose any alterations to them. However, no participant proposed major alterations. Again, detailed minutes were recorded and were shared among the participants after each meeting for consensus. The artifact and the source code were the outcomes of this phase.

4.4 The Artifact

The Smartphone App with data capture facility and the web-based front end combined is the artifact produced by this study. Details are in the Results section.

4.5 Assessment

This phase was carried out between November 2021 and February 2022. The designed application was made available online (e.g., iPhone TestFlight) to download and use. Participants C1, C2 and C3 were asked to download and test. Meanwhile, R2 constructed the questionnaire in (TTF Questionnaire, 2022) based on TTF to be shared with the users of the mobile CDSS to provide feedback. The intention was communicated to C1 to perform a wider assessment, by inviting more clinicians onboard and asking them to assess the app and provide feedback through the questionnaire in (TTF Questionnaire, 2022). C1 agreed and recruited 7 clinicians inclusive of C1 and C3. These 7 recruits were invited to test the app and then attend a focus group conducted virtually. In the focused group the participants were presented the questionnaire in (TTF Questionnaire, 2022) and were asked to provide qualitative and quantitative feedback. The qualitative feedback was recorded as meeting minutes. The qualitative feedback was also compiled as a report. In the report the feedback was summarized under the main themes of TTF, i.e., (1) Characteristics of the clinician's task involving the technology usage; (2) Characteristics of the technology (i.e., the CDSS), and (3) The impact the CDSS has on the clinician's performance. Several subthemes emerging from the qualitative feedback (inductive analysis) were also highlighted in the report. These findings are summarized in the Results section. This report was then shared with the participants of the focus group for consensus. This report containing user feedback was the outcome of this phase.

4.6 Partnering with a Commercialization Partner

This phase was carried out between March 2022 and August 2022. Different software product development companies were considered as candidates to be recruited as a commercialization partner. The track record of previous work and the experience of the candidates, and any preferences of the partnering client cancer hospital were considered as factors that would weigh our choice of a commercialization partner. A candidate was chosen, and several meetings were held to establish relationship and express our interest. Different plans for commercialization that could be offered by the partner were invited alongside quoted costs. The plans were reviewed by the research participants and the plan that matched the current budget constraints was chosen. Affordable amendments to the plans were also proposed. Then, the relevant contracts and nondisclosure agreements pertaining to intellectual property were signed. Finally, the developed artifact along with the source code (i.e., the outcome of phase 4.3), and the assessment report (i.e., the outcome of phase 4.5) were submitted to the commercialization partner for review.

4.7 Commercialization Partner's Assessment

This phase was carried out between September 2022 and November 2022. The commercialization partner conducted two activities. One activity was assessing the source code. The source code was assessed against several factors, such as industry best practices for quality of the source code (according to the commercialization partner's internally defined criteria that is partly covered by their intellectual property rights), the cyber security aspects, and the possibility to integrate with existing infrastructure of hospitals. The second activity was a replication of the assessment phase (i.e., phase 4.5) with end users, but again, according to an assessment criterion that is defined by the commercial partner. A report was submitted by the partner to the research team at the end of the assessment. The report contained the following: (1) A summary of the findings from the partner's assessment, i.e., code quality and user perceptions; (2) The partner's recommendations along with suggested pathways for commercialization; and (3) Tentative budgets estimates for each commercialization pathway. A couple of follow up meetings were held to clarify any unclear points and to reach consensus. The partner's report following consensus was the outcome of this phase which is consistent with DSRM approaches of getting consensus among all stakeholders/users.

4.8 Recommendations for Commercialization

Currently we are considering the recommendations of the commercial partner and are sourcing funding for pursual. The pathways suggested by the partner for commercialization are depicted in the Results section.

5 Results

Reference (CLOTS Demo, 2021) provides a video demonstration of the CDSS smartphone application. The smartphone application is available in (CLOTS App, 2022) for download and use. Reference (CLOTS Dashboard Demo, 2022) provides documented description about the app functionality and the web interface. Figures 2 and 3 provide snapshots of the artifact. End user feedback obtained from the focus group using the questionnaire in (TTF Questionnaire, 2022) are summarized in Figure 4. The feedback is summarized under the three main themes of TTF listed in subsection 4.5. The themes emerging from the data are highlighted in bolded font.

More discussion about these results is available in our previous work (Ulapane, et. al., 2023). The pathways suggested by the commercialization partner are depicted as a flowchart in Figure 5. Ultimately validation of superior fit-for-purpose is successful commercialization; so, this is a necessary first step in this regard.

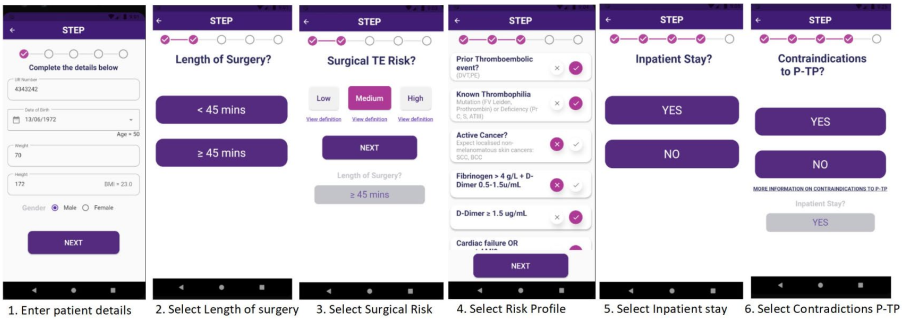

Figure 2: Some screenshots of the smartphone based CDSS app (the font in the figure is legible, please zoom to read)

Figure 3: Some screenshots of web interface for data display and analytics (the font in the figure is legible, please zoom to read)

6 Discussion

Our study made a twofold contribution: A contribution to theory and a contribution to practice.

The contribution to theory was a systematic design approach for mobile CDSSs. The approach was applied to design a mobile CDSS to a leading Australian cancer hospital. Key phases of the design process were detailed. The outcomes of each phase were mentioned, and it was emphasized that a successful plan for commercialization is a necessary step for commercialization which in turn is the ultimate evidence of superior fit-for-purpose. Our approach extended the typical analysis of fit-for-purpose to include validation and suggested pathways for commercialization. Our approach combines the theory of Task Technology Fit and the Design Science Research Methodology (DSRM). The pathways for commercialization came as input by a software product development partner.

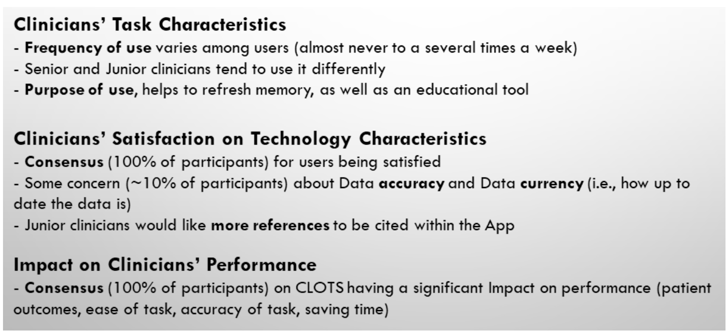

Figure 4: Findings from the TTF questionnaire-based focus group carried out to validate the CDSS (the font in the figure is legible, please zoom to read)

The contribution to practice was a designed and validated mobile CDSS. It included a smartphone application and a web-based data analytics platform. This CDSS was designed to assist clinicians to manage surgery patients during perioperative care. The specific health focus was prevention of thromboembolism. The CDSS can be downloaded from (CLOTS App, 2022) and be used in a smartphone. Key design considerations were discussed in this paper. More details are available in (CLOTS Dashboard Demo, 2022), (CLOTS Demo, 2021), and (Ulapane, et. al., 2023).

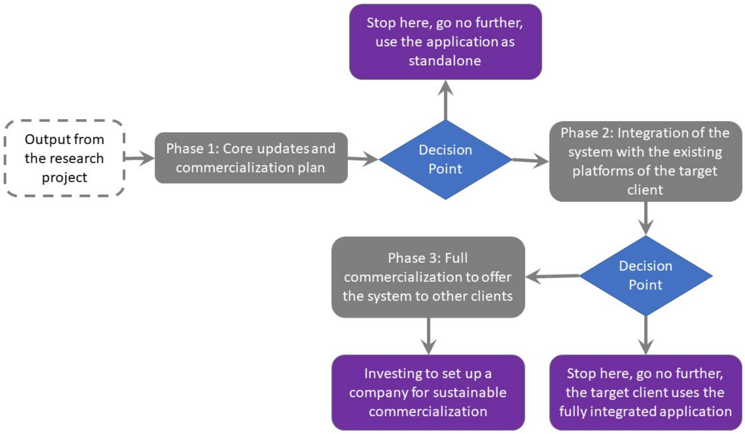

Figure 5: Pathways suggested by the commercial partner to commercialize the CDSS (the font in the figure is legible, please zoom to read)

Two major limitations or challenges were encountered during this study. The first was this being a project conducted during the COVID-19 pandemic. Thus, pandemic measures had to be strictly abided by in all the research activities. This also meant recruiting participants and finding available times being a challenge—the second limitation. This resulted in our participant groups being quite small.

Lessons learned and reflections can be summarized as follows. Making new developments interoperability with existing hospital systems can be challenging. Developing web-based applications instead of mobile applications has some advantages to alleviate the interoperability issue. Policy and regulatory barriers may exist to access health data especially on cyber security grounds.

7 Conclusions

This study reported a systematic design approach spanning from concept to commercialization. The design approach is governed by the Design Science Research Methodology and the theory of Task Technology Fit. The approach was followed to design a smartphone-based clinical decision support system (CDSS) for perioperative patient management. The CDSS was designed for a leading cancer hospital in Australia. The health focus is prevention of thromboembolism in surgery patients by optimally managing surgery patients during perioperative care. Our design approach and experiences gained are generalizable. They can be resourceful for many health tech developments.

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References

Ahmad, H. S., Yang, A. I., Joshi, D. S., Cleri, N., Basil, G., Wang, M. Y., ... & Yoon, J. W. (2022). 318 Classifying Peri-operative Course and Outcomes in Spine Surgery Using Smartphone-Based Accelerometry. Neurosurgery, 68(Supplement_1), 71-72.

Awaludin, S., Nurachmah, E., Soetisna, T. W., & Umar, J. (2022). The effect of a smartphone-based perioperative nursing intervention: Prayer, education, exercise therapy, hypnosis, and music toward pain, anxiety, and early mobilization on cardiac surgery. Journal of Public Health Research, 11(2).

Banning, M. (2008). A review of clinical decision making: models and current research. Journal of clinical nursing, 17(2), 187-195.

Boaro, A., Leung, J., Reeder, H. T., Siddi, F., Mezzalira, E., Liu, G., ... & Smith, T. R. (2021). Smartphone GPS signatures of patients undergoing spine surgery correlate with mobility and current gold standard outcome measures. Journal of Neurosurgery: Spine, 35(6), 796-806.

Chahal, R., Alexander, M., Yee, K., Jun, C. M. K., Dagher, J. G., Ismail, H., ... & Burbury, K. (2020). Impact of a risk-stratified thromboprophylaxis protocol on the incidence of postoperative venous thromboembolism and bleeding. Anaesthesia, 75(8), 1028-1038.

CLOTS App, App store link to download (2022): https://apps.apple.com/us/app/clots/id1436672491

CLOTS Dashboard Demo. (2022). A document demonstrating the CLOTS App and backend: https://dit.swin.edu.au/clotsapp/Overview.docx

CLOTS Demo. (2021). A video demonstration of the CLOTS App. Link (Date of last visit: Sep 21, 2022): https://dit.swin.edu.au/clotsapp/CLOTS_demo.mp4

Goodhue, D. L., & Thompson, R. L. (1995). Task-technology fit and individual performance. MIS quarterly, 213-236.

Hevner, A., & Chatterjee, S. (2010). Design science research in information systems. In Design research in information systems (pp. 9-22). Springer, Boston, MA.

Hevner, A. R., & Wickramasinghe, N. (2018). Design science research opportunities in health care. Theories to Inform Superior Health Informatics Research and Practice, 3-18.

Jones, O., Murphy, S. H., & Durrani, A. J. (2021). Regulation and validation of smartphone applications in plastic surgery: It's the Wild West out there. The Surgeon, 19(6), e412-e422.

Kabbani, J., & Kabbani, J. (2021). 452 Exploring the Merits and Availability of Smartphone Applications Related to Bariatric Surgery. British Journal of Surgery, 108(Supplement_2), znab134-208.

Lee, Y. L., Cui, Y. Y., Tu, M. H., Chen, Y. C., & Chang, P. (2018). Mobile health to maintain continuity of patient-centered care for chronic kidney disease: content analysis of apps. JMIR mHealth and uHealth, 6(4), e10173.

Lesher, A. P., Gavrilova, Y., Ruggiero, K. J., & Evans, H. L. (2021). Surgery and the Smartphone: Can Technology Improve Equitable Access to Surgical Care? Journal of Surgical Research, 263, 1-4.

Makary, M. A., & Daniel, M. (2016). Medical error—the third leading cause of death in the US. Bmj, 353.

Panda, N., Solsky, I., Cauley, C. E., Lipsitz, S., Desai, E. V., Huang, E. J., ... & Haynes, A. B. (2022). Smartphone-based assessment of preoperative decision conflict and postoperative physical activity among patients undergoing cancer surgery: A prospective cohort study. Annals of Surgery.

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A design science research methodology for information systems research. Journal of management information systems, 24(3), 45-77.

Skyttberg, N., Vicente, J., Chen, R., Blomqvist, H., & Koch, S. (2016). How to improve vital sign data quality for use in clinical decision support systems? A qualitative study in nine Swedish emergency departments. BMC medical informatics and decision making, 16(1), 1-12.

Soangra, R., & Lockhart, T. (2021). Smartphone-based prediction model for postoperative cardiac surgery outcomes using preoperative gait and posture measures. Sensors, 21(5), 1704.

TTF Questionnaire. (2022). Task Technology Fit Theory-Based Questionnaire, For Health Care CDSS Context. Link (Date of last visit: Sep 21, 2022): https://dit.swin.edu.au/clotsapp/20220119_TTF.xlsx

Ulapane, N., & Wickramasinghe, N. (2021). Critical issues in mobile solution-based clinical decision support systems: A scoping review. Optimizing health monitoring systems with wireless technology, 32-45.

van den Berg, L., Brouwer, P., Panda, N., Hoogbergen, M. M., Solsky, I., Onnela, J. P., ... & Sidey-Gibbons, C. J. (2022). Feasibility and performance of smartphone-based daily micro-surveys among patients recovering from cancer surgery. Quality of Life Research, 31(2), 579-587.

Voglis, S., Ziga, M., Zeitlberger, A. M., Sosnova, M., Bozinov, O., Regli, L., ... & Maldaner, N. (2022). Smartphone-based real-life activity data for physical performance outcome in comparison to conventional subjective and objective outcome measures after degenerative lumbar spine surgery. Brain and Spine, 2, 100881.

Wu, M. H., Wu, P. C., Hseih, L. B., Lin, L. M., & Tsai, C. L. (2022). A Smartphone Application for Monitoring Postoperative Symptoms and Signs with an Instant Bi-Direction Feedback System in Patients after Cataract Surgery.

Ulapane, N., Forkan, A. R. M., Jayaraman, P. P., Schofield, P., Burbury, K., & Wickramasinghe, N. (2023). Using Task Technology Fit Theory to Guide the Codesign of Mobile Clinical Decision Support Systems. Proceedings of the 56th Hawaii International Conference on System Sciences. pp. 2870-2879.

FICTION OR REALITY – WHICH GAME STORY PROMOTES LEARNING OUTCOME MORE?

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Digital Game-based Learning (DGBL) has achieved several positive results in recent years, e.g., increased fun, motivation, or learning outcome. However, many DGBL applications fail, which makes an isolated consideration of individual game elements and their influence on learning necessary to better design future DGBL applications. One widely used game element is the game story. As there is little research on how a game story should be designed to promote learning, this paper conducts an experiment comparing a fictional game story with a realistic one. The results show that both game stories lead to a significant objective knowledge gain. In terms of learning outcome, both game stories achieved similar results.

Keywords:
game story, serious game, presentation skills, motivation, learning outcome

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1 Introduction

With the introduction of the term digital game-based learning (DGBL) by Prensky (2001), the topic of combining games and learning has received a lot of attention in both research and practice (Breuer, 2010). Studies show that the use of game elements for educational purposes leads to positive effects such as increased motivation, engagement, creativity, or fun (Oliveira et al, 2023; Grogorick, 2021; Prensky, 2003). There are two forms of DGBL design: Gamification and serious games. Gamification is the integration of individual game elements into a non-game context (e.g., education) (Deterding et al., 2011). An example is the teaching concept 'GamEducation,' i.e., individual game elements are integrated into an existing lecture to create a 'gameful experience' in learning strategic decision-making and planning of digital businesses (Siemon and Eckardt, 2017). In contrast to gamification, a serious game does not simply integrate individual game elements into an existing environment, such as an existing lecture. Instead, a serious game is a complete game with fixed rules and objectives (Deterding et al., 2011). One example is 'Adapt or Die' to learn business model development (Schlimbach and Robra-Bissantz, 2022). The two forms of integrating game elements into education, gamification and serious game, are not always clearly distinguishable, so the terms are often used synonymously. However, both forms create a situation where learners expect fun and enjoyment and are thus motivated, promoting learning outcomes as the overriding goal (Grogorick, 2021; Manzano-León et al. 2021).

Nevertheless, many DGBL applications fail because learning is not fun. The reason for this is that DGBL designers focus on the achievement of learning rather than creating an environment that, in addition to the achievement of learning aims, also provides an intense gaming experience characterized by motivation and fun (Zichermann and Cunningham, 2011; Eckardt et al., 2018; Van Roy and Zaman, 2017). In order to support learning as effectively as possible, the development of DGBL focuses not only on the design of the application in general but also on the concrete design of individual game elements (Grogorick, 2021). The game story is a commonly used game element (Hamari et al. 2014). While not all DGBL applications use an accompanying game story, storytelling is still relevant to the learning experience and provides a context for processing learning content (Clark et al., 2016; Kapp, 2012). Studies conducted so far show contradictory results as to whether or not the integration of a game story positively impacts learning and engagement.

Some studies argue that learners use their cognitive capacities to process the game story instead of the learning content (Wouters et al., 2013; Adams et al., 2012). Other work has found that manipulating the game story influences learning. For example, a complex game story has a negative effect compared to a minimally designed game story (McQuiggan et al., 2008), or triggering surprises in a game story leads to a greater depth of knowledge processing (Spek, 2011; Hoeken and van Vliet, 2000). As the effects of manipulated game stories are still unexplored (Wouters et al., 2013), we want to address this topic in this paper.

Game stories are often fictional or based on reality (Nicholson, 2015). In commercial computer games, research has shown a realistic storyline has an inspiring effect, making the game more attractive to players (Olson, 2010). But other studies have also demonstrated the positive effect of fictional game stories, as one can become completely immersed in them and forget about 'real world' problems (Fullerton, 2014). In an educational context, for example, Kruse et al. (2014) chose a story and characters for learning mathematics due to the popularity of vampire series and films. However, many students did not identify with this and felt that they were not taken seriously, which led to a high drop-off in the use of the application. In addition, Eckardt and Robra-Bissantz (2018) evaluated a serious game for learning information literacy skills, in which students on a technical course take part in a fictional research expedition that more closely resembles a real-life story. Although this application achieved positive results regarding the learning outcome (Eckardt and Robra-Bissantz, 2018), these are not clearly attributable to the choice of the game story. Another study used an analog board game to investigate whether a fictional or a realistic storyline was more motivating to learn and found no significant differences regarding the motivational effect (Eckardt et al., 2019).

As previous results are mixed and a direct comparison between a fictional and a realistic story in learning has, to the best of our knowledge, only been done with a non-digital board game, this paper will report the results of a comparative study using a DGBL application, testing a realistic versus a fictional story. Therefore, the research question (RQ) of this paper is as follows:

RQ: How does the learning outcome differ between a fictional and a realistic story in digital game-based learning?

By answering our RQ, we aim to provide new knowledge about the learning outcome of fictional and realistic game stories in DGBL and inspire game story design in future DGBL applications. Overall, we would like to contribute to the improvement of game story design and thus supporting to solve the problem of DGBL's failure. Our paper is structured as follows. First, we start with the research background, addressing the story as a game element and the learning outcome concept. Second, we explain the design of our serious game with a fictional and realistic story. Third, we present the study we conducted, starting with an explanation of our experimental design, before going on to explain and then discuss our results. Finally, in our conclusion, we summarize our findings and show possibilities for further research.

2 Research Background

2.1 Game Story

Storytelling is highly relevant to the learning experience as it provides a narrative context for processing and applying learning content (Kapp, 2012). In general, stories are part of the real world. However, they create an artificially perceived fictional world in the minds of those who immerse themselves in them. For example, a game creates an imaginary world in the player's mind. Players gain new knowledge while immersed in the story by using their previous experience to transfer it to the story's meaning, thereby gaining new knowledge and skills that are relevant to real-life situations (Lugmayr et al., 2017). Integrating storytelling also enriches classroom activities. For example, storytelling can be one of the most relevant learning experiences, as shown by its implementation in HIV and AIDS education (Duveskog and Sutinen, 2013). The learning experience is shown through the consumption of the story. The story moves forward whenever learners have made learning progress (Lugmayr et al., 2017).

There are two ways to create a story in a learning application: fictional or realistic. Many films we watch in the cinema or on Netflix, and even games such as Super Mario, where Princess Peach has to be rescued again and again, have a fictional plot with people or characters that do not exist in real life. These are called fictional stories. The opposite of this is a realistic story. The realistic story actually happened, and the protagonists really existed (or still exist) (Andrews, 2010).

Overall, storytelling serves to structure individual actions and characters so that they have meaning (Kapp, 2012). Accordingly, the player's experience should become meaningful, leading to a narrative presence with which the player can identify (Laschke and Hassenzahl, 2011). This narrative presence is seen as an element of immersion that can lead to a positive willingness to use an application (Ryan et al., 2006). For DGBL, this means that the integration of stories can contribute to learners wanting to learn with the developed application because the DGBL application creates a sense of immersion. When learners want to learn with an application, they are also motivated, which can positively impact the learning outcome (Grogorick, 2021).

2.2 Learning Outcome

A successful game story supports the creation of a meaningful learning outcome. Therefore, we now consider the learning outcome and how it can be operationalized. Defining and measuring the variable learning outcome is difficult because many factors influence it (Kerres, 2001; Häussler, 2007). In general, learning outcome can be described as the result of all didactic activities and therefore means more than memorizing facts, events, or processes, to which it is often reduced, as shown by conducting numerous written knowledge tests (Kerres 2001; Adam, 2004). Kerres (2001) defines several factors that influence the learning outcome. Those relevant to the measurement carried out in this paper are listed below and then explained in more detail:

- Objective learning success or objective knowledge, measured at different time intervals.
- Subjective satisfaction with learning behavior and outcome, i.e., subjectively perceived knowledge gain.
- Emotional responses in terms of motivation to learn and identification with the learning application or game story.

Objective and Subjective Knowledge. In general, Probst et al. (2006) define the concept of knowledge as the totality of knowledge and skills that individuals use to solve problems. According to them, it is only through the combination of information and its application that knowledge is created, which in turn can become a skill (Mescheder and Sallach, 2012). In defining knowledge researchers distinguish between objective and subjective knowledge. A person's actual stored knowledge, also called factual knowledge, describes objective knowledge (Brucks, 1985). Factual knowledge is often collected by answering questions to verify what has been learned (Johann, 2008). Subjective knowledge is the assessment of a person's knowledge in a particular area. This knowledge assessment can be made by oneself or another person (Brucks, 1985).

Motivation. Emotional responses, such as learner motivation, can be measured using different models. One model for measuring learners' motivation is the ARCS model by Keller (1987). ARCS is an acronym for four factors that promote motivation, which we explain in the following: attention, relevance, confidence in success, and satisfaction. Arousing and maintaining the learner's interest is the attention dimension. As part of the learning process, learners need to be shown how the skills they are learning will be helpful to their everyday or professional lives. The dimension of relevance summarizes this aspect. Raising learners' expectations of success is important and can be achieved, for example, by making learning objectives clear. As a result, learners develop a sense of control over their own learning outcome, to which the motivational dimension of confidence in success refers. Satisfaction and motivation are closely related. If learners are satisfied with the learning application, they will be motivated to learn.

Identification. Identification with the learning application or game story is another emotional response. It is characterized as a mental process in which the user takes on a character's perspective and thus imagines that character's experiences, emotions, and perceptions (Konijn and Hoorn, 2005). In the design of a DGBL application, the narrative context determined by the story of the game is one element that significantly influences the end user's identification with the game (Reeves and Read, 2009).

3 Serious Game for Learning Presentation Skills

The DGBL application of this paper focuses on learning presentation skills. Effective presentation skills are essential for all students as they are associated with individual career opportunities and benefits (Chaney and Green, 2002). In both versions (fictional and realistic), the serious game has the same content for better comparability (e.g., aims and structure of convincing presentations). The DGBL application is a browser-based board game. Browser games have the advantage that they are easily accessible to students; for example, users do no not need to install additional software (Costu et al., 2009). The digital board game is more like a serious game, as it has fixed rules and objectives (Deterding et al., 2011).

First of all, players can choose an avatar. In the fictional story of the game, the characters are fantasy creatures called 'Badanklas.' As a Badankla, the player wants to improve the village and therefore intends to present an idea to the Great Council of Badanklas. Knowing that he/she does not have the best presentation skills, the Badankla wants to improve them before the presentation to convince the Great Council of his/her idea. The realistic game story is about a student that aims to finish his bachelor thesis and wants to work on his presentation skills before the oral defense. A game story with a theme closely linked to learning aims (as we do with presentation skills) can enhance the impact of a narrative (Wouters, 2013). Figure 1 shows the board game.

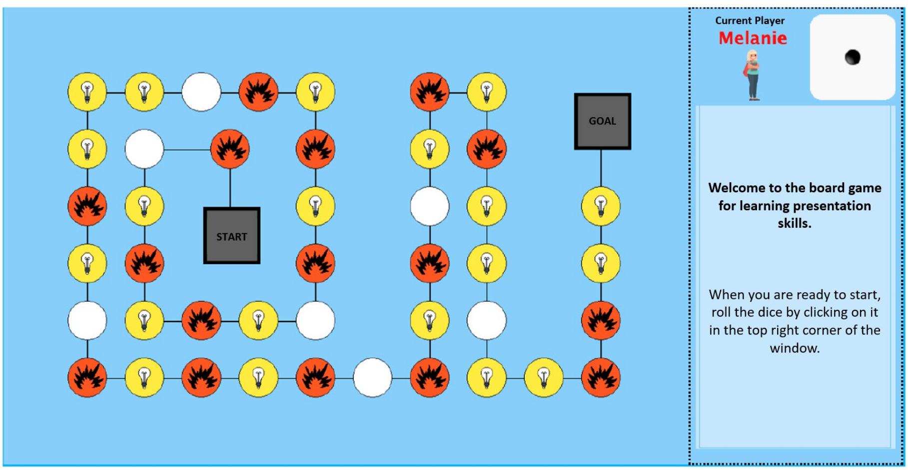

Figure 1: Screenshot of the Board Game

Up to four learners can play the digital board game at the same time. They are initially on the 'Start' field. Each player rolls a die and, depending on the number they roll, moves one step closer to the goal. The goal represents the final of the storytelling by applying the learned presentation skills in giving a presentation. On the way to the goal, players will come across event and knowledge cards. Players can draw event cards when they land on squares with explosions. The event cards are designed to fit and relate to the story of the game. For example, an event card might say in the fictional story, 'Your Badankla friends tell you that your presentation is getting better and better. Take two steps forward.' In the realistic story, it might say: 'You take a break and go for a run. Afterward, you feel much fitter mentally. Take one step forward.' In contrast, participants can draw knowledge cards when they land on squares with lamps. Each knowledge card contains new learning content that will be presented to all players.

Figure 2 summarizes the game elements used in the DGBL application. With the exception of storytelling, all game elements are designed identically in both versions of the game so that the influence on learning outcome depends as much as possible on the choice of the story (fictional or realistic).

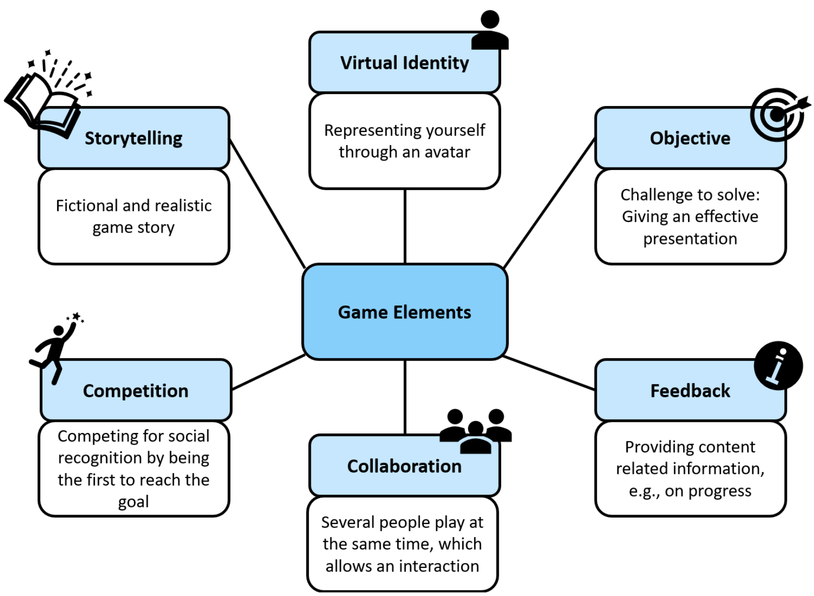

Figure 2: Game Elements of the Board Game

4 Fictional or Realistic Game Story: Study on Learning Outcome

4.1 Study Design

We conducted a controlled experiment under laboratory conditions lasting about approx. 30 minutes to evaluate how learners assess the two variants. The participants were randomly assigned into two groups (fictional vs. realistic game story) at the beginning of the study. The experiment begins with the completion of an online questionnaire to assess learners' prior knowledge. After a short explanation, the serious game follows, either with the fictional story (group 1) or the realistic story (group 2). After playing the serious game, the participants have to complete a post-test with questions on knowledge and emotional reactions (identification and motivation) to assess the learning outcome. Figure 3 shows the research process in summary.

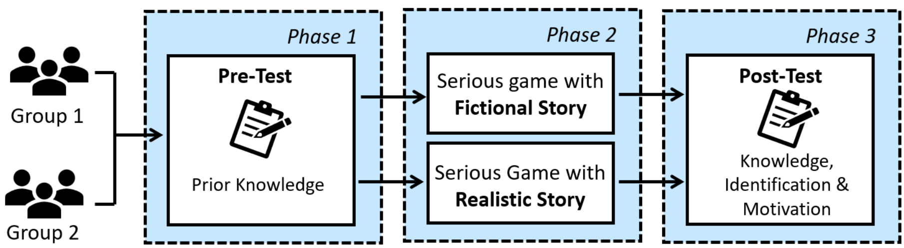

Figure 3: Study Design

We assessed the learning outcome using the factors defined by Kerres (2001) (see Chapter 2.2). We evaluated subjective knowledge according to Flynn and Goldsmith (1999). Our study includes knowledge questions and free-text questions to measure objective knowledge, as these allow the evaluation of a high processing depth of knowledge (Kibler and Eckardt, 2018; Biggs, 1999). We asked eight knowledge questions, e.g., about the aims of presenting or about recognizing different steps in the process of presenting. We measured motivation based on the ARCS model (Keller, 1987) using a scale by Chen and Chan (2008) adapted to the DGBL context. The scale divides motivation into attention, relevance, challenge, and satisfaction. The item "I am looking forward to the next session to use this game" (satisfaction) is not part of the questionnaire because participants only use the application during the experiment. Moreover, we used the identification scale according to Homburg et al. (2009). We measured subjective knowledge, motivation, and identification using a 5-point Likert scale (1 = strongly disagree, ..., 5 = strongly agree). Regarding the evaluation of objective knowledge, a value between zero (all questions answered incorrectly) and one (all questions answered correctly) corresponds to the result.

4.2 Study Results

52 learners participated in the experiment (24 male and 28 female). Of these, 27 participants chose the realistic game story, and 25 chose the fictional one. The average age was 24 years. In the following, we report the experiment results by giving each construct's mean values (MV) and standard deviations (SD). In addition, we conducted a Student's t-test for independent samples to test whether significant differences exist between the assessment of the fictional and realistic game story for the respective constructs ($\alpha = 0.05$). Table 1 shows our experiment results.

Table 1: Experiment Results Fictional Story vs. Realistic Story

Construct	Fictional Story		Realistic Story		t-Test	
	MV	SD	MV	SD	T	P
Objective Knowledge (Pre-Test)	0.34	0.43	0.37	0.44	0.69	0.49
Subjective Knowledge (Pre-Test)	2.54	1.05	2.46	1.00	0.54	0.59
Objective Knowledge (Post-Test)	0.56	0.47	0.54	0.46	0.38	0.71
Subjective Knowledge (Post-Test)	2.49	1.00	2.32	0.95	1.23	0.22
Attention (Motivation)	3.12	0.96	3.01	0.85	0.9	0.19
Relevance (Motivation)	3.03	0.95	2.95	0.91	0.59	0.28
Challenge (Motivation)	3.18	0.99	3.02	0.88	1.25	0.11
Satisfaction (Motivation)	3.01	1.2	2.98	0.89	0.23	0.41
Identification	3.25	1.15	3.13	0.91	0.82	0.21

First, we tested in a pre-test whether there were differences in prior knowledge (subjective and objective) between the two experimental groups (fictional vs. realistic story). We found no significant knowledge differences in the pre-test. Regarding the post-test, the two groups had only minimal differences in objective knowledge. However, the mean value for subjective knowledge gain was higher for the fictional story group (2.49 > 2.32), although not significantly ($p > 0.05$). Regarding the motivation effects according to the ARCS model as well as the identification, the fictional game story was also consistently rated slightly better than the realistic game story, although we found no significant effects. In addition, the mean value for the fictional story for motivation and identification was consistently above the scale mean (mean value > 3.00), so learning with the game story tended to be perceived positively. Overall, the participants perceived the fictional story slightly better after completing the experiment.

In addition, we conducted further t-tests to check whether the participants perceived a subjective or objective knowledge gain after playing the serious game ($\alpha = 0.05$). Table 2 presents the results of the knowledge gain analysis.

Table 2: Results Knowledge Gain

Construct	Pre-Test		Post-Test		t-Test	
	MV	**SD**	**MV**	**SD**	**T**	**P**
Objective Knowledge (Fictional Story)	0.34	0.43	0.56	0.47	4.89	< 0.01
Objective Knowledge (Realistic Story)	0.37	0.44	0.54	0.46	3.95	< 0.01
Subjective Knowledge (Fictional Story)	2.54	1.05	2.49	1.00	0.35	0.37
Subjective Knowledge (Realistic Story)	2.49	1.00	2.32	0.95	1.05	0.15

The results show that the participants subjectively perceive no gain in knowledge. For instance, the mean values of the post-test after learning with the serious game are even slightly worse for both forms of the game story than for the pre-test (not significant). However, we found a significant objective knowledge gain for both game stories ($p < 0.01$). Therefore, participants assumed they had not gained any knowledge, but their responses provided evidence that they had objectively gained new knowledge.

4.3 Discussion of Results

Objective knowledge improved significantly after the learning process in both the realistic and fictional game story. This was not the case for subjective knowledge. The reason for this may be an inaccurate self-assessment, which can be explained by a person's level of competence. According to this, incompetence often leads to overestimating one's own abilities, whereas increasing competence (in this case, increasing objective knowledge) leads to an underestimation of one's own level of knowledge (Kim et al., 2016). This phenomenon has also been shown in other studies of knowledge assessment in an educational context (Tashiro et al. 2021; Eckardt et al., 2019).

The comparison of the learning outcome, measured by knowledge (objective and subjective), motivation, and identification, shows no significant differences in both versions (fictional and realistic story). Both versions were perceived identically, except for slightly different mean scores. A study that also compared a fictional with a realistic game story shows similar results, but these refer to an analog serious game (Eckardt et al., 2019). In our study, we confirmed these results in the digital context. Furthermore, other studies that have analyzed whether the inclusion or exclusion of game stories impacts the learning outcome have also found no significant differences (Sailer and Homner 2020; Wouters et al. 2013). A possible reason could be that the storytelling element has less influence on the learning outcome in the context of DGBL than other game elements (e.g., feedback or collaboration). Therefore, the design of the element (e.g., fictional or realistic) or even its presence is not crucial. This finding is also supported by other studies concentrating on an isolated analysis of the impact of individual game elements. For example, the presence of collaboration has the same positive significant impact on the learning outcome as the combined integration of collaboration and competition (Eckardt and Finster, 2019). However, further studies are needed to confirm this, exploring both different designs of individual game elements and the integration or exclusion of individual game elements and their influence on the learning outcome. The need to consider the impact of individual game elements in isolation has also been highlighted in other studies (e.g., Khosrawi-Rad et al., 2021; Landers et al., 2017).

5 Conclusion and Future Research

In this paper, we presented a DGBL application in two versions (with a fictional and a realistic game story) for learning presentation skills. We evaluated it in terms of their learning outcome. In this analysis, we focused on the impact of static game stories on the learning outcome. Future studies could therefore explore the impact of dynamically designed game stories on the learning outcome or compare dynamic and static game stories. Dynamic stories allow for more autonomy and choice (Fullerton, 2014), which positively impacts learning according to self-determination theory (Van Roy and Zaman, 2017).

We contribute to answering our RQ by testing our serious game in an experiment with 52 students, whereby both versions were primarily rated similarly. Our findings provide new insights for both practice and research. On the one hand, we show that the choice of the game story (fictional or realistic) has no impact on the learning outcome, thus contributing to the isolated consideration of the impact of individual game elements and their manipulation. On the other hand, our results aim to inspire practitioners to design their own DGBL applications, as they can freely choose between realistic and fictional storytelling to achieve a learning outcome.

References

Adams, D. M., Mayer, R. E., MacNamara, A., Koenig, A., & Wainess, R. (2012). Narrative games for learning: Testing the discovery and narrative hypotheses. Journal of Educational Psychology, 104, 235–249.

Adams, S. (2004). Using Learning Outcomes. Report for United Kingdom Bologna Seminar. Heriot-Watt University.

Andrews, D. H. (2010). Story types and the hero story. In D.H. Andrews, T.D. Hull & J.A. Donahue (Eds.), Storytelling as an instructional method (pp. 1-10). Sense Publishers.

Biggs, J. (1999). What the student does: teaching for enhanced learning. Higher Education Research and Development, 18(1), 57–75.

Breuer, J. & Bente, G. (2010). Why so Serious? On The Relation of Serious Games and Learning. Journal for Computer Game Culture, 4, 7-24.

Brucks, M. (1985). The Effects of Product Class Knowledge on Information Search Behaviour. Journal of Consumer Research, 12(1), 1-16.

Chaney, L. and Green, C. (2002). Presenter behaviors: Actions often speak louder than words. Supervision, 63(5), 17-19.

Chen, Z. H., & Chan, T. W. (2008). Learning by substitutive competition: Nurturing my-pet for game competition based on open learner model. Proceedings of the International Conference on Digital Games and Intelligent Toys Based Education, 124-131.

Clark, D. B., Tanner-Smith, E. E., & Killingsworth, S. S. (2016). Digital games, design, and learning: A systematic review and meta-analysis. Review of educational research, 86(1), 79-122.

Costu, S., Aydn, S. & Filiz, M. (2009). Students' Conceptions About Browser-Game-based Learning in Mathematics Education: TTNetvitamin Case. Procedia-Social and Behavioral Sciences, 1(1), 1848-1852.

Deterding, S., Khaled, R., Nacke, L. E., & Dixon, D. (2011). Gamification: Toward a Definition. CHI 2011 Gamification Workshop Proceedings.

Duveskog, M. & Sutinen, E. (2013). Enrichtung student HIV awareness by digital storytelling. Journal of Educational Multimedia and Hypermedia, 22(4), 383-406.

Eckardt, L., & Finster, R. (2019). Kollaboration oder Wettbewerb: ein Vergleich der Motivation beim Game-based Learning. *HMD Praxis der Wirtschaftsinformatik*, *56*(1), 83-93.

Eckardt, L., Grogorick, S. & Robra-Bissantz, S. (2018). Play to Learn: Conducting a Playtest Session for Improving an Educational Game. Proceedings der American Conference on Information Systems.

Eckardt, L., Röske, D. & Robra-Bissantz, S. (2019). Influence of Belief in a Just World on Knowledge in Game-based Learning. Proceedings of the Bled eConference Humanizing Technology for a Sustainable Society, 507-522.

Eckardt, L., Schlaf, S. P., Barutcu, M., Ebsen, D., Meyer, J., & Robra-Bissantz, S. (2019). Empirische Untersuchung des Einflusses der Identifikation mit einer Spielgeschichte auf den Lernerfolg bei einem Serious Game, Proceedings of Teaching Trends, 139-145.

Eckardt, L. & Robra-Bissantz, S. (2018). Learning Success: A Comparative Analysis of a Digital Game-Based Approach and a Face-to-Face Approach. Proceedings of the 31th Bled eConference Digital Transformation - Meeting the Challenges, 331-343.

Flynn, L.R. & Goldsmith, R.E. (1999). A Short, Reliable Measure of Subjective Knowledge. Journal of Business Research. 46(1), 57-66.

Fullerton, T. (2014). Game Design Workshop: a Playcentric Approach to Creating Innovative Games. CRC Press.

Grogorick, L. (2021). Design und Implementierung eines Serious Games zur Steigerung des Lernerfolgs am Beispiel der Informationskompetenz. Technische Universität Braunschweig.

Häussler, P. (2007). Wie lässt sich der Lernerfolg messen? In E. Kircher, R. Griwdz, & P. Häußler (Eds.) Physikdidaktik (pp. 249-294). Springer.

Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does gamification work?--a literature review of empirical studies on gamification. Proceedings of the 47th Hawaii international conference on system sciences, 3025-3034.

Hoeken, H., & van Vliet, M. (2000). Suspense, curiosity, and surprise: How discourse structure influences the affective and cognitive processing of a story. Poetics, 27, 277–286.

Homburg, C., Wieseke, J., & Hoyer, W. D. (2009). Social identity and the service–profit chain. Journal of Marketing, 73(2), 38-54.

Johann, D. (2008). Probleme der befragungsbasierten Messung von Faktenwissen. Sozialwissenschaften und Berufspraxis, 31 (1), 53 65.

Kapp, K. M. (2012). The Gamification of Learning and Instruction: Game-based Methods and Strategies for Training and Education. John Wiley & Sons.

Kibler, S. & Eckardt, L. (2018). On the Role of Tasks in Virtual Game-based Learning: The Example of Lost in Antarctica. IATUL 2018 Proceedings, 2-13.

Keller, J. M. (1987). Strategies for stimulating the motivation to learn. Performance+ Instruction, 26(8), 1-7.

Kerres, M. (2001). Multimediale und telemediale Lernumgebungen: Konzeption und Entwicklung. De Gruyter Oldenbourg.

Khosrawi-Rad, B., Grogorick, L., Robra-Bissantz, S. (2021) Zwischen Frust und Freude – Wie nehmen Lernende verschiedene Spielmechaniken beim Digital Game-based Learning wahr?. Proceedings der Gemeinschaft neuer Medien, 75-91.

Kim, Y.-H., Kwon, H., Lee, J. & Chiu, C.-Y. (2016). Why Do People Overestimate or Underestimate Their Abilities? A Cross-Culturally Valid Model of Cognitive and Motivational Processes in Self-Assessment Biases. Journal of Cross-Cultural Psychology, 47(9), 1201-1216.

Kruse, V., Plicht, C., Spannagel, J., Wehrle, M., & Spannagel, C. (2014). Creatures of the Night: Konzeption und Evaluation einer Gamification-Plattform im Rahmen einer Mathematikvorlesung. DeLFI Workshop Proceedings, 246-253.

Konijn, E., & Hoorn, J. (2005). Some like it bad: Testing a model for perceiving and experiencing fictional characters. Media Psychology, 7, 107–144

Landers, R. N., Armstrong, M. B., & Collmus, A. B. (2017). How to use game elements to enhance learning: Applications of the theory of gamified learning. Serious Games and Edutainment Applications, 2, 457-483.

Laschke, M. & Hassenzahl, M. (2011). Mayor or Patron? The Difference Between a Badge and a Meaningful Story. Proceedings of the CHI 2011 Workshop on Gamification, 72-75.

Lugmayr, A., Sutinen, E., Suhonen, J., Sedano, C. I., Hlavacs, H. & Montero, C. S. (2017). Serious Storytelling – a first definition and review. Multimedia Tools and Applications, 76, 15707-15733.

Manzano-León, A., Camacho-Lazarraga, P., Guerrero, M. A., Guerrero-Puerta, L., Aguilar-Parra, J. M., Trigueros, R., & Alias, A. (2021). Between level up and game over: A systematic literature review of gamification in education. Sustainability, 13(4), 22-47.

Mescheder, B. & Sallach, C. (2012). Wettbewerbsvorteile durch Wissen. Springer.

Nicholson, S. (2015). A recipe for meaningful gamification. In Reiners, T., Wood, L. (Eds.) Gamification in Education and Business. Springer

McQuiggan, S., Rowe, J., Lee, S., & Lester, J. (2008). Story-based learning: The impact of narrative on learning experiences and outcomes. Proceedings oft he 9th International Conference on Intelligent Tutoring Systems, 530-539.

Prensky, M. (2001). Digital Game-based Learning. Paragon House.

Probst, G., Raub, S. & Romhardt, K. (2006). Wissen managen. Wie Unternehmen ihre wertvollste Ressource optimal nutzen. Gabler.

Reeves, B. & Read, J.L. (2009). Total engagement: Using games and virtual words to change the way people work and business complete. McGraw-Hill Professional.

Ryan, R. M., Rigby, C. S. & Przybylski, A. (2006). The Motivational Pull of Video Games: A Self-Determination Theory Approach. Motivation and emotion, 30(4), 344-360.

Sailer, M., & Homner, L. (2020). The gamification of learning: A meta-analysis. Educational Psychology Review, 32(1), 77-112.

Schlimbach, R., and Robra-Bissantz, S. 2022. Adapt or Die! - A Board Game to Support Dynamic Business Model Creation in Digital Darwinism, Proceedings of the 15th International Conference on Information Systems.

Siemon, D., & Eckardt, L. (2017). Gamification of Teaching in Higher Education. In S. Stieglitz, Lattemann, C. & Robra-Bissantz, S. (Eds.), Gamification (pp. 153–164). Springer.

Tashiro, J., Parga, D., Pollard, J., & Talanquer, V. (2021). Characterizing change in students' self-assessments of understanding when engaged in instructional activities. Chemistry Education Research and Practice, 22(3), 662-682.

Oliveira, W., Hamari, J., Shi, L., Toda, A. M., Rodrigues, L., Palomino, P. T., & Isotani, S. (2023). Tailored Gamification in Education: A literature Review and Future Agenda. Education and Information Technologies, 28(1), 373–406.

Olson, C. K. (2010). Children´s Motivation for Video Game Play in the Context of normal Development. Review of General Psychology, 14, 180-187.

van der Spek, E. D. (2011). Experiments in serious game design: A cognitive approach. Universiteit Utrecht.

Van Roy, R., & Zaman, B. (2017). Why gamification fails in education and how to make it successful: Introducing nine gamification heuristics based on self-determination theory. Serious Games and Edutainment Applications, 2, 485-509.

Wouters, P., van Nimwegen, C., van Oostendorp, H., & van der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. Journal of Educational Psychology, 105(2), 249–265.

Zichermann, G. & Cunningham, C. (2011). Gamification by Design: Implementing Game Mechanics in Web and Mobile Apps. O'Reilly Media.

IMPROVING COMPLETION RATE OF DIGITAL SKILL SELF-ASSESSMENT SURVEY: AN EMPIRICAL STUDY

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This study examines completion rate for a self-assessment survey designed to assess employees' digital skills levels in the workplace. The aim is to improve data quality by investigating completion of the survey. The study reviews the theoretical background related to self-assessment surveys and completion rate, and explores the influence of survey length and format in survey design on completion rate. The research design and data analysis are described in detail, with a focus on identifying factors that may influence completion rate. Results suggest that survey designers should consider using Likert scales to optimize completion rate and completion time. However, this study did not find a significant increase in completion rate as a result of motivation, which was claimed from the literature. The study concludes with implications for the design and implementation of self-assessment surveys in the workplace, including the importance of reducing length and complexity of survey items and questions.

Keywords:
self-assessment surveys, likert scale survey, slider survey, two-option survey, completion rate

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1 Introduction

The use of self-assessment surveys has become increasingly popular in recent years as a means of evaluating an individual's skills, knowledge, and abilities (Andrade, 2019; Benraghda et al., 2022; Noorka & Sarwar, 2020). These surveys have proven to be particularly useful in the workplace, where they can help identify areas where employees may require additional training or support. Although self-assessment surveys have the potential to offer numerous benefits, gathering accurate data can be challenging due to low response rates, low completion rate and early drop outs, particularly when the self-assessment survey results reflect one's own skills level that he/she sees private.

This study aims to investigate the factors that influence participants' fatigue and completion rate for a self-assessment survey designed to test employees' digital skills levels. The goal is to identify factors that can be used to increase participation and completion in the survey, thereby improving the quality of the data collected. Specifically, this research will explore the use of various perspectives in the survey design as a potential means of increasing completion rate.

The digital skills survey has been chosen for testing in this study due to two principal reasons. Firstly, this assessment tool was conceptualized and developed by the authors themselves, who possess an excellent grasp of its underlying theoretical constructs. Consequently, the authors are better equipped to effectively scrutinize and decipher the results yielded by this current study. Secondly, during the preliminary testing phase, the authors noted inconsistent completion rates, which served as a catalyst for devising the current study, which aims to delve deeper into the determinants of completion rates in self-assessment surveys employing diverse types of response scales.

The study will begin with a review of the theoretical background related to self-assessment surveys and completion rate. This will be followed by a detailed description of the research design, data analysis and results with a focus on identifying factors that may be influencing completion rate. Finally, conclusions will be drawn along with a discussion of their implications for the design and implementation of self-assessment surveys in the workplace.

2 Research background

Self-assessment survey for monitoring skills costs less resources to administer than other methods and requires less time than a testing (Allen & van der Velden, 2005), and web-based survey as a survey instrument is developed as an easy and economical method of collecting data (Parsons, 2007). An advantage of web-based survey is that it's possible to track the respondent behavior, namely "complete responders (respond to the entire survey), unit non-responders or refusals (do not respond to the survey at all), and item non-responders (respond to only some of the questions)" (Parsons, 2007). This study primarily focuses on the impact of length and formats/types of a survey on the respondent behavior by examining the completion rate of the survey, as these factors are often discussed as significant determinants (Beebe et al., 2010a; Buskirk et al., 2015; Dobronte, 2015; Galesic & Bosnjak, 2009; Hoerger, 2010; Nestler et al., 2015; Revilla & Ochoa, 2017; Roster et al., 2015).

Even though no significant relationship was found between survey length and quality (Beebe et al., 2010b), longer the survey, more fatigue and burden of the participants, especially web-paged surveys (Galesic, 2006; Savage & Waldman, 2008). Both Deutskens et al. (2004) and Marcus et al. (2007) found that participants were willing to complete the survey if it lasted shorter (15-30 minutes and 10-20 minutes), compared to those longer than 30 minutes. Galesic and Bosnjak (2009) tested survey length with 10/20/30 minutes, and found that more respondents started and completed the survey with 10 minutes than the rest. Brace (2013) suggested the length of an online survey as 15 mins and around 40-45 questions. Moreover, Revilla & Ochoa (2017) tested and concluded that ideal survey length is a median of 10 minutes and that the maximum survey length is 20 minutes.

Roster et al. (2015) compared traditional radio-button Likert scale and slider bar formats for five-point Likert scale questions and argued that "a more interactive experience may reduce survey fatigue and nonresponse, and potentially, lead to higher quality data". Stanley & Jenkins (2007) claimed that the "fun factor" of slider scales can engage respondents, especially for young respondents. Buskirk et al. (2015) found from experiment that even though slider starting position could lead to different responses, slider is more preferred than radio buttoned and more from Pc than smart phone users. However, systematic studies by academic researchers have investigated data quality in multiple ways with mixed empirical results (Roster et al., 2015).

Besides the design of the survey namely length and format, motivation of participants is an intrinsic factor in determining the completion rate of a survey, particularly when it comes to self-assessments of skills by employees. If employees do not see the value in it for their own job or career development, they are not willing to spend effort to help achieving the goal and need of the organization (Govender & Parumasur, 2010). They may not be motivated to fill out the survey and they may and may not take it seriously. This can lead to incomplete or inaccurate responses, which can in turn affect the usefulness of the data collected.

3 Method

The current study employs a design used by Galesic (2006) and Nestler et al. (2015), which involved dividing the survey into blocks of questions and soliciting participant evaluation of the previous blocks. However, this method was adapted with several modifications. Specifically, a button with the option to stop the survey was included at approximately one-third and two-thirds of the survey length. When clicking on the "stop" button, a message box appears showing how much of the survey was finished but that they could stop or continue if they wished. This button feature was used instead of immediate message box to prevent overt intervention of participants into ending the survey early. This feature aimed to measure the rate of survey dropouts and provide immediate feedback of the questionnaire. The feedback questions assessed the motivation level of the participants filling in the survey adopted from motivation questionnaire developed by Fiorella et al. (2021). Specifically three feedback questions were asked with five-point Likert scale: how interesting the questions are, how well you have answered the previous questions, are the questions relevant for your career; and one open question of why you (may) choose to stop the survey. In addition to the feedback opportunity provided if the participants choose to stop at designed places, the participants are also presented with the same feedback questions at the end of the survey if they complete the whole survey.

This study employs three survey formats: two-option choices, a slider bar with five scales, and a five-point Likert scale radio-button survey. The latter two formats have been discussed and compared in the literature. The reason why the two-option choices format is incorporated into this study is that, from the perspective of user experience, presenting participants with scenarios, particularly those related to topic of technology, which may be unfamiliar and complex, can be difficult to answer. The survey is divided into three blocks of questions based on three themes: Resilience (attitude toward technology), Analytical (information handling skills), and Technology (technology skills). Participants receive a random survey form and a random sequence of the three themes. For example, one participant may receive a slider form of survey starting with questions from the Analytical theme. Each type of survey takes approximately 15 minutes, with 32 questions for the two-option choice survey and 35 questions for both the slider and five-point Likert scale surveys. The reason for this difference is to account for the fact that the two-option survey included more text and involved more reading. An example of the three formats of surveys and three themes of questions is provided in Figure 1.

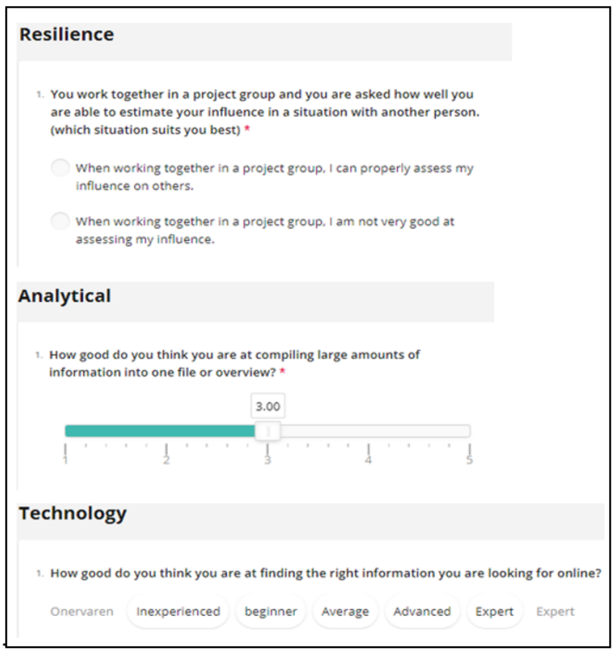

Figure 1: Example of survey formats

As an incentive for collecting more data (Nestler et al., 2015), participants are offered a chance to win a €40 gift card, and they are required to leave an email address at the end of the survey for registration in the lottery. To ensure compliance with GDPR regulations that prohibit the misuse of participant data, a privacy statement is presented at the start of the survey assuring participants that their email address will only be used for registration purposes, and all collected information will be used for research purposes only.

4 Analysis and results

After removing non-valued and duplicated data, the survey yielded a total of 121 responses out of the initial 161 data collected. Descriptions of respondents' age and gender are shown in Table 1. Morover, completetion rates for 1/3, 2/3 or the whole surevy are reported in the table. Specifically, among the 121 respondents, 20 individuals or 17% of the sample completed less than 1/3 of all questions, 10 individuals or 8% of the sample completed between 1/3 and 2/3 or all questions, while the majority (75%) of respondents completed more than 2/3 of all survey questions. This entails that most respondents complete the survey with length of around 15 mins.

Table 1: Sample profile

	Number of respondents	**%**
Gender		
Male	42	34.71%
Female	50	41.32%
Other genders	4	3.31%
Missing	25	20.66%
Age		
Younger than 20	25	20.66%
Between 20 and 22	33	27.27%
Between 23 and 25	21	17.36%
Older than 25	16	13.22%
Missing	26	21.49%
Survey completion		
Less than 1/3	20	16.53%
Between 1/3 and 2/3	10	8.26%
More than 2/3	91	75.21%

Note: N = 121, age (M = 23.41, SD = 7.61).

Completion rate[1] (calculated by dividing number of answered questions by total number of questions), completion time (calculated as sum of seconds used per question), and average time per answered question (calculated by completion time divided by number of questions answered) were compared among the three different survey formats (Likert scale, slider, and two options). ANOVAs show significant differences for all three variables (see Table 2). Likert-scale surveys were completed more (94%) than slider surveys (70%) and two-option surveys (72%). In terms of completion time, two-option surveys took the longest time (480 seconds), followed by Likert-scale surveys (366 seconds), and then slider surveys (225 seconds). Average time per answered question was the longest for two-option surveys (23 seconds per answered question), followed by Likert scale (11 seconds per answered question), and then slider (10 seconds per answered question).

Table 2: Analysis of variance on survey completion among three survey formats[2]

	Response type	**N**	**M**	**SD**	**F**
Completion rate	Likert scale	35	93.88%	11.68%	7.13**
	Slider	51	70.42%	37.70%	
	Two options	35	72.06%	30.52%	
Completion time	Likert scale	35	365.74	161.51	12.77**
	Slider	51	225.39	153.40	
	Two options	35	480.06	356.17	
Average time per answered question	Likert scale	35	11.29	4.91	22.14**
	Slider	51	10.14	6.11	
	Two options	35	23.37	15.51	

Note: Completion time and average time per answered question measured in seconds; ** $p < .01$

Moreover, the differences identified in completion rate and average time per answered question are visualized in Figures 2 and 3. Also noteworthy is that two options and slider items show similar completion rates, but two option items took much longer to complete. This can be indicative that two option items, although

[1] Completion rate is chosen instead of response rate in this study as it represents a meaningful indicator of the data quality. Given the research design of using a student sample, response rates were high across all surveys sent.

[2] Further Bonferroni post-hoc analyses reveal that for completion rate: Likert scale is significantly higher than both slider and two-option; for average time per answered question: two-option is significantly longer than both Likert scale and slider; and for overall completion time: two-option is significantly longer than slider but not Likert scale while Likert scale is significantly longer than slider. It is also noted that overall completion time should be viewed in the context of the other two variables as completion time itself is contingent upon the number of questions each respondent chose to answer.

time-consuming, are associated with less survey fatigue compared to the slider format. Taken together, the findings shown in the Figures as well as Table 2 indicate that for the administered survey among this sample, Likert-scale items led to the highest level of completion as respondents who were assigned this version of the survey answered the most questions and used relatively little time per answered question. For completion time, Likert scale response type lies in the middle. For both completion rate and average time per answered question, Likert scale is also associated with the lowest standard deviation (see Table 2), indicating a more consistent level of performance among respondents who were assigned surveys of this response type.

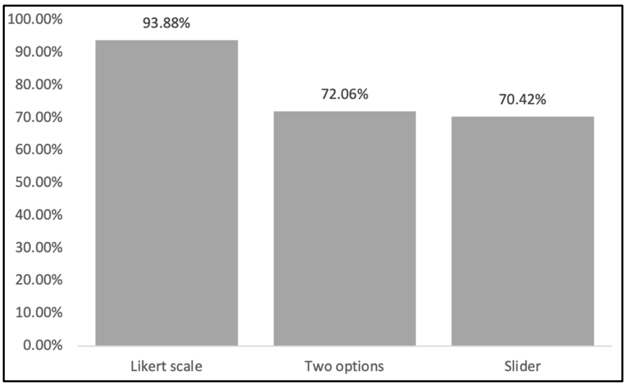

Figure 2: Completion rates among surveys of three survey formats

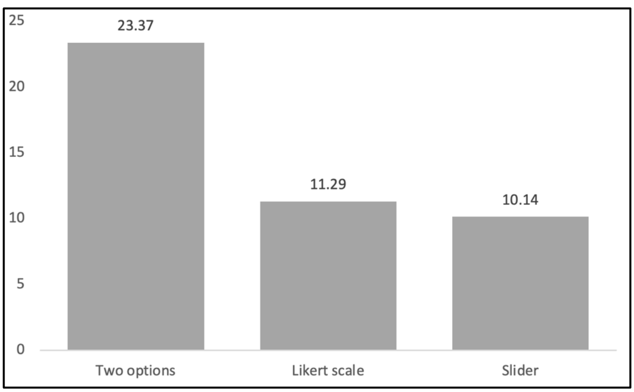

Figure 3: Average time in seconds per answered question among surveys of three survey formats

Additionally, average time per answered question and completion rate are significantly and negatively correlated (r = -.29, p < .01), indicating those respondents who completed more questions used relatively less time per question; another interpretation of this correlational finding is that those who were able to spend less time per question tended to complete the survey more fully.

Motivation of the participants is checked, especially because this survey is about employees' digital skills self-assessment, it is difficult to get response or honest response, may due to the reason that employees are not motivated. This is why the feedback questions regarding motivation were asked, the aim is to understand the relation between motivation of the participants and response, therefore motivate participation. Correlation from these three feedback questions with significant results are presented. First, the three feedback questions (questions being interesting, previous questions well answered, and questions being relevant for future career) are significantly and positively correlated among each other (see Table 3). This confirmed that the items chosen for measuring motivation level are reliable factors.

Table 3: Correlations

	1	**2**	**3**
1 Questions interesting			
2 Previous questions well answered	.61**		
3 Questions relevant for career	.41**	.37**	

Note: ** p < .01

A regression analysis is performed, using the three theoretical questions as predictors and completion rate as the dependent variable. It should be noted that not all respondents chose to answer the three theoretical control questions. Among the 121 respondents in this sample, 64 responded to these three questions. The outcome of this regression analysis shows no significant relationship between motivation questions and completion of the survey among participants in this study (see Table 4).

Despite the inclusion of an open-ended question inquiring about the reasons for survey discontinuation, only a limited number of respondents, specifically 22 out of 121, provided a response. This lack of responses can be attributed to the fact that most respondents did complete the survey to a large extent. Of those who did respond, the most commonly given reasons for discontinuation included: (1)

perceived irrelevance of the questions, (2) excessive number of questions, and (3) complexity and length of the survey items, which posed difficulties in reading and comprehending the survey content. These findings highlight the significance of designing surveys that are concise, relevant, and easy to navigate, to ensure optimal participation and minimize attrition.

Table 4: Regression analysis with completion rate as dependent variable

Predictor	*B*	*SE*	*Beta*	*t*	*p*
Intercept (constant)	.82	.06		14.23	.00
Questions interesting	.02	.02	.15	.92	.36
Previous questions well answered	.02	.02	.09	.55	.58
Questions relevant for career	-.01	.01	-.11	-.81	.42

Note: $R = .20$, $R^2 = .04$, $F = .81$ (*ns*).

5 Conclusions and implications

The results indicate that more than 75% participants complete the survey with the estimated length of 15 mins, this confirms the literature that the average length of 15 mins is appropriate supporting high completion rate. However, the incentive given in this study may contribute to the high completion rate as well. In the real self-assessment survey, a relevant reward could be considered for improving completion rate. For example, the employees would receive free career consult and training for self-development.

This study also shows that the formats of surveys significantly impact completion rates and completion time. Specifically, Likert scale surveys are completed more than two-option surveys and slider surveys. In terms of completion time per answered question, Likert-scale surveys involve less time than two-option surveys and only marginally more time than slider surveys. Likert scale is also associated with the lowest standard deviation among the three survey formats, indicating a more consistent level of performance among respondents who were assigned surveys of this response type both in the amount of time needed to complete the survey and the extent to which they completed the survey. This suggests that survey designers should consider using Likert scale to optimize completion rates and completion time. However, this conclusion is only based on the completion rates of this 121-student sample, it does not refer to any other factors. One concern that some participants tend to skip the later part of the survey by choosing middle (Likert scale) or 4 (in slider), whether they are not engaged in the survey, influenced by the incentive or it has to do with less relevance because they are students rather than employees, should be investigated further in future study.

In addition, given the longer time per answered question for two-option surveys, survey designers ought to consider using this survey format only when it is required (e.g.: complex reasoning is involved or when respondents must give a dichotomy answer). Even then, it is important to note that two-option format may still result in lower completion rates and longer overall completion time.

Moreover, the negative correlation between completion rate and average time per answered question suggests that reducing the time spent per question can increase completion rates. To improve completion rates, survey designers may consider simplifying survey items and questions, thereby reducing their length and complexity.

However, this study does not offer conclusive evidence of a relationship between motivation and completion rate. To increase motivation among employees, it can be helpful to clearly communicate the purpose and benefits of the survey, such as how the data will be used to improve employee development programs or support career growth. It can also be useful to emphasize the confidentiality and anonymity of responses to encourage employees to provide honest feedback. Additionally, offering incentives such as a free career consult and training can provide additional motivation for employees to participate. Overall, by emphasizing the importance and benefits of the survey, employers can help increase employee motivation and participation, resulting in more useful data and better outcomes for all involved.

Finally, the findings and conclusions of this study should be viewed in light of two potential limitations. The first limitation concerns the sample group and sample size. While the sample of students provides insightful findings, it may only partially reflect the behaviors of employees. Therefore, future research utilizing a larger employee sample is recommended to validate the generalizability of the present study's findings. Moreover, with a sample size of only 121, divided into three response type groups, the current study's sample size is limited, which further emphasizes the need for larger samples in future research. However, it is worth noting that the current study still produced statistically significant results, which mitigates some of the concerns associated with the sample size limitation. The second limitation pertains to the potential presence of common method bias. As all variables used in the correlation and regression analyses are self-reported by the sample, there exists a possibility of common method bias. To combat this issue, future studies could incorporate research designs that utilize multiple data sources. It is essential to note, though, that the correlation and regression analyses served primarily as supplementary analysis, and the key conclusions of this study are based primarily on the ANOVA results.

Despite the above mentioned two potential limitations, this study provides valuable insights into completion rates of self-assessment surveys. The findings indicate that survey designers should give careful consideration to survey length and format to optimize completion rates and completion time, with the use of Likert scales showing promise in enhancing survey completion. While the study did not find evidence of a significant relationship between motivation and completion rates, the results underscore the importance of reducing survey complexity and length to promote engagement and participation. These findings have implications for the design and implementation of self-assessment surveys in the workplace, highlighting the need to prioritize user experience and streamline survey design to maximize data quality and promote workforce development. Overall, this study contributes to the growing body of literature on survey design and completion rates, offering practical insights for HR managers and researchers seeking to improve the use of self-assessment surveys as a tool for evaluating digital skills in the workplace.

References

Allen, J., & van der Velden, R. (2005). The Role of Self-Assessment in Measuring Skills. http://www.reflexproject.org.2

Andrade, H. L. (2019). A Critical Review of Research on Student Self-Assessment. Frontiers in Education, 4, 87. https://doi.org/10.3389/FEDUC.2019.00087/BIBTEX

Beebe, T. J., Rey, E., Ziegenfuss, J. Y., Jenkins, S., Lackore, K., Talley, N. J., & Locke III, R. G. (2010a). Shortening a survey and using alternative forms of prenotification: Impact on response rate and quality. In BMC Medical Research Methodology (Vol. 10). http://www.biomedcentral.com/1471-2288/10/50

Beebe, T. J., Rey, E., Ziegenfuss, J. Y., Jenkins, S., Lackore, K., Talley, N. J., & Locke III, R. G. (2010b). Shortening a survey and using alternative forms of prenotification: Impact on response rate and quality. In BMC Medical Research Methodology (Vol. 10). http://www.biomedcentral.com/1471-2288/10/50

Benraghda, A., Mohd Radzuan, N. R., & Lardhi, F. A. S. (2022). Self-assessment as a self-regulated learning approach in English oral presentations: College students' choices and perceptions. Http://Www.Editorialmanager.Com/Cogentedu, 9(1). https://doi.org/10.1080/2331186X.2022.2123472

Brace, I. (2013). Questionnaire design : how to plan, structure and write survey material for effective market research.

Buskirk, T. D., Saunders, T., & Michaud, J. (2015). Are Sliders Too Slick for Surveys? An Experiment Comparing Slider and Radio Button Scales for Smartphone, Tablet and Computer Based Surveys. Methods, Data, Analyses, 9(2), 32. https://doi.org/10.12758/mda.2015.013

Deutskens, E., De, K. O., Nl, R. K. D. U., Oosterveld, P., & Nl, P. O. (2004). Response Rate and Response Quality of Internet-Based Surveys: An Experimental Study. In Marketing Letters (Vol. 15, Issue 1).

Dobronte, A. (2015, June 27). Likert scales vs. slider Scales in commercial market research.

Fiorella, L., Yoon, S. Y., Atit, K., Power, J. R., Panther, G., Sorby, S., Uttal, D. H., & Veurink, N. (2021). Validation of the Mathematics Motivation Questionnaire (MMQ) for secondary school students. International Journal of STEM Education, 8(52). https://doi.org/10.1186/s40594-021-00307-x

Galesic, M. (2006). Dropouts on the Web: Effects of Interest and Burden Experienced During an Online Survey. Journal of Official Statistics, 22, 313–328.

Galesic, M., & Bosnjak, M. (2009). Effects of questionnaire length on participation and indicators of response quality in a web survey. Public Opinion Quarterly, 73(2), 349–360. https://doi.org/10.1093/poq/nfp031

Govender, S., & Parumasur, S. (2010). The Relationship between Employee Motivation and Job Involvement. SAJEMS NS, 13(3), 237–253.

Hoerger, M. (2010). Participant Dropout as a Function of Survey Length in Internet-Mediated University Studies: Implications for Study Design and Voluntary Participation in Psychological Research. Cyberpsychology, Behavior, and Social Networking, 13(6), 697–700.

Marcus, B., Bosnjak, M., Lindner, S., Pilischenko, S., & Schütz, A. (2007). Compensating for Low Topic Interest and Long Surveys A Field Experiment on Nonresponse in Web Surveys. Social Science Computer Review, 25, 372–383. https://doi.org/10.1177/0894439307297606

Nestler, S., Thielsch, M., Vasilev, E., & Back, M. D. (2015). Will They Stay or Will They Go? Personality Predictors of Dropout in an Online Study. International Journal of Internet Science, 10(1), 37–48.

Noorka, I. R., & Sarwar, M. (2020). Self-Assessment for Students. 760–769. https://doi.org/10.1007/978-3-319-95870-5_90

Parsons, C. (2007). Web-Based surveys: Best practices based on the research literature. Visitor Studies, 10(1), 13–33. https://doi.org/10.1080/10645570701263404

Revilla, M., & Ochoa, C. (2017). FORUM Ideal and maximum length for a web survey. International Journal of Market Research, 59, 557. https://doi.org/10.2501/IJMR-2017-039

Roster, C. A., Lucianetti, L., & Albaum, G. (2015). Exploring Slider vs. Categorical Response Formats in Web-Based Surveys. Journal of Research Practice, 11(1), 1–19. http://jrp.icaap.org/index.php/jrp/article/view/509/413

Savage, S. J., & Waldman, D. M. (2008). Learning and fatigue during choice experiments: A comparison of online and mail survey modes. Journal of Applied Econometrics, 23(3), 351–371. https://doi.org/10.1002/jae.984

Stanley, N., & Jenkins, S. (2007). Watch What I Do! Using Graphic Input Controls in Web Surveys. Fifth International Conference of the Association for Survey Computing. http://www.asc.org.uk

USING SIMULATORS TO ASSIST WITH HEALTHCARE ISSUES: THE IMPACT OF A SAILING SIMULATOR ON PEOPLE WITH ADHD

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The use of simulators has grown a vast amount in the past few years, with various research reports on the advantages that come with the use of this technology. However, the use of simulators as a form of treatment/aids have yet to be fully embraced. Given the growing diffusion of technology, many people can benefit from simulators that are more accessible and improve specific qualities to help them cope with their deficiencies. To examine this current void, this research in progress examines the benefits of physical activity for people with attention deficit hyperactivity disorder (ADHD) through the use of a VSail Sailing Simulator. Specifically, we contend that there are benefits to addressing strength and balance. Thus, this paper analyzes the ramifications of the findings, along with knowledge gaps and a research plan.

Keywords:
simulators, ADHD, physical activity, intervention, sailing simulation, motor function

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1 Introduction

The COVID-19 pandemic has caused a significant increase in mental health issues, leading to a surge in the number of adults being prescribed ADHD medication in Australia. According to the Australian Department of Health and Aged Care, the number of patients receiving ADHD medication has grown at an annual rate of 12.43%, with a higher growth rate of 16% observed from 2018-2020. This growth rate is almost double that of the growth rate from 2014-2017 (9%) and serves to highlight the importance to address this issue. The number of prescriptions has also increased, with an average annual growth rate of 10.25% and the highest growth rate of 17.67% observed from 2018-2020. As a result, more adults are now receiving ADHD medication than children.

Attention-deficit hyperactivity disorder (ADHD) is a neurodevelopmental disorder that affects individuals across the lifespan. The global prevalence of ADHD in children is estimated to be around 5%, while in adults, it is around 3-4% (Polanczyk and Rohde, 2007, Shaw et al. 2007, AADPA). In early childhood, symptoms of ADHD may include impulsiveness, hyperactive behaviour, and low frustration tolerance. Longitudinal neuroimaging studies indicate that children with ADHD may be 2-3 years behind their peers in development. In adulthood, individuals with ADHD may experience memory problems, restlessness, and difficulty with mental focus. Notably, 4-11% of university students exhibit symptoms of ADHD (AADPA).

Separate from this, yet contemporaneous, have been the advances in technology and simulation solutions. In this paper, we outline research in progress work that aims to address the larger key research question of "What is the degree of fidelity with which a sailing simulator can reproduce the health benefits associated with real-life sailing?". This research in progress paper contribution is towards the feasibility of using inertial measuring units (IMU) to identify hand movement patterns and motor assessments that are beneficial in real-life sailing. The primary objectives of the research-in-progress paper are:

1. Objective 1: To measure the effect of sailing simulation on grip strength and postural balance in non-ADHD and ADHD participants

2. Objective 2: To measure the acceleration patterns of both hands in a sailing simulation between ADHD and non-ADHD students.
3. Objective 3: To understand the participant's perception of ADHD therapies and simulators as a part of their therapy.

The research design employs a grounded theory mixed methods approach, incorporating both quantitative and qualitative methodologies. The quantitative aspect focuses on examining the effectiveness of IMUs in measuring various aspects of sailing simulation, including motor assessments. Whilst the qualitative perspective delves into exploring the perceptions and attitudes of individuals with ADHD towards ADHD therapy and the use of simulation as therapy. By combining both quantitative and qualitative data, we can understand how sailing simulation can influence grip strength and postural balance, along with the perception and acceptance of sports simulators as a therapeutic intervention for individuals with ADHD. Preliminary testing has been conducted to consider all critical IMU aspects of the proposed research plan.

2 Related Work

2.1 Physical Activity and ADHD

Regulating the course of neural development has the potential to improve ADHD symptoms, suggesting that interventions targeting neural growth and development will be more effective than other treatments. Non-pharmacological treatments such as cognitive-based therapies or physical activity have demonstrated effectiveness. Engaging in physical exercise is one of the most advantageous strategies for treatment, providing numerous benefits and reducing symptoms (Xie et al. 2021). Physical therapy leads to enhanced coordination and motor function, while mental health improvements include processing speed, selective attention, and cognitive flexibility (Montalva-Valenzuela et al. 2022, Watemberg et al. 2007). However, challenges exist in introducing physical activity as a treatment for ADHD, with dropout rates of 17.5% (Vancampfort et al, 2016). This suggests a need for better engagement strategies and further studies to explore other forms of physical activity (Carta et al, 2014).

2.2 Physical Activity based Interventions

Physical exercise has a positive impact on health and well-being, including improving mood, quality of life, and mitigating stress. Research on physical activity and ADHD supports using exercise as an intervention strategy. Aquatics exercise programs and racquet sports have shown efficacy in improving cognitive, behavioural, and motor functions in children with ADHD. Sailing also offers numerous benefits for mental and physical health, including enhancing concentration, communication, mental wellness, endurance, and muscle strength. It has shown positive outcomes in improving quality of life, global functioning, social skills, outlook on life, and mental and physical health for individuals with disabilities and severe mental illnesses. Sailing may be a promising intervention for enhancing well-being, particularly for those with mental illnesses, and may be more engaging than standard rehabilitation methods.

2.3 Simulator Based Interventions

Simulators are effective tools for adaptive training, which adjusts the task's complexity to the user's skill level. They can break down cognitive activities into components that are difficult to train individually. For example, simulators can introduce factors involved in sailing gradually, preventing the operator from becoming overwhelmed. Studies using a horse-riding simulator have yielded positive results in various populations. A study by Borges et al. (2011) revealed that children with cerebral palsy spastic diplegia showed greater emotional happiness and overall satisfaction with the simulator than with conventional physical therapy. The simulator was also statistically superior in increasing postural control in a seated position compared to conventional therapy. Other studies have demonstrated the simulator's potential to enhance physiological functioning in elderly individuals, such as postural control, muscle activation, and dynamic stability (Mitani et al. 2008, Kim and Lee, 2015).

3 Research Design

3.1 Participants

Study participants are divided into two groups: "non-ADHD" students and "ADHD" students aged 18-30. Both groups are screened for physical conditions and injuries. The ADHD group includes students with self-diagnosed ADHD. Participants complete the APSS Screening Tool to determine those more vulnerable to adverse events caused by exercise. The ASRS-V1.1 Symptom Checklist is used for self-diagnosis of ADHD symptoms in the ADHD group.

3.2 Apparatus

Sailing Simulator: The simulator itself is a VSail-Trainer®, designed by the company Virtual Sailing Pty Ltd. It comprises one boat hull (size length: 230 cm, breadth: 150 cm). The simulator allows sailors to control the course and speed of the boat using a joystick and mainsheet, whilst being in a seated setup suitable for disabled individuals. The simulator has a range of tools and functionalities for researchers to design experiments around, such as the ability to adjust environmental conditions, boat characteristics, and sailor behaviours.

The Inertial Measuring Unit (IMU) is a form of accelerometer, composed of an electromechanical sensor that is designed to measure dynamic acceleration. In this case, two IMUs are placed on the back of each hand of the participant. This will look at the change in velocity for the rudder movement and mainsheet.

The Jamar hand dynamometer will be used to measure isometric grip force in the participants pre- and post-trial as part of their motor assessment.

3.3 Movement Assessment

Studies suggest that postural instability in adults with ADHD may contribute to difficulties with motor coordination and everyday activities related to balance and postural control. Grip strength differences in individuals with ADHD may be influenced by a combination of motor coordination deficits, attentional deficits, and medication use. The relevance of grip strength and postural balance in real-life sailing has been shown to improve both areas. Participants will undergo a pre and post-simulator training movement assessment. The first motor assessment test will be the strength component (Hove, et al. 2015, Jansen, et al.2019, Jeoung, et al. 2014, Neely, et al. 2017, Clarke, et al. 2020). The Jamar hand dynamometer will be used to assess grip strength before and after each scenario. Balance will be assessed through a force plate or through a Balance Error Scoring System to assess overall static balance before and after each scenario.

3.4 Interviews

Semi-structured interviews can provide valuable insights into the perception and acceptance of sports simulators as a therapeutic intervention for individuals with ADHD. Including whether individuals with ADHD would be willing to use sports simulators regularly, and investigating potential benefits such as improved motor skills and ADHD symptoms, along with potential drawbacks. This can help with the development of more effective interventions for individuals with ADHD. The interviews are conducted with a consistent set of questions, while the order of the questions may be adjusted based on responses.

4 Data Collection

4.1 Participant setup

Before testing begins each participant is briefed on the simulator, equipment, and safety features. Participants sign a consent form and wear two IMUs on their hands. After being seated in the V-Sail simulator, participants are given an adaptation period to learn how to sail using the information provided in the HUD. Steering is introduced first, followed by the main sheet, teaching participants how to adjust the main sail and coordinate the boat's speed based on wind direction. Participants also learn maneuvers such as tacking and aligning the twin tails on the mainsail to use the wind to their advantage. The final step is to introduce the pneumatic rams, which allow participants to understand how the boat handles at certain angles relative to the wind.

4.2 Sailing Program

Participants will train on a Sydney 2000 Olympic Games Trapezoid course in the Sydney harbour. The course involves sailing upwind to the first buoy, then downwind past three buoys, and back upwind. The training program consists of 6 sprints per week for three weeks, with each sprint lasting 3-4 minutes on average. The sprints progressively increase in difficulty and challenge the participants' decision-making and technique accuracy. The wind speeds will be implemented through a blocked and serial schedule in the first and final weeks.

4.3 Data Analysis

Pre and Post Movement Assessment: The measurements obtained for both sets of pre and post scenarios are evaluated. To evaluate whether the mean difference between the two sets of data varies, a paired sample t-test is performed.

IMUS:

1. Average acceleration magnitude (AAM): The standard deviation of acceleration from the mean. More task stability is indicated by smaller values.
2. Root mean square (RMS): An evaluation of the fluctuating signal strength. Significant stability is indicated by smaller values.

Interviews: Thematic Analysis

5 Preliminary Findings

The pilot study aimed to determine if IMU placement and hand movement are appropriate measures for testing and comparing real-life sailing. The study collected data from a healthy participant using two IMUs on the back of both hands in three different wind conditions (8, 12, and 16 knots). The approach was based on a previous study by Mackie and Legg (1999) that focused on how force output varies with wind speed, finding that force on the mainsheet increases with higher winds. Mackie and Legg (1999) also found a trend between force and wind through experience level in sailing. Specifically, the mainsheet force increased for club sailors with less experience, while the opposite trend was found for pro sailors. This is due to differences in sailing techniques found with experience as conditions get more difficult.

Table 1: Differences between both hands and the wind speed, expressed as an average acceleration magnitude (AAM) and root-mean-squared (RMS)

	Hand	8 Knots Wind Speed	12 Knots wind speed	16 Knots wind speed
Average acceleration magnitude (AAM) (m/s^2)	Left (Tiller)	9.52	9.53	9.56
	Right (Mainsheet)	9.76	9.76	9.8
Root mean square (RMS) (m/s^2)	Left (Tiller)	5.51	5.52	5.54
	Right (Mainsheet)	5.66	5.67	5.68

The study aims to quantify the difference in acceleration for hand movement between ADHD and healthy students. The preliminary study showed variability in both AAM and RMS parameters with increasing wind speed. At 8 and 12 knots wind speed, there were similarities in the acceleration of both hands, while 16 knots showed less stability during the sprint. The results are consistent with Mackie and Legg's study, which found higher force in the mainsheet between wind speeds of 15-20 knots. The findings of the IMU showed an increase in acceleration for both hands as wind speed increased, similar to real-life sailing. The methodology allowed for finding variability in the set conditions in the simulator. Through the research, we can observe how the movement patterns of students with ADHD differ from those of healthy students in the sailing simulator, and how these patterns progress with experience.

This study has a few parts worth considering and should help inform future research directions. With this research looking at the feasibility of IMUs future research will be focusing on using the IMUs towards the comparison of movement in real-life sailing. Future Research In this current generation of human and computer interaction, simulator use will also provide insight into values, interests, and user experience giving a good basis for how simulators are taken as a form of therapy in managing ADHD.

6 Conclusion

This research in progress study has served to highlight a potential role for the use of simulators to address mental health/mental wellness issues. Specifically, we have focused on the benefits of a sailing simulator to assist students with ADHD. To date, the application of simulators to assist with addressing mental health/ mental wellness issues is embryonic at best; but we contend that the potential benefit of this approach justifies more research in this area. We believe our study will serve as one of the first to shed light on this major area.

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References

BARKLEY, R. A., FISCHER, M., SMALLISH, L. & FLETCHER, K. 2002. The persistence of attention-deficit/hyperactivity disorder into young adulthood as a function of reporting source and definition of disorder. Journal of Abnormal Psychology, 111, 279-289.

BEHRMANN, J. T., BLAABJERG, J., JORDANSEN, J. & JENSEN DE LÓPEZ, K. M. 2022. Systematic Review: Investigating the Impact of COVID-19 on Mental Health Outcomes of Individuals With ADHD. Journal of Attention Disorders, 26, 959-975.

BELL, D. R., GUSKIEWICZ, K. M., CLARK, M. A. & PADUA, D. A. 2011. Systematic review of the balance error scoring system. Sports Health, 3, 287-95.

BORGES, M. B. S., WERNECK, M. J. D., DA SILVA, M. D., GANDOLFI, L. & PRATESI, R. 2011. Therapeutic effects of a horse riding simulator in children with cerebral palsy. Arquivos De Neuro-Psiquiatria, 69, 799-804.

CARTA, M. G., MAGGIANI, F., PILUTZU, L., MORO, M. F., MURA, G., CADONI, F., SANCASSIANI, F., VELLANTE, M., MACHADO, S. & PRETI, A. 2014. Sailing for rehabilitation of patients with severe mental disorders: results of a cross over randomized controlled trial. Clin Pract Epidemiol Ment Health, 10, 73-9.

CHANG, Y. K., HUNG, C. L., HUANG, C. J., HATFIELD, B. D. & HUNG, T. M. 2014. Effects of an aquatic exercise program on inhibitory control in children with ADHD: a preliminary study. Arch Clin Neuropsychol, 29, 217-23.

CLARKE, M. L., CLAPHAM, E. D. & SHIM, M. 2020. Sailing as Therapy: Adapted Sailing on Children with Disabilities. Palaestra, 34, 37-43.

COTTERILL, S. T. & BROWN, H. 2018. An exploration of the perceived health, life skill and academic benefits of dinghy sailing for 9-13-year-old school children. Journal of Adventure Education and Outdoor Learning, 18, 227-241.

COUSINS, M. & SMYTH, M. M. 2003. Developmental coordination impairments in adulthood. Human Movement Science, 22, 433-459.

DAVOODY, S., GOESCHL, S., DOLATSHAHI, M., DAVARI-ASHTIANI, R., SAFFARPOUR, R., SODEIFIAN, F. & BRAND, S. 2022. Relation between ADHD and COVID-19: A Narrative Review to Guide Advancing Clinical Research and Therapy. Iran J Psychiatry, 17, 110-117.

D. U. S. C., (DUSC). 2021. Attention Deficit Hyperactivity Disorder:

Utilisation Analysis. In: DHAC (ed.). Pharmaceutical Benefits Scheme (PBS): Drug utilisation sub-committee (DUSC).

ECONOMICS, D. A. 2019. The social and economic costs of ADHD in Australia. Australian ADHD Professionals Association (AADPA)

GIEDD, J. N. & RAPOPORT, J. L. 2010. Structural MRI of pediatric brain development: what have we learned and where are we going? Neuron, 67, 728-34.

GUADAGNOLI, M. A. & LEE, T. D. 2004. Challenge point: a framework for conceptualizing the effects of various practice conditions in motor learning. J Mot Behav, 36, 212-24.

HOVE, M. J., ZEFFIRO, T. A., BIEDERMAN, J., LI, Z., SCHMAHMANN, J. & VALERA, E. M. 2015. Postural sway and regional cerebellar volume in adults with attention-deficit/hyperactivity disorder. Neuroimage-Clinical, 8, 422-428.

HOZA, B., SMITH, A. L., SHOULBERG, E. K., LINNEA, K. S., DORSCH, T. E., BLAZO, J. A., ALERDING, C. M. & MCCABE, G. P. 2015. A randomized trial examining the effects of aerobic physical activity on attention-deficit/hyperactivity disorder symptoms in young children. J Abnorm Child Psychol, 43, 655-67.

JANSEN, I., PHILIPSEN, A., DALIN, D., WIESMEIER, I. K. & MAURER, C. 2019. Postural instability in adult ADHD - A pilot study. Gait & Posture, 67, 284-289.

JEOUNG, B. J. 2014. The relationship between attention deficit hyperactivity disorder and health-related physical fitness in university students. Journal of Exercise Rehabilitation, 10, 367-371.

KIM, S. G. & LEE, J. H. 2015. The effects of horse riding simulation exercise on muscle activation and limits of stability in the elderly. Archives of Gerontology and Geriatrics, 60, 62-65.

KIRBY, A., EDWARDS, L., SUGDEN, D. & ROSENBLUM, S. 2010. The development and standardization of the Adult Developmental Co-ordination Disorders/Dyspraxia Checklist (ADC). Res Dev Disabil, 31, 131-9.

LATHAN, C. E., TRACEY, M. R., SEBRECHTS, M. M., CLAWSON, D. M. & HIGGINS, G. A. 2002. Using virtual environments as training simulators: Measuring transfer. Handbook of virtual environments: Design, implementation, and applications, 403-414.

MACKIE, H. W. & LEGG, S. J. 1999. Preliminary assessment of force demands in laser racing. J Sci Med Sport, 2, 78-85.

MARTIN, N. C., PIEK, J. P. & HAY, D. 2006. DCD and ADHD: A genetic study of their shared aetiology. Human Movement Science, 25, 110-124.

MATHIOWETZ, V., WEBER, K., VOLLAND, G. & KASHMAN, N. 1984. Reliability and Validity of Grip and Pinch Strength Evaluations. Journal of Hand Surgery-American Volume, 9a, 222-226.

MERCURIO, L. Y., AMANULLAH, S., GILL, N. & GJELSVIK, A. 2021. Children With ADHD Engage in Less Physical Activity. Journal of Attention Disorders, 25, 1187-1195.

MITANI, Y., DOI, K., YANO, T., SAKAMAKI, E., MUKAI, K., SHINOMIYA, Y. & KIMURA, T. 2008. Effect of exercise using a horse-riding simulator on physical ability of frail seniors. Journal of Physical Therapy Science, 20, 177-183.

MONTALVA-VALENZUELA, F., ANDRADES-RAMIREZ, O. & CASTILLO-PAREDES, A. 2022. Effects of Physical Activity, Exercise and Sport on Executive Function in Young People with Attention Deficit Hyperactivity Disorder: A Systematic Review. European Journal of Investigation in Health Psychology and Education, 12, 61-76.

NEELY, K. A., WANG, P., CHENNAVASIN, A. P., SAMIMY, S., TUCKER, J., MERIDA, A., PEREZ-EDGAR, K. & HUANG-POLLOCK, C. 2017. Deficits in inhibitory force control in young adults with ADHD. Neuropsychologia, 99, 172-178.

PAN, C. Y., CHU, C. H., TSAI, C. L., LO, S. Y., CHENG, Y. W. & LIU, Y. J. 2016. A racket-sport intervention improves behavioral and cognitive performance in children with attention-deficit/hyperactivity disorder. Research in Developmental Disabilities, 57, 1-10.

POLANCZYK, G. & ROHDE, L. A. 2007. Epidemiology of attention-deficit/hyperactivity disorder across the lifespan. Current Opinion in Psychiatry, 20, 386-392.

RECIO, A. C., BECKER, D., MORGAN, M., SAUNDERS, N. R., SCHRAMM, L. P. & MCDONALD, J. W. 2013. Use of a virtual reality physical ride-on sailing simulator as a rehabilitation tool for recreational sports and community reintegration: A pilot study. American Journal of Physical Medicine and Rehabilitation, 92, 1104-1109.

SHAW, P., ECKSTRAND, K., SHARP, W., BLUMENTHAL, J., LERCH, J. P., GREENSTEIN, D., CLASEN, L., EVANS, A., GIEDD, J. & RAPOPORT, J. L. 2007. Attention-deficit/hyperactivity disorder is characterized by a delay in cortical maturation. Proceedings of the National Academy of Sciences of the United States of America, 104, 19649-19654.

SHAW, P., GILLIAM, M., LIVERPOOL, M., WEDDLE, C., MALEK, M., SHARP, W., GREENSTEIN, D., EVANS, A., RAPOPORT, J. & GIEDD, J. 2011. Cortical Development in Typically Developing Children With Symptoms of Hyperactivity and Impulsivity: Support for a Dimensional View of Attention Deficit Hyperactivity Disorder. American Journal of Psychiatry, 168, 143-151.

TENBRINK, T. & DYLLA, F. 2017. Sailing: Cognition, action, communication. Journal of Spatial Information Science, 3-33.

VANCAMPFORT, D., FIRTH, J., SCHUCH, F. B., ROSENBAUM, S., PROBST, M., WARD, P. B., VAN DAMME, T., DE HERT, M. & STUBBS, B. 2016. Dropout from physical activity interventions in children and adolescents with attention deficit hyperactivity disorder: A systematic review and meta-analysis. Mental Health and Physical Activity, 11, 46-52.

WATEMBERG, N., WAISERBERG, N., ZUK, L. & LERMAN-SAGIE, T. 2007. Developmental coordination disorder in children with attention-deficit-hyperactivity disorder and physical therapy intervention. Dev Med Child Neurol, 49, 920-5.

WILENS, T. E., BIEDERMAN, J., FARAONE, S. V., MARTELON, M., WESTERBERG, D. & SPENCER, T. J. 2009. Presenting ADHD Symptoms, Subtypes, and Comorbid Disorders in Clinically Referred Adults With ADHD. Journal of Clinical Psychiatry, 70, 1557-1562.

XIE, Y. T., GAO, X. P., SONG, Y. L., ZHU, X. T., CHEN, M. G., YANG, L. & REN, Y. C. 2021. Effectiveness of Physical Activity Intervention on ADHD Symptoms: A Systematic Review and Meta-Analysis (vol 12, 706625, 2021). Frontiers in Psychiatry, 12.

THE ANATOMY OF A PERSONAL SERVICE: THE EIGHT DIMENSIONS OF 'PERSONAL'

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Digitalization enables public organizations to personalize their services, tuning them to the specific situation, abilities, and preferences of the citizens. At the same time, digital services can be experienced as being less personal than face-to-face contact by citizens. The large existing volume of academic literature on personalization mainly represents the service provider perspective. In contrast, in this paper we investigate what makes citizens experience a service as personal. The result are eight dimensions that capture the full range of individual experiences and expectations that citizens expressed in focus groups. These dimensions can serve as a framework for public sector organizations to explore the expectations of citizens of their own services and identify the areas in which they can improve the personal experiences they offer.

Keywords:
personalisation, personal service, public services, digitalisation customer experience, Bled eConference

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1 Introduction

One of the promises of digitalization of data-intensive services is the ability to deliver personalized services that lead to personal customer experiences, catering to the unique needs, preferences, and situations of individual consumers. The expectation is that such personalized services will result in enhanced customer experiences and yield better outcomes for service providers (Chandra et al., 2021). However, since the advent of digital services, private and public sector organizations have been struggling to offer their customers an authentic personal experience in the digital age. It has been shown that personalization does not always lead to personal service (Pol et al., 2020). Ironically, excessive personalization in digital services often misses the mark by failing to make customers feel valued and, instead, causing alienation (White et al., 2008; Teeny et al., 2021; Riegger et al., 2021; Kim et al., 2022). Apparently, organizations have yet to grasp what constitutes a genuinely personal service to customers. Designing personalized digital services that are truly personal is a complex challenge, with at its heart the question of what customers or citizens perceive as 'personal' in a service interaction.

Although there is a proliferation of literature on personalization, by far most studies are concerned with the technical aspects or, to a lesser extent, with the impact of personalization on the effects aimed for by the organization (Zanker et al., 2010; Sunikka & Bragge, 2008). The voice of the citizen in terms of what makes a service personal to them is hardly heard, let alone taken as starting point. This lacking perspective represents a significant gap in existing literature.

This paper aims to address this gap within the context of public organizations. To explore experiences with and expectations of public services being personal, we analysed 12 interviews with managers of digital services provided by public organizations (i.e. tax services, utility companies, municipalities) and 16 focus group sessions with citizens who had interacted with those public organizations. The resulting analysis led to eight dimensions that describe the anatomy of a truly personal service from a citizen's perspective rather than an organizational perspective. We consider these eight dimensions a starting point for a framework that organizations can employ to assess the personal quality of their services, and to drive potential redesign of their personalized services.

In this paper, section 2 delves into the history and current usage of the concepts of personalized versus personal service, while section 3 outlines the context and research methodology of our study. The results are presented in section 4, followed by a discussion of the findings and limitations in section 5. Section 6 presents the conclusions.

2 Personalized and personal

The concept of personalization was originally introduced by Surprenant & Solomon (1987) as a means of describing the transformation of formal customer-organization interactions into more intimate and personal ones, which recognize the customer as a unique individual. In their seminal work, Surprenant & Solomon differentiated between outcome personalization, which is focused on the end result for the customer, and process personalization, which is concerned with the customer journey. Process personalization, in turn, can be classified into two types: programmed personalization, which is intended to convey the appearance of personalized service (e.g., a "Dear {First name}-email"), and customised personalization, which involves making genuine efforts to find ways to best help each individual customer.

Today, "personalization" typically denotes interactions in digital contexts that use data to tailor the services to the characteristics of the consumption experience (e.g., the consumer, context, and history) (Chandra et al., 2022). The majority of the literature on personalization of services focuses on the technical interventions that make a service more personalized (Fan & Poole, 2006; Morana et al., 2017).

Tuning a service to the needs of the service consumer requires knowledge. Various types of knowledge can be used to improve the experience. Examples are knowledge of the situational circumstances in which interaction takes place, knowledge of the service consumer's goals and state of mind, and knowledge of their personal characteristics (Fischer, 2012; Barwitz & Maas, 2018). Systems possessing this kind of information, however, also entails potential risks. Firstly, in research carried out in commercial contexts, when automatic processes present a consumer with a supposedly relevant selection of all content based on available data, this selection inherently reflects some degree of subjectivity as well as nudging, which impairs consumer autonomy (Mittelstadt et al., 2016). Secondly, the consumer can develop personal reactance, a situation where excessive personalization can lead to psychological resistance to subjectively inappropriate personalization (White et al., 2008). In such cases, consumers experience too much familiarity with their preferences and behaviours. Utilizing consumer data alone is, therefore, insufficient to create true personal services.

A different approach to assessing the personal quality of a service is to consider it in terms of relational models. Fiske (1991) proposes the Relational Models Theory, which identifies four fundamental relational models that people use unconsciously in their interactions with each other, and with organizations (McGraw & Tetlock, 2005): communal sharing, market pricing, authority ranking, and equality matching. Communal sharing represents a common interest and a desire to connect, and it is the most intimate of the four models, thus closest to the concept of personal service. Pol et al. (2020) demonstrated that the presence of communal sharing has a positive effect on customer experience and satisfaction. As communal sharing increases, positive emotions are amplified, and negative emotions are mitigated.

In our paper, we adopt the term "personal" to refer to how individuals perceive a service, recognizing that this perception is subjective and unique to each person. This has important implications. Firstly, it underscores that there is no universal solution for personalization. Secondly, it implies that conventional metrics for personalization success, such as engagement, conversion, and convenience, may not capture the essence of a personal experience, as they fail to account for the citizen's true experience (Sunikka & Bragge, 2008; Zanker et al., 2010). Thirdly, it suggests that the only reliable way to determine whether a service is personal is to ask the consumer of the service. Accordingly, this study does exactly that.

3 Research Method

This study was performed within the context of a research project conducted in the Netherlands on the effects of digital transformation on public services. For an earlier study within this project both public service providers and citizens, as the users of their services, were involved in interviews and focus group sessions about digital service experiences and expectations (see table 1 for specifics on the participants). For the current study we returned to the data collection of this study, using the transcripts of the recordings as a secondary data source. We identified passages in the transcripts of both interviews and focus groups in which participants speak about personal services and what aspects makes these services personal to them. The research design included two stages. In the first stage, 12 transcripts of organizational interviews were subjected to open coding, focusing on those parts where the organizational representatives discussed the expectations of their citizens with regard to the personal quality of their services. We focused our coding on fragments where the organizational representatives discussed actual feedback from and experiences with their customers, for instance through customer panels. The saturation point was reached after analysing 12 organizational interviews: no more new themes or dimensions were identified.

Table 1: Participants on organizational and individual level

	Number of organizational interviews (number of participants)	**Number of citizen focus groups (number of participants)**
National government services (e.g. DMV, tax, foreign affairs, student loans)	5 (6)	4 (11)
Municipalities (large and smaller counties)	3 (3)	4 (11)
Public transport companies	1 (2)	4 (11)
Insurances and pension funds	3 (5)	
Utility companies	1 (2)	4 (11)

The second stage focused on validating these dimensions with relevant passages in the focus groups, using template coding. As the original study was exploratory in nature, the interviews were semi-structured according to a topical interview guide. Participants were invited to bring up experiences and observations they deemed relevant and react to each other's contributions. To ensure the quality and consistency of our data set, we devised the following protocol on identifying relevant passages. The first step consisted of identifying parts of the interviews that explicitly talked about or asked for qualifications and assessments of personal. Those parts were then divided into passages to be coded. The first four transcripts were processed by two researchers independently, to validate identification and partitioning processes, and the criteria used for both were calibrated. The other transcripts were then divided between two researchers and processed individually.

As the interviews were wide ranging, strict criteria were used for establishing whether an individual passage was to be coded: 1) all passages that were direct responses to questions that pertained explicitly to the personal qualities of services were considered for coding; 2) other passages in the interview were only considered if direct references were made to a service being personal; 3) only direct responses to questions of the interviewer and/or passages concerning a participant's own experience or expectations were considered. Passages where participants reflected on each other's experiences or in which they hypothesized on what people in general might prefer were excluded. All transcripts were first coded by two researchers independently and then compared. Coding differences were discussed and resolved. 12 of the available 16 focus group transcripts were analysed, after which saturation occurred. No new dimensions were found.

4 Results

The analysis of the interviews with organizations and citizen focus groups led to eight dimensions that capture the full range of citizen's experiences and expectations of personal services. These dimensions are *time, location, language, complexity, individual relevance, confidence to act, empathy* and *autonomy* (see Table 2; the examples in this table are translated from Dutch for the benefit of this paper).

Under *time* we classified all statements that pertained to aspects such as opening hours, flexibility in when to get in touch, and the amount of time needed for a service. *Location* pertains to statements concerning the locations where the service can be received and for instance the amount of travel time needed to get to a physical location of the service provider. *Language* refers to inclusiveness of the verbal statements (use of jargon, available languages), but also mode (spoken, written, visual, etc.) and tone of voice as well as form of address. *Complexity of the task* was mentioned, for instance, in relation to situations where the process was more complex than the underlying task or issue (an official document that could only be sent via physical mail and not digitally, felt cumbersome to one of the respondents). *Individual relevance* refers to all situations where processes, answers or suggestions (generated for instance on the citizen's known history) were felt to be truly geared to the situation.

Table 2: Eight dimensions of personal services

Dimension	Definition	Examples of aspects	Quotes
Time	The extent to which the moments when and the duration in which the service (can) take place are experienced as being appropriate.	• The times of the day the service is available and whether it is offered at a time that suits citizens • The freedom of choice that citizens are given ("fixed call time, schedule an appointment yourself or just walk in") • Sufficient time is taken for the service • The service is fast/on time (relative to expectations)	"And make just a little more time for that. And don't rush."
Location	The extent to which the location where the service (can) be delivered is experienced as being appropriate.	• The location from which the service can be used • The distance one must travel to purchase the service	"So the first time you had to go to the town hall after birth, now it could all be done digitally."
Language	The extent to which the form in which the communication about the service (can) take place is experienced as being appropriate.	• The language spoken • The tone of voice and manner of address • Visual, spoken, written • Use of jargon	"I think being polite, is very important to me."
Complexity	The extent to which the mental effort required to do or understand something is experienced as being appropriate.	• Whether the complexity of the process is in proportion to the complexity of the underlying task or issue • Whether the time it takes to acquire a service is in proportion to the complexity of the task. •	"If it is complicated then it is fine, they should take their time"
Individual Relevance	The extent to which the service is experienced as being in line with the current context.	• Solutions, alternatives, help, tips, that match the situation	"I don't want a general answer, but

		• Known history (contact moments, usage and consumption behaviour) • Proactive suggestions that meet the needs of citizens	an answer specific to my situation."
Confidence to act	The extent to which someone experiences that the service provides an action perspective.	• Feeling confident that past actions or actions to be taken led or will lead to a solution or to next steps towards a solution. • The felt need for confirmation • Interim feedback	" So, then you can say again: 'oh that means that I that and that..', and you don't have that option if you look at something on the website."
Empathy	The extent to which someone experiences that they are being seen and heard and that their concerns are taken seriously.	• Providing space to tell the story • Showing interest • Summarizing and checking • Thinking along and providing solutions and alternatives • Expressing understanding	"Think along with someone. Try to empathize a little bit and that has to do with caring."
Autonomy	The extent to which someone experiences that they can shape or influence the service in terms of process and outcome.	• Outcome is not predetermined • Not being forced into an ill-fitting pattern • Being able to act in accordance with yourself	"In different ways, eh, there are different options. You can also make an appointment without a DigiD"

Confidence to act is about how much someone feels that the service gives them enough information to proceed (clear feedback, transparent information, well-written answers). *Empathy* captures all statements where citizens felt the organization truly cared, and *autonomy*, finally, is about whether someone feels that the outcome of an interaction is predetermined or that they are being forced into an inflexible process.

All eight dimensions were strongly represented in both data sets (organizational and citizen focus groups), with language, individual relevance and empathy being coded relatively most frequently, and location and confidence to act less frequently. Passages that led to discussions fall into three clusters. The first cluster contains statements by respondents who, as a matter of definition, seem to equate personal services with services offered by a human. Or conversely, some respondents seem to classify services offered digitally as not personal by definition. Their statements do not fit any of the eight dimensions well, but also do not contribute new dimensions on what makes a service personal. In a similar fashion, the second cluster contains statement by respondents who equate personal services with services that deal with sensitive aspects of a citizen's life, equivalent to the classification of medical or financial information as personal information. This, however, does not attribute any properties to the way a service is offered, but more to the area or domain the service is in. These statements, too, were not coded. Finally, the last cluster contains statements that begged reflection on the completeness of the eight dimensions. The first type were statements that refer to the importance of two-way communication, including physical and non-verbal aspects of communication. An example is the respondent who stated: "when I am in a face-to-face conversation, I can see by the way they react that something is wrong". Careful consideration of these type of statements led to them begin mapped to the *language* dimension (i.e. being able to interpret the sincerity of a response). The second type included statements on the types of feedback that are needed to feel 'noticed', which is part of the definition of the *empathy* dimension. The final set of statements in this cluster concerned experiencing relatedness to the service provider. This is in line with the conclusion by Pol et al. (2020) that communal sharing has a positive effect on customer experience. As it addresses another level than individual services, we did not translate these into an additional dimension.

5 Discussion

The eight dimensions that emerged from the interviews and focus groups seem to have an interesting relation to existing areas of academic work.

From the beginnings of digital service provisions, attention has been given to *accessibility* aspects. Being able to interact with a service provider at one's own time and from any location has been one of the selling points of digitalized services. Interface design and tone of voice of digital conversations has also received plenty of attention from the start. We recognize this in the dimensions of time, location and language.

With the increasing availability of data, attention turned to the *cognitive* aspects of digital services, creating personal relevance based on situational data. Large amounts of data enable context-awareness in service provision, providing the 'right' information, at the 'right' time, in the 'right' place, in the 'right' way, to the 'right' person (Fischer, 2012). Morana et al. (2017) discusses the influence of task complexity. Complexity has a bi-directional relation with the way service interactions are designed: interaction design may be aimed at reducing complexity, but the effect of design or execution choices is also influenced by the complexity of the task (Morana et al., 2017). Users benefit more from suggestive guidance if the task is simple while the benefits of informative guidance increase as the complexity of the task increases. In the focus groups, various citizens expressed varying expectations that were specific for either high or low complexity tasks. We recognize these cognitive aspects in the dimensions of complexity and individual relevance.

Research in artificial intelligence is fostering a large volume of literature on the ethical impact of digitalization, with attention for *personal values and beliefs*. The emerging literature on social AI deals with social relations including showing empathy (Kim et al., 2021). Confidence to act is much discussed in relation to the use of algorithms (Lee & See, 2004; Gaertig & Simmons, 2018; Longoni et al., 2019; Dietvorst & Bartels, 2020). Users may have the impression that algorithms are less able to respond to their unique, individual situation than a human advisor. Longoni et al. (2019) introduce the construct Uniqueness neglect for this. Users may also have the impression that algorithms always "just" maximize a one-dimensional utility function and therefore trust algorithms less in ethically difficult domains (Dietvorst

& Bartels, 2020). In the algorithmic decision making, autonomy plays an important role, and as a result the concept of algorithmic affordances (options for the user to actively influence the outcome of the algorithm, by for instance tweaking the weight of parameters) receives more and more attention (Hekman et al., 2022, Smits et al., 2019, Dietvorst et al., 2018). Having some control over what to do with the outcomes of AI can increase adoption rates (Dietvorst et al., 2018), and can make the recommendations feel more personal (Hekman et al., 2022). The importance of maintaining control is also found in broader research into human-machine interaction. Personal values and beliefs we recognize in the dimensions of confidence to act, empathy and autonomy.

This same progress from attention for accessibility to cognitive aspects to values and beliefs in literature is partly mirrored in service provider strategies and development plans found in the professional field. Time, place and language are mentioned in any omnichannel strategy. Content personalization and advice robots are becoming increasingly common. However, providers are currently discovering that other, softer, dimensions remain that determine whether citizens experience their service as being personal.

A final observation that results from this study is that, interestingly enough, none of the dimensions are, by their definition, inherently bound to either digital or human services. For each dimension, both personal and non-personal experiences were mentioned, and those experiences have taken place in the context of human-to-human services and digital services. That leads to the conclusion that the eight dimensions may also have descriptive value for organizations that offer mixed portfolios of human and digital services and are striving for a more personal service experience.

6 Conclusions

The main contribution of this paper is capturing and organizing the language that citizens use when they assess the personal quality of a service. Although literature on personalization of services abound, this explicit perspective was still missing. The eight dimensions (time, location, language, complexity, individual relevance, confidence to act, empathy and autonomy) that citizens use to describe their experiences with and expectations of personal services is a first step towards a framework of personal service.

A limitation of the study presented here is that it is grounded in the context of public services in The Netherlands. Similar studies will have to be conducted in other domains and other cultural situations to assess the extent to which these dimensions and, in its wake, the preliminary clustering into three categories, can be generalized. For now, both the professional practice and the academic research community seem to recognize the dimensions. They are all regularly encountered in both domains, al be it in a fragmentary manner, distributed over various disciplines, and rarely discussed from the perspective of the citizen who uses the service.

Further validation is needed to determine the completeness of our list of dimensions, and the extent to which a potential resulting framework of dimensions can, in fact, be used to evaluate and improve services. Currently, this preliminary framework does provide a structure to reflect on the personal quality of services (digital and human-to-human). The main contribution of this paper, therefore, is its insights on what makes a public service personal from the perspective of the service consumer, and its operationalization of the personal quality of services in terms of eight dimensions.

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References

Barwitz, N., Maas, P. (2018). Understanding the omnichannel customer journey: determinants of interaction choice. Journal of interactive marketing, 43(1), 116-133.

Chandra, S., Verma, S., Lim, W. M., Kumar, S., Donthu, N. (2022). Personalization in personalized marketing: Trends and ways forward. Psychology & Marketing, 39(8), 1529-1562.

Dietvorst, B. J., Simmons, J. P., Massey, C. (2018). Overcoming algorithm aversion: People will use imperfect algorithms if they can (even slightly) modify them. Management Science, 64(3), 1155-1170.

Dietvorst, B. J., Bartels, D. M. (2020). Consumers object to algorithms making morally relevant tradeoffs because of algorithms' consequentialist decision strategies. Journal of Consumer Psychology.

Fan, H., Poole, M. S. (2006). What is personalization? Perspectives on the design and implementation of personalization in information systems. Journal of Organizational Computing and Electronic Commerce, 16(3-4), 179-202.

Fischer, G. (2012, May). Context-aware systems: the 'right' information, at the 'right' time, in the 'right' place, in the 'right' way, to the 'right' person. In Proceedings of the international working conference on advanced visual interfaces (pp. 287-294).

Fiske, A. P. (1991). Structures of social life: The four elementary forms of human relations: Communal sharing, authority ranking, equality matching, market pricing. Free Press.

Gaertig, C., Simmons, J. P. (2018). Do people inherently dislike uncertain advice? Psychological Science, 29(4), 504-520.

Hekman, E., Nguyen, D., Stalenhoef, M., Van Turnhout, K. (2022). Towards a Pattern Library for Algorithmic Affordances. Joint Proceedings of the IUI 2022 Workshops, vol. 3124, 24-33.

Kim, J., Merrill Jr, K., Collins, C. (2021). AI as a friend or assistant: The mediating role of perceived usefulness in social AI vs. functional AI. Telematics and Informatics, 64, 101694.

Kim, J. J., Kim, T., Wojdynski, B. W., Jun, H. (2022). Getting a little too personal? Positive and negative effects of personalized advertising on online multitaskers. Telematics and Informatics, 101831.

Lee, J. D., See, K. A. (2004). Trust in automation: Designing for appropriate reliance. Human factors, 46(1), 50-80.

Longoni, C., Bonezzi, A., Morewedge, C. K. (2019). Resistance to medical artificial intelligence. Journal of Consumer Research, 46(4), 629-650.

McGraw, A. P., Tetlock, P. E. (2005). Taboo trade-offs, relational framing, and the acceptability of exchanges. Journal of Consumer psychology, 15(1), 2-15.

Mittelstadt, B. D., Allo, P., Taddeo, M., Wachter, S., Floridi, L. (2016). The ethics of algorithms: Mapping the debate. Big Data & Society, 3(2), 2053951716679679.

Morana, S., Schacht, S., Scherp, A., Maedche, A. (2017). A review of the nature and effects of guidance design features. Decision Support Systems, 97, 31-42.

Pol, H., Galetzka, M., & Pruyn, A. (2020). New perspectives on customer relationships: how relational models influence customer experience and how they are activated. Journal of relationship marketing, 19(1), 29-51.

Riegger, A. S., Klein, J. F., Merfeld, K., Henkel, S. (2021). Technology-enabled personalization in retail stores: Understanding drivers and barriers. Journal of Business Research, 123, 140-155.

Smits, A., Van Turnhout, K., Hekman, E., Nguyen, D.: Data-driven design. Proceedings of the 22nd International Conference on Engineering and Product Design Education. (2020). https://doi.org/10.35199/EPDE.2020.10

Sunikka, A., & Bragge, J. (2008, January). What, who and where: insights into personalization. In Proceedings of the 41st annual Hawaii international conference on system sciences (HICSS 2008) (pp. 283-283). IEEE.

Surprenant, C. F., Solomon, M. R. (1987). Predictability and personalization in the service encounter. Journal of marketing, 51(2), 86-96.

Teeny, J. D., Siev, J. J., Briñol, P., Petty, R. E. (2021). A review and conceptual framework for understanding personalized matching effects in persuasion. Journal of Consumer Psychology, 31(2), 382-414.

White, T. B., Zahay, D. L., Thorbjørnsen, H., Shavitt, S. (2008). Getting too personal: Reactance to highly personalized email solicitations. Marketing Letters, 19, 39-50.

Zanker, M., Ricci, F., Jannach, D., Terveen, L. (2010). Measuring the impact of personalization and recommendation on user behaviour. International Journal of Human-Computer Studies, 68(8), 469-471.

DERIVING DECISION MINING SYSTEM CAPABILITIES: A RESEARCH AGENDA

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Decision Mining (DM) is increasingly gaining attention from academia and slowly progressing towards instrumental application in practice by leveraging decision logs to automatically discover, check for conformance and improve derivation patterns for operational decision-making. This study aims to further operationalize DM by identifying capabilities in the form of functional and non-functional requirements that are posed in the current body of knowledge. By identifying and analysing DM contributions with a focus on derivation patterns we were able to point out the aspects of DM getting attention as well as which did not, e.g., a strong focus on input data and algorithms regarding the discovery phase while the output (data) of the improvement phase seems to be detailed insignificantly. Based on this we formulated a research agenda in which five key points for future research studies are presented.

Keywords:
decision mining, capabilities, systems, requirements, research agenda, literature

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1 Introduction

Proper operational decision-making is one of the most important capabilities of an organization (Mircea et al., 2012). Especially when organizations designed products and services that focus on high volumes of data processing for operational decision-making (Chalvatzis et al., 2019; Rula et al., 2016), such as governmental services focusing on calculation and application of benefits or financial services for opening accounts at a bank. Adequately managing these operational decisions is becoming increasingly difficult as the digitization of products and services as well as the transition towards fully automated operational decision-making becomes more prevalent. One way of reducing complexity in IT is to separate concerns such as 'data', 'user interfacing', and 'processes' from each other (Dijkstra, 1974; Ossher & Tarr, 2001), which resulted in separate systems to do so as well. A whole research field now focuses on separating decisions, sometimes also referred to as 'the logic', so that its management can be simplified and made more explicit (Bajec & Krisper, 2005; Boyer & Mili, 2011; De Smedt et al., 2017; Graham, 2006; Schlosser et al., 2014; Smit, 2018).

The next step in properly managing decisions is to optimally use data to improve decisions that are explicitly managed, which is similar to what happened in the field of business process management, referred to as Process Mining (van der Aalst, 2011). In the context of separating the concern of 'decisions' and 'logic', a similar approach is referred to as Decision Mining (DM), which is defined as: "*the method of extracting and analyzing decision logs with the aim to extract information from such decision logs for the creation of business rules, to check compliance to business rules and regulations, and to present performance information*" (Leewis, Smit, et al., 2020). DM comprises 1) Discovery, 2) Conformance Checking, and 3) Improvement of decisions and underlying logic (Leewis, Smit, et al., 2020). These phases are very similar to Process Mining. The goal of process mining is to discover process models, check their conformance to theoretical process models and improve process models based on the outcome of the first two phases.

The present state of the research field and the knowledge base on Data Mining (DM) is currently deemed inadequate by scholars (Leewis, Smit, et al., 2020; Vanthienen, 2021). However, there is an increasing interest in DM, particularly in academic circles (Goossens et al., 2023; Scheibel & Rinderle-Ma, 2022), where there is a significant emphasis on quality metrics such as the accuracy of the mining algorithm. However, the comprehensibility of the application of DM algorithms to stakeholders like analysts or end-users is often ignored (Vanthienen, 2021). Therefore, it would be worthwhile to investigate the capabilities of a

DM system, as this would help to advance the research field by putting into practice the theoretically proposed stages that are currently presented in a high level of abstraction in the existing body of knowledge. Within this context, a capability is defined as "*an ability that an organization, person, or system possesses*" (The Open Group, 2011).

In this study, a first step is made towards operationalizing capabilities for discovery, conformance checking, and improvement as part of DM. This paper comprises the exploration of capabilities derived from the current body of knowledge on DM. In a follow-up study we aim to derive capabilities using an empirical approach so that both inputs can be compared and a final set of validated capabilities can be presented so that organizations are able to more swiftly experiment with DM. Therefore, in this paper, we answer the following research question: '*What capabilities can be identified from DM literature focused on the decision viewpoint for the development of DM systems and how should future research into DM systems be conducted?*'

The remainder of the paper is structured as follows. In the following section, section two, we discuss the phases of DM in more detail and explore the current state-of-the-art on DM. Then, in section three, we present the research method used in this study to derive capabilities for the DM system, which we use as a basis to formulate a research agenda. This is followed by the data collection and data analysis in section four. Then, in section five, the identified DM system capabilities are presented. The limitations of the study and its results are presented in section six. Lastly, the paper is concluded in section seven by presenting a research agenda.

2 Background

DM is also referred to as decision point analysis, which "*aims at the detection of data dependencies that affect the routing of a case*"(Rozinat & van der Aalst, 2006). The difference between the two is that decision point analysis mines 'sequencing patterns' from a process viewpoint, while DM, in line with the definition presented in the previous section, mines 'derivation patterns' from a decision viewpoint (Leewis, Smit, et al., 2020). Previous studies indicate that the focus towards DM and mining on derivation patterns is necessary to take steps forward in DM (De Smedt et al., 2017; Leewis, Smit, et al., 2020; Sarno et al., 2013).

DM consists of three phases (Leewis, Smit, et al., 2020): discovery of decisions, conformance checking of decisions, and the improvement of decisions, see Figure 1. These phases comprise extracting information from decision logs (discovery), checking this information for compliance with business rules and regulations (conformance), and presenting possible performance information (improvement) (Leewis, Berkhout, et al., 2020).

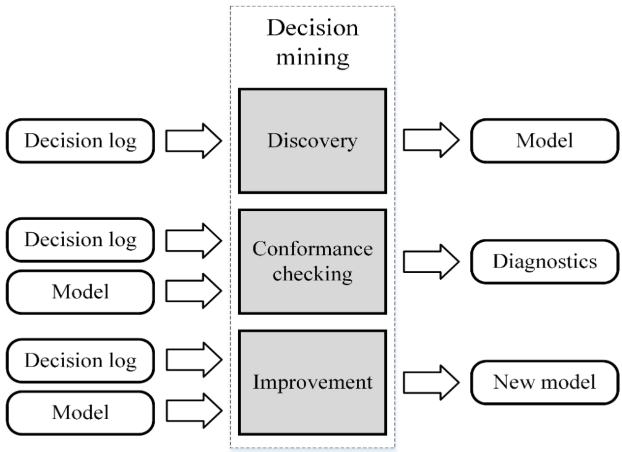

Figure 1: DM phases with corresponding inputs and outputs

As depicted in Figure 1, the input data necessary to leverage DM is the 'decision log' (De Smedt et al., 2017; Leewis, Smit, et al., 2020). The structure of this specific log file is essential for the success of DM. De Smedt et. al. (2017) introduced the necessity of decision logs in order to properly mine decisions and Leewis et. al. (2022)described the importance of a decision log for mining decisions with a decision viewpoint in mind. Additionally, DM aims at mining decisions from structured data. Structured data has a predefined data model compared to unstructured data. Therefore, a structure needs to be defined in the form of a decision log.

The structure of a decision log consists of a minimum of four attributes. The first attribute is a unique identifier, for example, a Case ID. Moreover, the condition(s) (second attribute) and conclusion(s) (third attribute) connected to that Case ID are part of the decision log, for example, all the data that is necessary for acquiring a loan and the decisions made with that data. The last required attribute is a timestamp. For example, the time certain input data was received or a decision was made by an actor. An example of a decision log is shown in Figure 2.

		Input values			Output value
		Conditions			*Conclusion*
ID	**Timestamp**	**Gender**	**Age**	**Temperature**	**Treatment**
1	2021-22-10	Male	30	37,4	Treatment A
2	2021-26-10	Female	25	39,1	Treatment B
5	2021-30-10	Female	50	38,7	Treatment A
7	2021-21-10	Male	19	37,2	Treatment A
8	2021-22-10	Male	18	36,8	Treatment A
10	2021-26-10	Female	24	37,1	Treatment B
11	2021-28-10	Female	20	37,6	Treatment B

Figure 2: Example of a decision log with the required attributes

Despite the current focus on DM with structured data, more and more research is being conducted on extracting and discovering decision logic and decision dependencies in (semi) unstructured data such as laws and regulations or protocols and guidelines (Etikala et al., 2020; Goossens et al., 2022; Vanthienen, 2021). While mining decision logic from text using text mining algorithms and remodelling them to a decision table is a complex task in itself, finding relations between the individual decision tables by mining dependencies, among the other elements on the requirements level, is even more complex and is currently being explored (Vanthienen, 2021).

Recent studies also focus on the conformance-checking phase of DM where anomalies in individual decision tables, as well as decision requirements diagrams, are found (Batoulis & Weske, 2018; Corea & Delfmann, 2018; Smit et al., 2017). The techniques described in these studies deal with the completeness and consistency of the individual rules, the decision table as a whole, and the dependencies between decisions. All models can be completely checked and audited, and anomalies can be found. Additionally, they can even be (semi) automatically altered (Corea & Delfmann, 2018). We argue that the current body of knowledge, although with a limited focus on the decision viewpoint, contains useful pointers for the operationalization towards capabilities.

One way to define capabilities is by formulating functionalities that a system supporting the DM phases must possess. In software engineering, requirements are used to express functionalities (Kotonya & Sommerville, 1998). Different types of requirements exist, for example, functional requirements, non-functional requirements, business requirements, user requirements, and constraints

(Sommerville & Sawyer, 1997). In this paper, we solely focus on functional and non-functional requirements as these are recognizable archetypes (Kotonya & Sommerville, 1998). Furthermore, a functional requirement emphasizes *what* is required and a non-functional requirement emphasizes the general properties of a system. This does not define the *how*, which is in line with the notion of a capability, that also focuses on *what* (value) an organization can deliver, but not *how* the value is delivered. In this study, we use thematic coding to give meaning to a wide range of possible functional requirements and are domain-specific. For non-functional requirements we use the ISO25010 standard comprising system and software quality clustering, which is a thoroughly validated framework (ISO, 2014). Examples of clusters are Reliablity (e.g., availability, fault tolerance) and operability (e.g., learnability, technical accessibility).

3 Research method

In order to identify functional and non-functional requirements for the development of DM systems we start, in this study, with a thorough analysis of the scientific literature. As described earlier, the focus lies on requirements which are defined for solutions specified from a decision viewpoint. Therefore, these sources need to be identified and coded with regard to functional and non-functional requirements. Because the field of DM is in a nascent state (Leewis, Smit, et al., 2020) the body of knowledge is limited. Even more so when limiting contributions to the decision viewpoint. Therefore, the study is considered an explorative one.

4 Data Collection & Analysis

The data collection of relevant contributions focussed on DM from a decision viewpoint focusing on deriving derivation patterns took place during November 2022. For this search, two criteria were adhered to exclude non-relevant contributions; 1) contributions referring to the utilization of event logs only to derive sequence data, and 2) papers referring to decision-point analysis as a form of DM. The first criterion was used because it excludes contributions that focus (predominantly) on process mining, which is not the focus of this study. The second criterion was used because decision-point analysis is considered a form of DM, which however, aims at deriving sequencing patterns in the context of business processes and business process management, i.e., how a sequence of a business process is routed based on one or more conditions. Google Scholar has been used as our search engine. The exclusion criteria were as follows: 1) the contribution focuses on decision-point analysis (thus using a process instead of a decision perspective), 2) the contribution is accessible for the research team, and 3) the paper is written in English. The search resulted in eight relevant contributions, presented in Table 1.

The analysis of the identified contributions started by identifying functional and non-functional requirements through thematic coding as specified by Gibbs (Gibbs, 2007). We employed four individual coders that used a pre-defined coding scheme, based on the definitions of functional and non-functional requirements from (Sommerville & Sawyer, 1997): "*functional requirements describe what the system should do and non-functional requirements place constraints on how these functional requirements are implemented.*"

Table 1: Identified contributions focusing on the decision viewpoint

ID:	**Title:**	**Reference:**
1	Utilizing Algorithms for Decision Mining Discovery	(Berkhout & Smit, 2022)
2	Decision Mining versus Process Mining: a Comparison of Mining Methods	(de Jong et al., 2021)
3	Decision Mining in a Broader Context: An Overview of the Current Landscape and Future Directions	(De Smedt et al., 2017)
4	Business Rules Management and Decision Mining-Filling in the Gaps	(Leewis et al., 2022)
5	Deep Learning for the Identification of Decision Modelling Components from Text	(Goossens et al., 2021)
6	Putting Decision Mining into Context: A Literature Study	(Leewis, Smit, et al., 2020)
7	Extracting Decision Model and Notation models from text using deep learning techniques	(Goossens et al., 2023)
8	Future challenges in decision mining at governmental institutions	(Leewis, Berkhout, et al., 2020)

Three coding rounds were conducted in order to reliably identify functional (F) and non-functional (NF) requirements from the identified contributions, depicted in Figure 3. During the first round of coding, all coders coded all contributions with regard to functional and non-functional requirements separately. An example of a functional requirement code is: "*all main functionalities: text classification, decision dependency extraction and decision logic extraction.*" An example of a non-functional requirement code is: "*The output of an algorithm must be explainable and comprehensible by Subject Matter Experts.*"

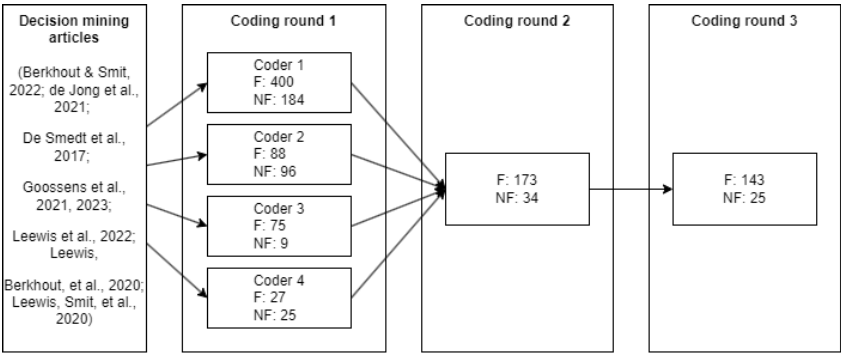

Figure 3: Coding process and results per step

A total of 590 functional requirements and 157 non-functional requirements were coded during coding round one. Table 2 shows the coding results of each coder, for each contribution, regarding both functional and non-functional requirements.

The second round of coding is used as a consolidation round. During this round, all coders discussed the individual coding results from the first round. Consensus or disagreement was focused on keeping or removing individual codes. The second coding round resulted in 173 functional requirements (417 were identical or removed) and 34 non-functional requirements (123 were identical or removed).

Table 2: Coding totals

	Coder 1:		Coder 2:		Coder 3:		Coder 4:	
Article ID:	F	NF	F	NF	F	NF	F	NF
1	10	1	8	2	6	1	0	0
2	60	2	34	24	25	0	14	5
3	31	4	2	9	6	0	6	4
4	13	7	12	2	15	0	1	0
5	62	0	13	10	5	0	1	0
6	25	0	1	11	5	0	3	0
7	173	4	8	15	6	0	1	0
8	26	9	10	23	7	8	1	16

Then, a third coding round was used to further validate the results of the first two coding rounds. This was done by one of the original coders that worked on coding during the first two rounds but was accompanied by two senior researchers with more experience in the field of study. This resulted in a total of 143 functional requirements (30 were removed) and 25 non-functional requirements (9 were removed). In this last round, we used an additional coding scheme presented in Table 3. The coding scheme is based on the three DM phases on the x-axis, while the y-axis comprises three attention areas concerning DM that we chose to further explore concerning the research agenda for further operationalisation of DM. The attention areas are selected based on the fact that, for each of the DM phases on the x-axis, the algorithm needs specific 1) *input data*, characterized by requirements (e.g., a minimum of one condition and one conclusion). Furthermore, there are requirements for what the 2) *algorithm* itself should be able to do with the input data (e.g., which transformative steps have to be taken). The transformation of data then results in certain 3) *output data*, which is characterized by requirements as well (e.g., which types of data need to be presented in what manner).

Table 3: Round 3 functional requirements coding scheme

	Discovery	Conformance Checking	Improvement
Input data	- Code 1 - Code 2 - Code n	... ...	... ...
Algorithm	...	...	...
Output data	...	...	...

5 Results

Based on the coding of our data we describe the functional requirements in this section using the three phases of DM. Additionally, we describe the non-functional requirements according to the ISO25010 categories. Due to space limitations, we summarize the results for each category.

5.1 Discovery phase

Input data – 26 requirements

As the second-largest category by requirements identified, many assumptions and requirements were posed in the literature about how the input data should (ideally) be structured so that it can be used for the discovery of decisions and underlying logic. All contributions seem to focus on the need for a decision log and refer to the same composition of a decision log used to generate output, including implicit or explicit conditions, conclusions, timestamps, and dependencies. An example of a coded fragment referring to this category is: *"The DMN model extraction tool takes as input a decision description and automatically classifies sentences into irrelevant(for the decision model), dependency or logic."*

Algorithm – 51 requirements

The predominant category of requirements applies to the algorithmic technique used for decision discovery. The found literature revealed specific specifications that decision discovery algorithms must satisfy. These specifications apply to both structured data, which utilizes event or decision logs, and (semi) unstructured data, such as laws and regulations or textual descriptions. While there is significant overlap in the requirements presented, minor differences are noticed. For instance, some algorithms must create a decision requirements diagram (DRD) with supporting elements prior to discovering the decision logic, while others first discover the decision logic and then create a DRD based on the decision logic. An example of a coded fragment referring to this category is: *"The construction of a decision model from text requires a sequence of steps, each with their own challenges, regardless of whether a human or a machine is performing it: coreference resolution (where all expressions that refer to the same entity are resolved); preprocessing (preparing the data for analysis); text classification (identifying the* *relevant sentences for a modelling problem) and decision dependency and logic extraction (identifying the relevant elements needed for the construction of the model).*"

Output data – 13 requirements

The requirements identified in this category entail the transformation of data into various representations, guided by the construction of a decision model. The resulting output comprises a DRD, decision tables, and/or business rules. Additionally, a crucial aspect of the output data is that the algorithms should indicate the under or overfitting of data. An example of a coded fragment referring to this category is: *"The output of the Discovery phase is a business decision architecture, e.g., a DRD, as well as decision tables, and business rules."*

5.2 Conformance Checking phase

Input data – 8 requirements

The requirements identified in the literature highlighted the relevant components necessary for conformance checking. DM utilizes decision logs and models, such as DMN models, during the conformance-checking phase. Therefore, the input for the conformance-checking activity consists of the log file and the discovered model, which usually emerges from the output of the discovery activity. An example of a coded fragment referring to this category is: *"Decision conformance checking has the same purpose and consists of the same input components as described for Process mining (log file and discovered model).*"

Algorithm – 10 requirements

Requirements in this category emphasize the diagnostic aspect of conformance checking. The algorithms or techniques used must possess the capability to identify and quantify discrepancies between the model and associated log files. Conformance checking should function to identify, locate, and detect deviations. Furthermore, by analyzing the conditions present in the decision log, the model can be utilized to detect bottlenecks and incorrect dependencies on both the DRD level as well as decision logic level. An example of a coded fragment referring to this category is:

"Conformance checking analyzes whether the reality, as recorded in a logbook, corresponds to the model and vice versa. The aim is to measure their severity and to detect abnormalities."

Output data – 5 requirements

As the smallest category of identified requirements, the focus of the discovered requirements for output data was diagnostic in nature. For example, the diagnosis, in the form of output data, examines whether decisions are executed as intended, providing diagnostic information that highlights differences and similarities between the model and the input data. An example of a coded fragment referring to this category is: "*The output consists of diagnostic information that shows differences and similarities between the model and the input data (log files).*"

5.3 Improvement phase

Input data – 10 requirements

The majority of the found assumptions and requirements in this category overlap with conformance checking. The focus is on the utilization of structured data within an algorithm to enhance or improve discovered models in DM activities. A decision log is employed as input but the improvement phase also needs the inclusion of both a decision log and a decision model, which is the same as conformance checking. An example of a coded fragment referring to this category is: *"The enhancement/improvement activity needs an event or decision log and a model as input.*"

Algorithm – 8 requirements

As the second smallest category coded, most requirements found in the literature were about providing potential improvements to an existing model ultimately resulting in a new model. The algorithm must support the changing or extending of a decision model, based on a decision log and the theoretical model. An example of a coded fragment referring to this category is: *" enhancement/improvement activity aims at changing or extending the model."*

Output data – 12 requirements

The last category coded is output data during the improvement phase. The requirements coded in this category were mainly about a new model that is created using the input of a discovered model and the decision log. This phase must not only identify and present improvements but also outputs a new model with the improvements, which acts as a basis for revision during the improvement phase. An example of a coded fragment referring to this category is: "*In the enhancement/ improvement activity a new process/ decision model is created or an existing process or decision model is adapted.*"

5.4 Non-functional requirements

In terms of non-functional requirements, most codes referred to the usability (8 codes) and reliability (12 codes). Regarding usability, we see that contributions mention different stakeholder groups from different domains that should be able to work with DM systems. Therefore, the output of the algorithm should be explainable and understandable. For example, one of the coded fragments referring to this is: "*Further focus seems required to ensure a user-friendly interface where non-experts could use the capabilities of DM and thereby not confronted with algorithms where expert interpretation is needed.*" Another contribution mentioned that offering too much transparency can pose a risk to the accuracy of the DM algorithm used, which should be further explored. Regarding reliability, many generic data science constraints are identified, such as data quality (comprising the decision log), avoidance of data contamination, over and underfitting of DM algorithms, DM algorithm accuracy levels, (sample) data representativeness, and detection of outliers. An example of a coded fragment referring to this is: "*High validity can be ensured by utilizing accurate and reliable DM techniques (ensuring internal validity), and utilizing a data sample representative towards the population when decision mining (ensuring external validity).*"

6 Discussion

This study and its results have some limitations that should be discussed. Firstly, this study only aimed to identify capabilities from a theoretical perspective. Although the eight sources have some empirical basis, most of them are conceptual in nature and should be further supplemented and validated using empirical observations in a realistic context, i.e., using case studies. This also helps integrate DM processes into other IT processes as the current contributions on DM with a decision viewpoint mostly examine DM systems as a standalone phenomenon. A second limitation is the low number of contributions in the current body of knowledge with a focus on the decision viewpoint that aims to identify derivation patterns. This severely limits the theoretical richness of capabilities identified in this paper, but also points out a gap in the current body of knowledge that should be covered by future research. Another direction for future research would be to include contributions from the process mining research field that focus on the operationalisation of the three phases and look at systems for process mining specifically, a perspective that has not been included in this study. A third limitation would be the overestimation of depth and richness we expected the current body of knowledge to have in terms of potential for operationalisation of capabilities into requirements. If we look at the results from the first coding round alone, we identified many coded fragments of concepts that are described at a high level of abstraction. This also limits the value of the (patterns of) requirements we unearthed in this study, although we argue that the results are still a useful starting point for the development of tooling to support DM systems as well as that it serves as a research agenda for what needs further consideration in future research. The high level of abstraction adhered to in the identified contributions is presumably also caused by the focus of these studies as they are not meant to operationalize capabilities to the level we pursued to do so in this study. Thus, this observation also calls for future research focused on applying DM capabilities and their operationalization in DM systems in practice.

7 Conclusion

To conclude this paper we revisit the research question posed in the introduction section: '*What capabilities can be identified from Decision Mining literature focused on the decision viewpoint for the development of decision mining systems and how should future research into DM systems be conducted?*' Based on a thorough analysis of the current body of knowledge on DM focusing on the decision viewpoint we derived requirements on nine areas on a functional level and used the ISO 25010 software quality standard to identify a predominant focus on usability and reliability non-functional requirements for DM systems. From a theoretical perspective, our results point out directions for future research. Additionally, we demonstrated that our theoretical model of DM phases and focus areas for the operationalisation of DM system capabilities could be a useful approach, which can be used in future studies as suggested further in this section. From a practical perspective, our results help practitioners to 'unbox' the conceptual level of DM that the current body of knowledge on DM comprises. Doing so, DM capabilities can be further exploited in practice as proper tooling requires attention from both researchers and practitioners in the coming years, similar to the development of process mining systems in the last decade.

Based on the results we formulate the following research agenda for the operationalisation of DM capabilities:

1. Analysis of the current body of knowledge on DM reveals that most contributions focus on deriving sequencing patterns and are also referred to as decision-point analyses based on event data from business processes. In general, we argue that (more) research attention should be directed towards DM from a decision point of view focused on discovering, conformance checking and improvement of derivation patterns in data captured in decision logs. This also further helps in maturing the research field of DM and provides a basis for further operationalisation towards proper software systems to support businesses in leveraging the power of their operational decision-making.
2. Although the identified contributions did not primarily focus on presenting requirements for DM systems we argue that many of them describe DM capabilities from a high level of abstraction that should be further explored in the future, e.g., by describing how to process open norms in decision logs, how outliers in decision logs can be detected and managed, or what changing or extending of decision models exactly entails. Doing so helps future research in becoming more practically applicable as the current contributions are limited in their use for practitioners. Also, future studies can focus on validating capabilities that are detailed well enough.
3. Our findings show that most contributions focus on exploring the discovery phase of DM, while the conformance checking and improvement phases seem to be defined in less detail. Future studies should secure that both the conformance checking and improvement phases are considered and explored further. This is important to close the feedback loop of decision-making using DM capabilities as only discovery only gets organisations so far. Furthermore, we see that the identified contributions primarily focus on

detailing the input data, while less attention is focused on the algorithm and especially the output (data) of the conformance checking and improvement phases. This observation also calls for further exploration and definition regarding these aspects.

4. The current body of knowledge offers a narrow glimpse into non-functional requirements specifically relevant to DM systems. From the contributions, we identified a focus on usability and reliability, but how the other software quality aspects come into play is yet to be discovered. Exploration of the non-functional requirements (also referred to as constraints by some) is important as these are contextual boundaries that should be taken into account by design as much as possible. Future studies that explore the use of DM systems in practice could benefit from these findings.
5. We argue that it is important to conceptually ground DM phases and concepts. The identified contributions focus on theoretically proving that DM based on deriving derivation patterns is a technique that should be further explored. However, the current body of knowledge seems to lack a strong empirical basis, which should be taken into account in future studies, e.g., involving subject-matter experts and experts from outside academia as well as setting up case studies in which DM phases and systems are integrally evaluated and lessons learned formulated.

References

Bajec, M., & Krisper, M. (2005). A methodology and tool support for managing business rules in organisations. Information Systems, 30(6), 423–443. https://doi.org/10.1016/j.is.2004.05.003

Batoulis, K., & Weske, M. (2018). Disambiguation of DMN Decision Tables. In Lecture Notes in Business Information Processing (Vol. 320, Issue March, pp. 236–249). https://doi.org/10.1007/978-3-319-93931-5_17

Berkhout, M., & Smit, K. (2022). Utilizing Algorithms for Decision Mining Discovery. 35 Th Bled EConference Digital Restructuring and Human (Re)Action, 343–358. https://doi.org/10.18690/um.fov.4.2022.21

Boyer, J., & Mili, H. (2011). Agile business rule development: Process, Architecture and JRules Examples. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-19041-4

Chalvatzis, K. J., Malekpoor, H., Mishra, N., Lettice, F., & Choudhary, S. (2019). Sustainable resource allocation for power generation: The role of big data in enabling interindustry architectural innovation. Technological Forecasting and Social Change, 144(March 2018), 381–393. https://doi.org/10.1016/j.techfore.2018.04.031

Corea, C., & Delfmann, P. (2018). A tool to monitor consistent decision-making in business process execution. CEUR Workshop Proceedings, 2196(September), 76–80.

de Jong, R., Leewis, S., & Berkhout, M. (2021). Decision Mining versus Process Mining: a Comparison of Mining Methods. 2021 5th International Conference on Software and E-Business (ICSEB), 28–32. https://doi.org/10.1145/3507485.3507490

De Smedt, J., vanden Broucke, S. K. L. M., Obregon, J., Kim, A., Jung, J.-Y., Vanthienen, J., B, J. D. S., Broucke, S. K. L. M., & Obregon, J. (2017). Decision Mining in a Broader Context: An Overview of the Current Landscape and Future Directions. In Lecture Notes in Business Information Processing (Vol. 281, pp. 197–207). Springer International Publishing. https://doi.org/10.1007/978-3-319-58457-7_15

Dijkstra, E. W. (1974). On the Role of Scientific Thought. In Selected Writings on Computing: A personal Perspective (pp. 60–66). Springer New York. https://doi.org/10.1007/978-1-4612-5695-3_12

Etikala, V., Veldhoven, Z. Van, & Vanthienen, J. (2020). Text2Dec: extracting decision dependencies from natural language text for automated DMN decision modelling. … Management Workshops: BPM …. https://doi.org/10.1007/978-3-030-66498-5_27

Gibbs, G. (2007). Thematic Coding and Categorizing. In Analyzing Qualitative Data (pp. 38–55). SAGE Publications, Ltd. https://doi.org/10.4135/9781849208574.n4

Goossens, A., Claessens, M., Parthoens, C., & Vanthienen, J. (2021). Deep Learning for the Identification of Decision Modelling Components from Text (pp. 158–171). https://doi.org/10.1007/978-3-030-91167-6_11

Goossens, A., Claessens, M., Parthoens, C., & Vanthienen, J. (2022). Extracting Decision Dependencies and Decision Logic from Text Using Deep Learning Techniques (pp. 349–361). https://doi.org/10.1007/978-3-030-94343-1_27

Goossens, A., De Smedt, J., & Vanthienen, J. (2023). Extracting Decision Model and Notation models from text using deep learning techniques. Expert Systems with Applications, 211(August 2022), 118667. https://doi.org/10.1016/j.eswa.2022.118667

Graham, I. (2006). Business rules management and service oriented architecture a pattern language (1st ed.). John Wiley & Sons.

ISO. (2014). ISO/IEC 25000:2014. https://www.iso.org/standard/64764.html

Kotonya, G., & Sommerville, I. (1998). Requirements engineering: processes and techniques. Wiley Publishing.

Leewis, S., Berkhout, M., & Smit, K. (2020). Future Challenges in Decision Mining at Governmental Institutions. AMCIS 2020 Proceedings., 6. https://doi.org/https://aisel.aisnet.org/amcis2020/adv_info_systems_research/adv_info_systems_research/6

Leewis, S., Smit, K., & Berkhout, M. (2022). Business Rules Management and Decision Mining - Filling in the Gaps. Proceedings of the 55th Hawaii International Conference on System Sciences, 6229–6238. https://doi.org/10.24251/HICSS.2022.755

Leewis, S., Smit, K., & Zoet, M. (2020). Putting Decision Mining into Context: A Literature Study. In Lecture Notes in Information Systems and Organisation (Vol. 38, Issue September, pp. 31–46). https://doi.org/10.1007/978-3-030-47355-6_3

Mircea, M., Ghilic-Micu, B., & Stoic, M. (2012). An Agile Architecture Framework that Leverages the Strengths of Business Intelligence, Decision Management and Service Orientation. In Business Intelligence - Solution for Business Development.

Ossher, H., & Tarr, P. (2001). Using multidimensional separation of concerns to (re)shape evolving software. Communications of the ACM, 44(10), 43–50. https://doi.org/10.1145/383845.383856

Rozinat, A., & van der Aalst, W. M. P. (2006). Decision Mining in ProM. In S. Dustdar, J. L. Fiadeiro, & A. P. Sheth (Eds.), Business Process Management: 4th International Conference, BPM 2006, Vienna, Austria, September 5-7, 2006. Proceedings (pp. 420–425). Springer Berlin Heidelberg. https://doi.org/10.1007/11841760_33

Rula, A., Maurino, A., & Batini, C. (2016). Data and Information Quality: Dimensions, Principles and Techniques (1st ed.). Springer. https://doi.org/10.1007/978-3-319-24106-7

Sarno, R., Sari, P. L. I., Ginardi, H., Sunaryono, D., & Mukhlash, I. (2013). Decision mining for multi choice workflow patterns. Proceeding - 2013 International Conference on Computer, Control, Informatics and Its Applications: "Recent Challenges in Computer, Control and Informatics", IC3INA 2013, 2007, 337–342. https://doi.org/10.1109/IC3INA.2013.6819197

Scheibel, B., & Rinderle-Ma, S. (2022). Decision Mining with Time Series Data Based on Automatic Feature Generation. In Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics): Vol. 13295 LNCS (Issue c, pp. 3–18). https://doi.org/10.1007/978-3-031-07472-1_1

Schlosser, S., Baghi, E., Otto, B., & Oesterle, H. (2014). Toward a Functional Reference Model for Business Rules Management. 2014 47th Hawaii International Conference on System Sciences, 3837–3846. https://doi.org/10.1109/HICSS.2014.476

Smit, K. (2018). Organization and Governance of Business Rules Management Capabilities. Open University. https://research.ou.nl/en/publications/organization-and-governance-of-business-rules-management-capabili

Smit, K., Zoet, M., & Berkhout, M. (2017). Verification capabilities for business rules management in the Dutch governmental context. 2017 International Conference on Research and Innovation in Information Systems (ICRIIS), 1–6. https://doi.org/10.1109/ICRIIS.2017.8002499

Sommerville, I., & Sawyer, P. (1997). Requirements engineering: a good practice guide. John Willey & Son Ltd.

The Open Group. (2011). TOGAF v9.1 standard. http://pubs.opengroup.org/architecture/togaf9-doc/arch/

van der Aalst, W. M. P. (2011). Process Mining. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-19345-3

Vanthienen, J. (2021). Decisions, advice and explanation: An overview and research agenda. In A Research Agenda for Knowledge Management and Analytics (pp. 149–170). https://doi.org/10.4337/9781800370623.00016

How to Design a Participation Companion: A Conversational Interface to Foster Motivation and Support Participation

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Smart cities are no longer based only on technologies because it is their citizens who significantly influence the development. Lack of motivation plays a major role in the area of bottom-up participation. The digital transformation is creating new opportunities to support people in their participation process and increase motivation. Through the use of artificial intelligence, systems such as virtual companions can be improved further to create a valuable relationship between the human and the machine by incorporating interpersonal elements. A virtual companion that supports people in their participation process could be a solution to motivate people to participate. To provide a basis for deriving design knowledge for a Participation Companion this research starts by identifying the stakeholders' needs and problems based on literature reviews and interviews. It then follows an iterative, user centered prototype development and evaluation.

Keywords: conversational agent, participation, smart city, virtual companion, human-computer interaction

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1 Introduction

The growth of urban population presents challenges such as traffic congestion, waste management, resource access, and crime (Simonofski et al., 2021). Smart cities, initially based on IoT, cloud computing, and sensor networks, are considered as the answer to these challenges (Harrison and Donnelly, 2011; Perera et al., 2014). However, recent research emphasizes that smart cities should be driven by citizens' needs and expectations (Becker et al., 2022; Hollands, 2008; Vácha et al., 2016). Information and communication technologies (ICT) are integral to smart city concepts and support participation (Becker et al., 2022; Viale Pereira et al., 2017). Currently, design knowledge on participation information systems is limited, focusing on top-down digital solutions (Becker et al., 2022). Our suggestion is a shift towards a bottom-up approach by designing a Participation Companion (PaCo) based on the knowledge of artificial intelligence (AI) and Virtual Companions (VC), that helps people to participate and motivates them to seize participation opportunities. VC work with users to achieve a common goal while fostering valuable, long-term human-machine relationships (Krämer et al., 2015; Strohmann et al., 2022). Though chatbots and virtual assistants are explored in healthcare (Ahmad et al., 2022; Müller and Reuter-Oppermann, 2022) and education (Gubareva and Lopes, 2020), there is a lack of scientifically based design knowledge for virtual companions and other AI-based technologies aiming at encouraging and supporting participation. For this reason, the following research question (RQ) is to be answered: *How can a VC be designed to encourage and support good and purposeful participation?*

Our study adopts the design science research paradigm (Hevner et al., 2004) and, specifically, employs the reflective approach for generating design knowledge, as proposed by Möller et al. (2020). Initially, we conduct a structured literature research and interviews to gain a comprehensive understanding of the problem space. Based on this, we initiate an iterative artifact design process. Following the reflective approach, we first instantiate an artifact as a prototype, designed as a conversational interface, and extract design principles from our design process. Finally, we perform an exploratory study to gather feedback and promote participatory design with stakeholders. The scope of our study is related to the organization "Sandkasten" at the Technische Universität (TU) Braunschweig, which aims to support students in creating a sustainable and livable campus. By examining participation dynamics within this context, we seek to generate knowledge applicable to promoting engagement in smart cities.

2 Theoretical Background

2.1 Participation and motivation

Simonefski et al. (2021) define a Smart City as "a city that provides innovative solutions, in collaboration with its citizens and with the support of technology, to solve the specific challenges of its territory" (Simonofski et al., 2021, p. 1). Therefore, citizen participation is crucial, and people require intrinsic or extrinsic motivation to engage. Intrinsically motivated people engage in an activity because they find it interesting and inherently satisfying (Alamri et al., 2020; Di Domenico and Ryan, 2017). On the other hand, extrinsically motivated people engage in an activity to achieve a consequence e.g., a reward (Di Domenico and Ryan, 2017). Our study is grounded on two kernel theories (KT) (Kuechler and Vaishnavi, 2008), that describe motivation. **KT1:** The Self-Determination Theory (SDT) by Ryan and Deci (2000) is a motivation theory that identifies three basic psychological needs that influence motivation: *Competence* describes the need for mastery and control over the outcome of a challenge. *Autonomy* means the need to overcome a challenge on one's own power. *Relatedness* describes the need to feel connected (Birk et al., 2016; Ryan and Deci, 2000). **KT2:** The theory of self-efficacy by Bandura (1977) describes that a person's expectation of an ability influences their perception of performance and promotes motivation to perform. To perform tasks, intrinsic motivation and the perception that success has been/can be achieved are needed (Bandura, 1977).

2.2 Conversational Agents and Virtual Companions

Conversational Agents (CA) are digital systems based on natural language (McTear et al., 2016), interacting with users by text (as a chatbot) or voice (as a virtual assistant) (Gnewuch et al., 2017). CA can have different characteristics in terms of the scope of the task and the intensity of the relationship between the agent and the user (Janssen et al., 2020; Strohmann et al., 2022). Virtual Companions (VC) are emotionally and socially acting virtual collaboration partners (Krämer et al., 2011; Strohmann et al., 2022) with autonomous, proactive interactions (Strohmann et al., 2022). To develop a VC supporting participation, another relevant KT is introduced: **KT3:** The Computers Are Social Actors-Theory (CASA) states that people transfer social heuristics to computers by assigning social attributes to the system. Despite recognizing the system as non-human, users form attachments through the social behavior of the system. (Nass et al., 1994; Nass and Moon, 2000)

3 Methodology/Design Science Research

The Design Science Research (DSR) paradigm enhances knowledge and understanding of a problem domain and potential solutions through designing and applying DSR artifacts (Hevner et al., 2004). Vom Brocke et al. (2020) assert that knowledge of a context-specific problem and knowledge about potential solutions can independently coexist. Therefore, design knowledge arises from the fact that the context and quality criteria dependent on it (problem space) as well as the representations of possible solutions and their development process (solution space) are related to each other via the evaluation of artifacts. Design knowledge can be either in the form of theoretically abstract knowledge (design theory), such as design principles, or in the form of instantiated artifacts (design entities) (Brocke et al., 2020). In the DSR, there are different strategic approaches to arrive at the design theoretical knowledge (Iivari, 2015; Möller et al., 2020). Möller et al. (2020) propose two possible approaches in their method for design principles development: *reflective* (instantiation first, then extract knowledge) and *supportive* (identify and synthesize knowledge, then instantiate). In our research approach, we want to use the reflective approach. In our design cycle, we focus on a very creative, participatory, and user-centered approach to instantiate a prototype in three stages and then extracting reflective design principles.

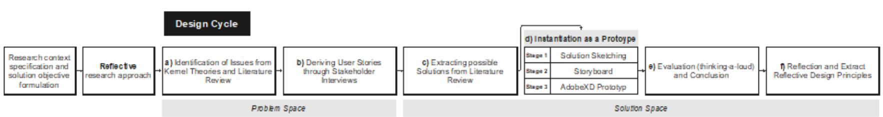

Figure 1: Design Cycle (Reflective Approach)

3.1 Problem Space

Understanding the problem space is crucial for generating design knowledge, comprising the four key components: needs, goals, requirements, and stakeholders (Maedche et al., 2019). In our approach we divide the process of understanding the problem space into the following three consecutive steps: (1) Identification of issues from kernel theories and literature review, (2) Deriving User Stories through stakeholder interviews and (3) Extracting possible solutions from literature review.

In the first step, interviews were conducted to identify the basic problems and needs of the stakeholders. Two systematic literature reviews based on the PRISMA Statement of Moher et al. (2009) were used to frame the questions for the interview. The databases selected for the literature search were Scopus, IEEE Xplore Digital Library, and ACM Digital Library to identify literature from two important categories (1) participation and (2) motivation. Accordingly, the final search query was as follows: *(participation OR e-participation OR collaboration) AND (service OR support OR experience OR benefit OR utility OR incentive OR gain OR inspiration OR encouragement OR interest)*. Furthermore, we aimed to gain insights into the general attitude of stakeholders towards VC. Using the same databases, we searched within the categories of (1) virtual companion and (2) service. The final search query was: *(virtual assistant OR virtual companion OR companion OR virtual collaborator OR artificial intelligence OR conversational agents) AND (service OR support OR experience OR benefit OR utility OR incentive OR gain OR inspiration OR encouragement OR interest).*

To capture user stories on VC and participation, we conducted additional interviews using an open questionnaire based on the literature. In the interviews, we explored experiences with virtual assistants, differentiating between assistants and companions, and defined "participation" in the context of TU Braunschweig's “Sandkasten” examining experiences, motives, and restraints. Finally, we introduced the PaCo concept to explore potential motivation and support methods. 30-minutes-interviews with six students were conducted, recorded, transcribed and coded to ensure a complete evaluation and identification of their problems and needs. The age range of interviewees was 21-28 years, with 66.6% male and 33.3% female participants. All interviewees are currently studying at the TU Braunschweig. For the evaluation of the interviews, we used the text analysis software MAXQDA[1], that provides the option of assigning a code to individual text segments (coded segments). The codes were developed inductively and data-driven after reviewing the transcribed interviews, therefore the categories were created afterwards (Kuckartz and Rädiker, 2019).

Finally, a literature review was conducted to identify approaches for motivating individuals in other areas, searching the same databases for the categories (1) motivation and (2) encouragement. The search query was: *(develop OR increase OR attract OR motivate OR animate) AND ("intrinsic motivation" OR "intrinsic encouragement").*

3.2 Solution Space

The resulting proposal features a prototype of a VC assisting students in participation activities and adapting to their needs. To ensure a user centered development and practical relevance, three students (1 female, 2 male) participated in shaping the solution space within the scope of an innovation project at the TU Braunschweig. In order to generate design knowledge, we followed two main steps: (1) Iterative artifact design based on the design sprint approach (Knapp et al., 2016) and (2) Explorative Evaluation with stakeholders.

The first step included three substeps, inspired by the design sprint approach by Knapp et al. (2016): (a) *Sketching and evaluating possible solutions within the problem space:* We started by generating ideas for motivating individuals to participate by a VC. Every co-creator sketched eight individual ideas each, resulting in a total of 24 ideas. To prepare for the next substep, the ideas were then voted, to decide on the three best solutions. (b) *Creating and evaluating final solutions and decide on the best*: In the second substep, every co-creator created a storyboard using one of the top-three-solutions developed in substep a). The storyboards aimed to show the stakeholders' problem, the possible solutions and the desired goal in a comic-like way. In the end the three storyboards were evaluated by the co-creators and three additional students (2 female, 1 male) via dot voting, to decide on the final solution. (c) *Development of a testable prototype:* We started by developing a conversational path for an interaction

[1] www.maxqda.com

between the PaCo and a potential user based on the final solution (see step b). Based on the conversational path we created a clickable prototype-chat using AdobeXD[2].

The second step involved an explorative evaluation with 26 students to collect and analyze early feedback. The user test took approximately 20 minutes, and the students were encouraged to speak their thoughts aloud while using the prototype. The thoughts were collected in keywords, to create a relaxed scenario by not using an audio recording device and transcribing every spoken word. The age range of interviewees was 19-33 years, with 58% male and 42% female participants, with everyone currently studying at the TU Braunschweig.

4 Designing a Participation Companion

4.1 Deriving User Stories for Participation Companions

In total, during the analysis of the transcribed interviews in MAXQDA we collected and evaluated 104 passages of text, with 14 codes. The results were then classified into three main categories: (1) Participation, (2) Virtual Companion and (3) Participation Companion. In the next step, the codes were further sorted within these categories and assigned to experiences, challenges, and value. The results represent three main reasons for the lack of motivation to participate among students: lack of interest, lack of knowledge and lack of time. First, the lack of interest was identified, which refers to both missing interest in participation and in the projects offered by the "Sandkasten". Furthermore, it was found that most of the students are unaware of the projects or lack knowledge on how to participate. Furthermore, the students cited their preference for other activities as the reason for their limited time and lack of participation. In addition to identifying the main reasons for the lack motivation to participate, we were able to develop 12 user stories (US) for the categories *support*, *purpose*, *behaviour* and *safety* from the interviews. In summary users desire the PaCo to introduce and connect them to projects, clarify participation goals and meaning, and suggest supportable activities. They expect the PaCo to understand them, display (or not display) emotions, and provide motivation. Users also prioritize establishing (or avoiding) a relationship with the PaCo and ensuring personal data protection. The following literature research aimed to identify

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[2] www.adobe.com/products/xd

possible solutions, that can increase motivation and can be used for our next steps of developing a prototype. The identified literature is primarily from the fields of education, sports, and work. An excerpt about the main findings is given in Table 1.

Table 1: Excerpt from motivating activities from literature review

#	Applicable motivating activities from literature review	Notable KT
S1	The motivating person should be self-motivated and authentic (Bejtic, 2021; Brophy, 1972; Hanke, 2019).	KT3
S2	Content and tasks should be manageable, but not too easy or repetitive (Bejtic, 2021).	KT2
S3	Verbal praise and positive feedback increase motivation (Cameron and Pierce, 1994; Taylor and Alla, 2019).	KT3
S4	By solving a task and/or improving social skills, the possibility of professional development arises, which promotes motivation (Chen et al., 2019).	KT1, KT2
S5	Gamification, i.e. the application of the game idea and its basic mechanisms in non-game contexts can promote motivation (Aditya et al., 2018; Birk et al., 2016; Helmefalk et al., 2020).	-
S6	Task should have a clear goal and structure (Pange et al., 2018).	KT1, KT2
S7	Deciding on their own which task to fulfill, increases motivation (Koskialho, 2017; Pange et al., 2018; Syahril et al., 2021).	KT1

4.2 Designing of the artifact

The artifact design process was based on the design sprint approach (see Figure 2). We started by generating 24 ideas inspired by our findings from literature review and internet search. Afterwards, the co-creators voted for the 3 best solutions, which can be divided into 3 phases: (1) attract attention, (2) facilitate participation process and (3) stay involved. The first phase consisted of a push-notification combined with an extrinsic motivator, to attract attention. The second phase included the subdivision of the main goal into subgoals, to ease the participation process. The third phase targets the moment, when the participation is over and the competition among friends can keep people stay involved.

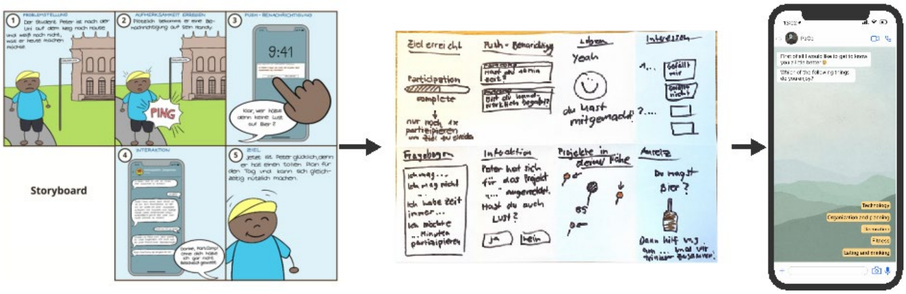

Figure 2: Process of the design sprint

The ideas were then refined and drawn in five comic-style slides using storyboards that depicted the stakeholders' problem, the possible solution, and the desired goal. Subsequently, the storyboards were voted by the co-creators which led to the final choice: the facilitation of the participation process by subdividing the main goal into subgoals. For the final solution motivating activities from literature and internet searches were integrated into the storyboard, along with the matching task assignment based on the stakeholder interviews. To represent the assignment to a task, a fictional project was developed and divided into subtasks that were assigned to interests and time slots. By creating a conversational path, which outlines a rough flow for the interaction between the user and the PaCo, we specified the steps required for the prototype implementation. Using the Virtual Companion Canvas (Strohmann et al., 2019), we framed the PaCo's behavior and appearance as friendly and courteous, with a neutral humanlike avatar. The prototype was designed as a clickable interface in AdobeXD (see Figure 3). To simulate the assignment of the matching task, different click paths were created that lead to the correct task according to the previously selected interests. The participants had to choose from prefabricated answers as the prototype wasn't able to provide individual messages.

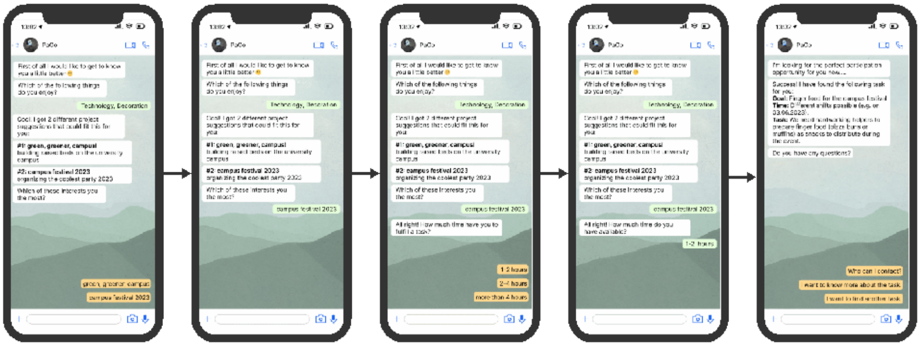

Figure 3: Conversation Flow of the Prototype

5 Explorative evaluation

The explorative evaluation of the prototype had the goal of obtaining feedback for further developments as early as possible. While using the prototype the participants phrased their thoughts about the PaCo, which led to results outlining first impressions of the stakeholders. Participants expressed some thoughts on the language, particularly related to the design of the PaCo's text messages, that should be shorter, more structured, use emojis and hyperlinks. The appearance of the PaCo was partially criticized, as it was perceived as strange and uncanny. But in general, the human-like appearance was perceived as positive. Regarding the capabilities, it was noted that the PaCo should communicate in a goal-oriented and open manner to ensure transparency. In the area of participation, the participants would like to see clear goals and motives, as these motivate them to participate.

In addition to the collection of the participants thoughts, we developed a post-test questionnaire to assess the participants' experience with the task assignment of the PaCo. The questionnaire covered questions about the task assignment, the purpose, the use and the sustainability. We rated all items on a five-point Likert-scale. A summary of the results of the post-test questionnaire can be found in Table 2. Looking at the descriptive data, the assignment of the task by the PaCo was generally rated as positive. Especially the low standard deviation (0,49) for the first question also indicates, that the participants agree that the task assignment facilitates the entry into the project. Furthermore, it can be stated that the participants are aware of the goal and the benefit of the task and would recommend the PaCo to friends.

Table 2: Results of the Post-test Questionnaire

Category	**Question**	**Mean**	**SD**
Task-assignment	PaCo's assignment of a task made it easier for me to get started in the project.	4,60	0,49
	The structuring of the project into tasks by PaCo makes it easier for me to get started with the project.	4,48	0,57
	I can identify with my assigned task.	4,28	0,78
Purpose	It is clear to me what goal I am supposed to achieve with my task.	4,56	0,70
Use	My activity in the project has a clear use.	4,40	0,80
Sustainability	After my first experience, I would recommend the participation opportunity to friends	4,16	0,83

6 Discussion

Based on the findings of the explorative evaluation, there are some notes for further adjustments of the PaCo prototype: The study's participants highlighted the importance of clear, interactive, and engaging communication in the PaCo, ensuring that the language used by the PaCo facilitates understanding of the information being conveyed. The design of the PaCo should be non-prejudiced, customizable, and human-like to foster relatability and emphasize the importance of humanity in participation. This can enhance the user experience and creates a sense of connection between the user and the PaCo, thus encouraging participation. To foster transparency and trust, there is the need for openly communicating the benefits and capabilities of PaCo, clarifying goals and background of tasks early on, and providing precise details on time commitments. Clarifying goals, creating motives for participation, and providing value to users when compared to internet research is an essential feature.

According to the reflective approach (Möller et al., 2020) we first instantiated the prototype and then derived five reflective design principles (see Table 3). These design principles cover areas such as information transparency (DP1), motivating people to participate through matching algorithms and subtasks (DP2, DP3), implementing a systematic conversation structure (DP4), and providing valuable interactions compared to traditional internet research (DP5).

Table 3: Derivation of Reflective Design Principles

#	Reflective Design Principle (DP)
DP1	For designers and developers to design a Participation Companion (PaCo) that promotes transparency and purposefulness, clear information must be given about the goal, the time required, and the content of the participation opportunity.
DP2	For designers and developers to design a PaCo that promotes autonomy, relatedness and competence, a matching algorithm can be integrated that suggests different participation opportunities based on interests, skills, and available time.
DP3	For designers and developers to design a PaCo that supports self-efficancy and autonomy, participation tasks need to be divided into sub-steps that are clearly defined and explained in order to make participation understandable and accessible.
DP4	For designers and developers to design a PaCo that introduces the participation scenario to the user the conversation must be designed systematically, logically and intuitively by explaining the functions and contents of the PaCo, introducing the participation project and then asking about the user's interests and skills.
DP5	For designers and developers to design a PaCo that enhances the value and motivation for participation, goals must be articulated clearly, incentives (e.g., community, commitment, certificates) must be created and a unique value proposition compared to traditional internet research must be offered.

Our study has some limitations that should be acknowledged. First the sample size of the user test was relatively small. Additionally, the participants in the study were mainly students, which may not fully represent the diverse range of potential users of the PaCo. Second, the prototype's limited interactive capabilities, with users choosing prefabricated answers, may have affected feedback due to the lack of personalized conversations.

7 Conclusion

To address the lack of design knowledge for VC supporting bottom-up participation, we identified stakeholder needs and motivational issues. Based on possible solutions from literature, a prototype, designed as a conversational interface, was developed and evaluated in an iterative, user-oriented process. In the final step five reflective DP were derived, that cover areas such as information transparency, motivating people to participate through matching algorithms and subtasks, implementing a systematic conversation structure, and providing valuable interactions compared to traditional internet research. The DP contribute to the to the body of knowledge on designing a VC supporting participation and provide guidance for designers in developing a PaCo. Although our research focuses on students, its findings on the potential of a PaCo in promoting engagement and motivation can contribute to municipal participation. More research is needed to determine how our DP can be extended to urban contexts. In addition, future research should refine the DP as well as develop an advanced prototype, and investigate the long-term effects of the PaCo on user engagement and motivation for participation.

References

Aditya, Y., Kusumo, D., Nurjanah, D., 2018. Gamification for Learning Basic Algorithm. https://doi.org/10.1109/ICoICT.2018.8528723

Ahmad, R., Siemon, D., Gnewuch, U., Robra-Bissantz, S., 2022. Designing Personality-Adaptive Conversational Agents for Mental Health Care. Information Systems Frontiers 24. https://doi.org/10.1007/s10796-022-10254-9

Alamri, H., Lowell, V., Watson, W., Watson, S.L., 2020. Using personalized learning as an instructional approach to motivate learners in online higher education: Learner self-determination and intrinsic motivation. Journal of Research on Technology in Education 52, 322–352. https://doi.org/10.1080/15391523.2020.1728449

Bandura, A., 1977. Self-efficacy: Toward a unifying theory of behavioral change. Psychological Review 84, 191–215. https://doi.org/10.1037/0033-295X.84.2.191

Becker, F., Siemon, D., Robra-Bissantz, S., 2022. Smart Participation Design: Prescriptive Knowledge for Bottom-Up Participation. Communications of the Association for Information Systems 51.

Bejtic, Z., 2021. Instructor's Personal Qualities and Meaningful Behaviors That Positively Impact Students' Intrinsic Motivation in Studio-Based Disciplines. Journal of Higher Education Theory and Practice 21. https://doi.org/10.33423/jhetp.v21i3.4144

Birk, M.V., Atkins, C., Bowey, J.T., Mandryk, R.L., 2016. Fostering Intrinsic Motivation through Avatar Identification in Digital Games, in: Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, CHI '16. Association for Computing Machinery, New York, NY, USA, pp. 2982–2995. https://doi.org/10.1145/2858036.2858062

Brocke, J. vom, Winter, R., University of St. Gallen, Switzerland, Hevner, A., University of South Florida, USA, Maedche, A., Karlsruhe Institute of Technology, Germany, 2020. Accumulation and Evolution of Design Knowledge in Design Science Research: A Journey Through Time and Space. JAIS 21, 520–544. https://doi.org/10.17705/1jais.00611

Brophy, J.E., 1972. The role of rewards and reinforcements in early education programs: II fostering intrinsic motivation to learn. Journal of School Psychology 10, 243–251. https://doi.org/10.1016/0022-4405(72)90059-3

Cameron, J., Pierce, W.D., 1994. Reinforcement, Reward, and Intrinsic Motivation: A Meta-Analysis. Review of Educational Research 64, 363–423. https://doi.org/10.3102/00346543064003363

Chen, P., Ma, T., Cheng, X., Liu, C., Gan, L., 2019. Participation motivations of product innovation in the crowdsourcing system, in: 2019 International Conference on Industrial Engineering and Systems Management (IESM). Presented at the 2019 International Conference on Industrial Engineering and Systems Management (IESM), pp. 1–6. https://doi.org/10.1109/IESM45758.2019.8948108

Di Domenico, S.I., Ryan, R.M., 2017. The Emerging Neuroscience of Intrinsic Motivation: A New Frontier in Self-Determination Research. Front Hum Neurosci 11, 145. https://doi.org/10.3389/fnhum.2017.00145

Gnewuch, U., Morana, S., Maedche, A., 2017. Towards Designing Cooperative and Social Conversational Agents for Customer Service.

Gubareva, R., Lopes, R.P., 2020. Virtual assistants for learning: A systematic literature review. pp. 97–103.

Hanke, D., 2019. How to talk to an expatriate: The International Trade Journal: Vol 33, No 1 [WWW Document]. URL https://www.tandfonline.com/doi/abs/10.1080/08853908.2018.1524801 (accessed 11.16.22).

Harrison, C., Donnelly, I.A., 2011. A Theory of Smart Cities. Proceedings of the 55th Annual Meeting of the ISSS - 2011, Hull, UK.

Helmefalk, M., Marcusson, L., Sell, A., 2020. "Who cares about fireworks?" – A Study on Digital Coaching, Gamification and Exercise Motivation. Proceedings of the Annual Hawaii International Conference on System Sciences.

Hevner, A.R., March, S.T., Park, J., Ram, S., 2004. Design Science in Information Systems Research 32.

Hollands, R., 2008. Will the Real Smart City Please Stand Up? City 12, 303–320. https://doi.org/10.1080/13604810802479126

Iivari, J., 2015. Distinguishing and contrasting two strategies for design science research. European Journal of Information Systems 24, 107–115. https://doi.org/10.1057/ejis.2013.35

Janssen, A., Passlick, J., Rodríguez Cardona, D., Breitner, M.H., 2020. Virtual Assistance in Any Context. https://doi.org/10.1007/s12599-020-00644-1

Knapp, J., Zeratsky, J., Kowitz, B., 2016. Sprint: How to Solve Big Problems and Test New Ideas in Just Five Days, Illustrated Edition. ed. Simon & Schuster, New York.

Koskialho, J., 2017. A Manager's Means to Motivate Experts at Work. pp. 1047–1054. https://doi.org/10.1007/978-3-319-42070-7_95

Krämer, N., Eimler, S., Rosenthal-von der Pütten, A.M., Payr, S., 2011. Theory of Companions: What Can Theoretical Models Contribute to Applications and Understanding of Human-Robot Interaction? Applied Artificial Intelligence 25, 474–502. https://doi.org/10.1080/08839514.2011.587153

Krämer, N.C., Rosenthal-von der Pütten, A.M., Hoffmann, L., 2015. Social Effects of Virtual and Robot Companions, in: Sundar, S.S. (Ed.), The Handbook of the Psychology of Communication Technology. Wiley, pp. 137–159. https://doi.org/10.1002/9781118426456.ch6

Kuechler, B., Vaishnavi, V., 2008. On theory development in design science research: anatomy of a research project. European Journal of Information Systems 17, 489–504. https://doi.org/10.1057/ejis.2008.40

Maedche, A., Gregor, S., Morana, S., Feine, J., 2019. Conceptualization of the Problem Space in Design Science Research, in: Tulu, B., Djamasbi, S., Leroy, G. (Eds.), Extending the Boundaries of Design Science Theory and Practice, Lecture Notes in Computer Science. Springer International Publishing, Cham, pp. 18–31. https://doi.org/10.1007/978-3-030-19504-5_2

McTear, M., Callejas, Z., Griol, D., 2016. Introducing the Conversational Interface, in: McTear, M., Callejas, Z., Griol, D. (Eds.), The Conversational Interface: Talking to Smart Devices. Springer International Publishing, Cham, pp. 1–7. https://doi.org/10.1007/978-3-319-32967-3_1

Möller, F., Guggenberger, T.M., Otto, B., 2020. Towards a Method for Design Principle Development in Information Systems, in: Hofmann, S., Müller, O., Rossi, M. (Eds.), Designing for Digital Transformation. Co-Creating Services with Citizens and Industry, Lecture Notes in Computer Science. Springer International Publishing, Cham, pp. 208–220. https://doi.org/10.1007/978-3-030-64823-7_20

Müller, H., Reuter-Oppermann, M., 2022. Chatblood - Towards designing chatbots for blood donors.

Nass, C., Moon, Y., 2000. Machines and Mindlessness: Social Responses to Computers. Journal of Social Issues 56, 81–103. https://doi.org/10.1111/0022-4537.00153

Nass, C., Steuer, J., Siminoff, E., 1994. Computer are social actors. Presented at the Conference on Human Factors in Computing Systems - Proceedings, p. 204. https://doi.org/10.1145/259963.260288

Pange, J., Lekka, A., Katsigianni, S., 2018. Serious Games and Motivation. pp. 240–246. https://doi.org/10.1007/978-3-319-75175-7_25

Perera, C., Zaslavsky, A., Christen, P., Georgakopoulos, D., 2014. Sensing as a Service Model for Smart Cities Supported by Internet of Things. European Transactions on Telecommunications. https://doi.org/10.1002/ett.2704

Ryan, R.M., Deci, E.L., 2000. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. American Psychologist 55, 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Simonofski, A., Vallé, T., Serral, E., Wautelet, Y., 2021. Investigating context factors in citizen participation strategies: A comparative analysis of Swedish and Belgian smart cities. International Journal of Information Management 56, 102011. https://doi.org/10.1016/j.ijinfomgt.2019.09.007

Strohmann, T., Siemon, D., Khosrawi-Rad, B., Robra-Bissantz, S., 2022. Toward a design theory for virtual companionship. Human–Computer Interaction 1–41. https://doi.org/10.1080/07370024.2022.2084620

Strohmann, T., Siemon, D., Robra-Bissantz, S., 2019. Introducing the Virtual Companion Canvas – Towards Designing Collaborative Agents. https://doi.org/10.5445/IR/1000095222

Syahril, S., Nabawi, R., Safitri, D., 2021. Students' perceptions of the project based on the potential of their region: A Project-based learning implementation. Journal of Technology and Science Education 11, 295. https://doi.org/10.3926/jotse.1153

Taylor, A.K., Alla, S., 2019. Influence of Reward Systems on motivation: pros and cons based on current literature 8.

Vácha, T., Přibyl, O., Lom, M., Bacúrová, M., 2016. Involving citizens in smart city projects: Systems engineering meets participation, in: 2016 Smart Cities Symposium Prague (SCSP). Presented at the 2016 Smart Cities Symposium Prague (SCSP), pp. 1–6. https://doi.org/10.1109/SCSP.2016.7501027

Viale Pereira, G., Cunha, M.A., Lampoltshammer, T.J., Parycek, P., Testa, M.G., 2017. Increasing collaboration and participation in smart city governance: a cross-case analysis of smart city initiatives. Information Technology for Development 23, 526–553. https://doi.org/10.1080/02681102.2017.1353946

Comparative Analysis of Market Structures of p2p Energy Trading in a Local Energy System

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Peer-to-peer (P2P) energy trading has been recognized as an important technology to increase the local self-consumption of photovoltaics in the local energy system. Different auction mechanisms and bidding strategies haven been investigated in previous studies. However, there has been no comparatively analysis on how different market structures influence the local energy system's overall performance. This paper presents and compares two market structures, namely a centralized market and a decentralized market. Two pricing mechanisms in the centralized market and two bidding strategies in the decentralized market are developed. The results show that the centralized market leads to higher overall system self-consumption and profits. In the decentralized market, some electricity is directly sold to the grid due to unmatchable bids and asks. Bidding strategies based on the learning algorithm can achieve better performance compared to the random method.

Keywords:
P2P energy trading, local energy system, market structure, bidding strategies, Bled eConference

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1 Introduction

In order to reach carbon neutrality, the local energy system is undergoing a huge transformation (Salvia et al., 2021). Distributed generation resources, particularly photovoltaics (PVs) are becoming more and more popular at the demand side (B. Zhou et al., 2021). However, the large-scale penetration of PVs has a significant impact on the safe operation of the power system (Kumar et al., 2021). Therefore, to promote the self-consumption of PV within the local energy system is the focus of current research.

Peer-to-peer (P2P) energy trading has been proposed as a critical technology to increase the PV consumption in recent years (Y. Zhou et al., 2020). P2P energy trading enables direct energy trading between prosumers and consumers within the local energy system (Zhang et al., 2018). A prosumer is defined as an entity that can produce and consume electricity, such as residential households with PVs (Iazzolino et al., 2022). In the P2P energy trading, prosumers can obtain additional benefits from selling their electricity to individual consumers (Zheng, 2022). Furthermore, P2P energy trading can facilitate power balance for the power system (Soto et al., 2021).

The research on the P2P energy trading can be categorized into two main streams according to the market structure: the centralized market and the decentralized market (Muhsen et al., 2022). In the centralized market, the coordinator collects information on electricity production and consumption of all prosumers and consumers. After the trading, the coordinator allocates the payoffs of the whole system to the participants according to a predefined rule. Some rules distribute costs or profits according to each participant's contribution to the aggregate system net consumption or surplus generation (Reis et al., 2020). Some rules calculate the local market price based on the pricing mechanism, such as supply and demand ratio (SDR) (Liu et al., 2017), mid-market rate (MMR) (Long et al., 2017) and bill sharing (BS) (Y. Zhou et al., 2018). In this market, market participants are considered as price takers and they can only accept the price made by the coordinator. In the decentralized market, prosumers and consumers are able to make autonomous decisions about the amount and price of electricity to bid. These bids are submitted to a P2P trading platform and then cleared by a certain clearing approach. Different auction mechanisms, such as Discriminatory k-Double Auction (k-DA), Uniform k-

DA, Vickrey-Clark-Groves (VCG), and Trade Reduction (TR), have been proposed and compared (Lin et al., 2019). Several bidding strategies have also been introduced to investigate their influence on the conditions of the market (Yu et al., 2018). Although current studies have investigated auction mechanisms and bidding strategies, there has been no comparatively analysis on how different market structures influence the local energy system's overall performance.

This paper presents and compares two market structures, namely a centralized market and a decentralized market, with the aim of providing valuable insights into establishing a P2P energy market. Firstly, two pricing mechanisms in the centralized market and two bidding strategies in the decentralized market are developed. Secondly, a comprehensive assessment of the local energy system's overall performance including costs, profits and self-consumption, is analyzed.

2 Methodolodgy

2.1 Simulation model

We simulate a local energy market with the P2P energy trading in a local energy system. The market participants include N residential consumers or prosumers (I = 1, 2, 3, ..., N), and a coordinator. A coordinator plays a different role in different market structures. In a centralized market, they typically act as the system operator responsible for managing the system's operations. In a decentralized market, they are generally the trading platforms where electricity order matching takes place. The simulation are conducted for the day-ahead at the time interval of 1 hour (Δt = 1 h). The internal market price in the local market should lie between the electricity feed-in price and the retail electricity price. Therefore, consumers and prosumers can benefit from participating in the energy market. This can increase the local PV consumption and reduce the amount of electricity sold from the local energy system to the higher-level power grid.

2.2 Centralized market

In the centralized market, the information about the requested electricity from consumers and the available surplus PV generation from prosumers is transmitted to the coordinator. The coordinator calculates the total electricity demand and electricity surplus of the local energy system. Then the coordinator trades with the grid to balance local supply and demand. After the trading, the coordinator decides how to distribute the system profits according to a predefined rule. This paper compares two rules: the costs and profits distribution rule, and the internal pricing mechanism.

2.2.1 Costs and profits distribution rule

The costs and profits distribution rule represents a fair mechanism to directly distribute the system costs and profits. Different rules have been proposed to achieve fairness in the distribution. Allocation based on the amount of each participant's electricity consumption and electricity injected is the most basic rule. The costs and profits of participants are calculated by Eq. (1).

$$\textit{Costs and profits distribution} = \begin{cases} PE_{i,t} \cdot f_{in},\ \textit{if}\ NC_{i,t} \geq 0 \\ SE_{i,t}^{local} \cdot f_{market} + SE_{i,t}^{grid} \cdot f_{out},\ \textit{if}\ NC_{i,t} < 0 \end{cases} \tag{1}$$

$NC_{i,t}$ is the net consumption of the paticipant *i* at time *t* [kWh]. If $NC_{i,t} \geq 0$, the paticipant *i* is a buyer; otherwise the paticipant *i* is a seller. f_{in} is the retail electricity price from the grid [$/kWh]. f_{market} is the internal market price [$/kWh]. f_{out} is the electricity feed-in price [$/kWh]. $PE_{i,t}$ is the purchased electricity of the paticipant *i* at time *t* [kWh]. $SE_{i,t}^{local}$ is the locally sold electricity of the paticipant *i* at time *t* [kWh]. $SE_{i,t}^{grid}$ is the sold electricity into the grid of the paticipant *i* at time *t* [kWh]. If $\sum NC_{i,t} < 0$, the system sells the surplus electricity to the grid, and the sold electricity is distributed among sellers according to the proportion of thier contribution to the system's net comsuption; otherwise, no surplus electricity is sold to the grid.

2.2.2 Internal pricing mechanism

As the costs and profits distribution rule are unable to reflect real-time electricity prices in the current trading market, various internal pricing mechanisms are proposed. Supply and demand ratio (SDR), mid-market rate (MMR) and bill sharing (BS) are three typical pricing mechanisms. Taking the SDR mechanism as an example, an internal pricing model for energy sharing is established, where the internal price is defined as a segmented function of the energy supply-demand ratio within the market. Specifically, the supply-demand relationship in the P2P energy market can be represented by the total surplus and demand electricity at each time interval. The supply-demand ratio of electricity is defined by Eq. (2).

$$SDR_t = \frac{\sum_{i \in N_S} SE_{i,t}}{\sum_{i \in N_B} PE_{i,t}} \tag{2}$$

SDR_t is the supply-demand ratio at time *t*. $SE_{i,t}$ is the sold electricity of the paticipant *i* at time *t* [kWh]. $PE_{i,t}$ is the purchased electricity of the paticipant *i* at time *t* [kWh]. N_S and N_B are the collection of sellers and buyers.

Typically, there is an inverse proportion relationship between the price and the supply-demand ratio. Therefore, the selling and purchasing prices within the market are calculated by Eq. (3) and Eq. (4), respectively.

$$p_{sell,t} = \begin{cases} \dfrac{f_{out} \cdot f_{in}}{(f_{in} - f_{out}) \cdot SDR_t + f_{out}}, & 0 \leq SDR_t < 1 \\ f_{out} & , SDR_t > 1 \end{cases} \tag{3}$$

$$p_{buy,t} = \begin{cases} p_{sell,t} \cdot SDR_t + f_{in}(1 - SDR_t), & 0 \leq SDR_t < 1 \\ f_{out} & , SDR_t > 1 \end{cases} \tag{4}$$

$p_{sell,t}$ and $p_{buy,t}$ is the selling and purchasing prices within the market at time *t* [$/kWh].

2.3 Decentralized market

In the decentralized market, P2P energy trading allows consumers and prosumers to directly buy and sell PV resources using a blockchain-based platform. Consumers and prosumers can submit their own electricity bidding to the trading platform, and the platform settles orders through a specific clearing algorithm. In this paper, the periodic double auction market that leads to a single clearing price for every trading period is implemented (Zade et al., 2022). During the trading period, participants submit bids or asks according to their roles of buyers or sellers. Once all bids and asks have been received, they are collected in an order book. At clearing time, bids are sorted in descending order and asks are sorted in ascending order by price. All bids where the buy price exceeds or equals the ask price are matched. At the end, the clearing prices are calculated based on the uniform price calculation method. Different bidding strategies have been proposed to test the feasibility of implementing a P2P trading market. This paper compares two bidding strategies: random bidding strategies and learning algorithm based bidding strategies.

2.3.1 Random bidding strategies

During the trading period, each consumer or prosumer bids with a random buy or sell price without any strategic foresight. This means that it does not take into account historical or retail electricity costs on the market. Participants randomly bid in a certain price interval. Prosumers are unwilling to accept a price below the electricity feed-in price, while consumers are unwilling to pay a price above the retail electricity price. Therefore, the upper price limit is set to the retail electricity price, and the lower price limit is set to the electricity feed-in price. Bid and ask prices are randomly sampled from a uniform distribution between f_{out} and f_{in}.

2.3.2 Learning algorithm based bidding strategies

In a real-world setting, consumers and prosumers are capable of learning from past decision-making experiences, which reflects their intelligent characteristics. Based on the income they earn as prosumers and the costs that incur to them consumers, they adjust their propensities to place specific orders. Different reinforcement learning algorithms have been proposed to simulate the learning ability of participants, such as Roth-Erev (RE) algorithm (Nicolaisen et al., 2001) and Q-learning algorithm (Chiu et al., 2022). This paper takes the RE algorithm as an example to illustrate the performance of reinforcement learning algorithms (Mengelkamp et al., 2017). The basic idea of the algorithm is to give priority to previous successful decisions and to learn from recent experiences.

Firstly, participants determine their own set of bidding strategies. In this paper, the market price range is discretized into an integer number of bid strategies according to its upper and lower bounds. Therefore, the set $S = \{ f_{out}, \ldots, f_{in} \}$ represents all possible bidding strategies of the participants. In the beginning, the participants have the same initial propensities for each strategy.

Secondly, as the P2P energy trading clears, participants update their own propensities for each strategy, as shown in Eq. (5).

$$pr_{i,j,t+1} = (1-\lambda) \cdot pr_{i,j,t} + \begin{cases} R_t(s_t) \cdot (1-\varepsilon), j = s_t \\ pr_{i,j,t} \cdot \dfrac{\varepsilon}{|S|-1}, otherwise \end{cases} \tag{5}$$

$pr_{i,j,t}$ represents the propensity of the participant *i* for each strategy *j* at time *t*. The parameter $\lambda \in [0,1]$ represents the participant's memory factor. The higher the value of λ is, the faster the participant forgets the past decision results. The parameter $\varepsilon \in [0,1]$ represents the participant's learning speed. As the value of ε decreases, the importance of the previous action in future decisions increases for the participant. $R_t(s_t)$ is the achieved income or the saved costs of the participant when its chosen strategy is *s* at time *t*. For prosumers and consumers, $R_t(s_t)$ is calculated by Eq. (6) and Eq. (7).

$$R_{prosumer,t}(s_t) = SE_{i,t}^{local} \cdot f_{market} + SE_{i,t}^{grid} \cdot f_{out} \tag{6}$$

$$R_{consumer,t}(s_t) = PE_{i,t} \cdot (f_{in} - f_{market}) \tag{7}$$

Finally, the probabilities with which the participant *i* chooses strategy *j* are then derived from these propensities at time $t+1$, as shown in Eq. (8). The roulette method is employed to select the final bid strategy.

$$prob_{i,j,t+1} = \frac{pr_{i,j,t+1}}{\sum_{j=1}^{S} pr_{i,j,t+1}} \tag{8}$$

3 Case study description

This study targets a hypothetical local energy system of 100 residential homes. In order to reflect the diversity of the houses, the size of the house is randomly sampled from 1,000 to 4,000 square feet. Figure 1 presents the hourly base load and PV generation profiles of a 2,546 square feet house during a summer month, which are obtained from (Lin et al., 2019). The load and PV generation profile of each house in the system is determined by scaling the base load and PV generation profile proportionally to the previously generated house size. The retail electricity price is \$0.123/kWh and the electricity feed-in price is \$0.033/kWh. For the system, two PV penetration levels are tested (40% and 60%) with two market structures (the centralized market with the distribution rule and SDR pricing mechanism, and the decentralized market with random and learning algorithm based bidding strategies).

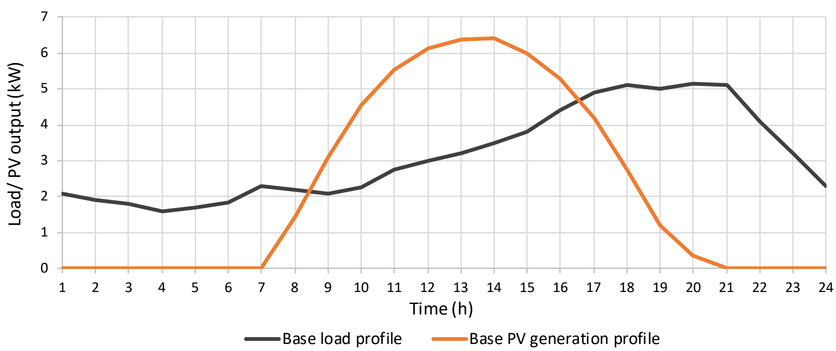

Figure 1: A 24h base load and PV generation profile

4 Simulation results

4.1 Case I: 40% PV penetration

The 24h load and PV generation profiles of the local energy system with 60 consumers and 40 prosumers are illustrated in Figure 2. It should be noted that the load profile for the 60 consumers is superimposed on the aggregate load profile for the 40 prosumers. By combining these two profiles, the total load of the system can be determined. As a result of the 40% ratio of prosumers to consumers, the total prosumer load is lower than the total consumer load. Between approximately 8:30

am and 16:30 pm, prosumers in the system generate surplus PV energy that can be exchanged with their neighbors.

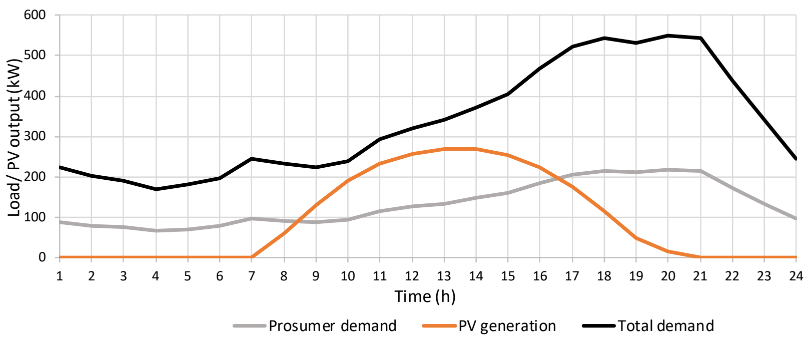

Figure 2: System supply vs demand at 40% PV penetration

Some key performance evaluation indicators regarding the overall performance of the system under different market structures are analyzed in Table 2. The centralized market achieved 100% local PV self-consumption, while in the decentralized market, some prosumers have to sell electricity directly to the grid due to the failure of some bidding orders. This leads to lower self-consumption in the decentralized market. In both pricing rules of the centralized market, the same total system profits are achieved. However, the benefits obtained by different consumers and consumers vary. Consumers earned revenue by selling electricity to consumers and the grid, while consumers saved costs through the P2P energy trading. Under the distribution rule, consumers could not benefit from energy trading. The SDR mechanism appears to be a fair mechanism that can benefit both consumers and consumers. In the decentralized market, bid strategies based on the learning algorithm achieves higher system self-consumption and total profits. However, the cost savings obtained by consumers actually decrease. As shown in Figure 3, this is due to the higher clearing prices resulting from the learning algorithm. The increase of the average percentage traded through the learning algorithm is not significant compared to the random algorithm. This is because the key to achieving higher self-consumption lies in the bidding of a small number of prosumers.

Table 1: The system performance of different market structures at 40% PV penetration

	Self-consumption	**Profits ($)**			**Average Percentage traded**
		Consumer	**Prosumer**	**Total**	
Centralized – Distribution rule	100%	0	95.29	95.29	/
Centralized – SDR mechanism	100%	56.46	38.83	95.29	/
Decentralized – Random bidding	64.79%	16.72	45.02	61.74	46%
Decentralized – Learning algorithm	92.32%	10.06	77.91	87.97	48%

From Figure 3, it can be seen that in the centralized market, the internal selling price and buying price determined by the SDR mechanism are highly correlated with the power supply-demand ratio. The greater the supply-demand ratio is, the lower the internal price is. In the decentralized market, the clearing price obtained through the learning algorithm gradually increases because it is a seller's market and the electricity cannot fully meet the needs of all consumers.

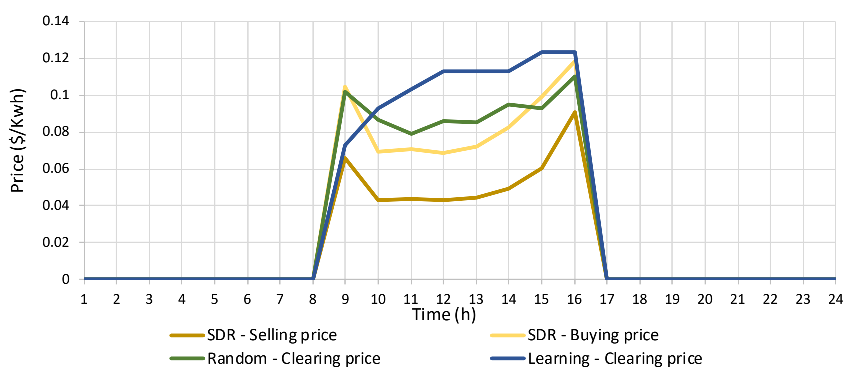

Figure 3: Internal market price of different market structures at 40% PV penetration

4.2 Case II: 60% PV penetration

Figure 4 displays the load and PV generation profiles for the system at 60% PV penetration. Even after meeting the electricity demand of the system, there is an excess of PV output from the system between approximately 9:30 am and 14:30 pm due to a higher penetration of PV.

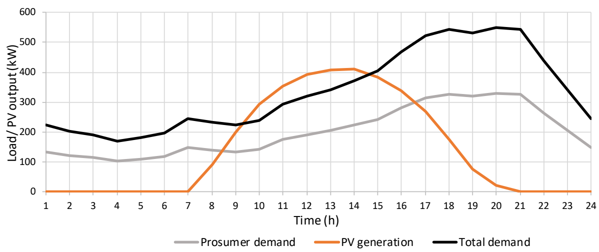

Figure 4: System supply vs demand at 60% PV penetration

According to Table 2, the centralized market can only achieve an ideal 75.43% local energy consumption. Higher total system profits are achieved at a 60% PV penetration rate compared to a 40% PV penetration rate. The conclusions drawn from Table 2 are similar to those in Table 1, where the centralized market leads to higher self-consumption and total profits compared to the decentralized market. In the decentralized market, bid strategies based on the learning algorithm can achieve better performance than the random method.

In Figure 6, due to the surplus of electricity caused by PV generation being greater than consumers demand at noon, the internal electricity price in the centralized market equals the electricity feed-in price. Similarly, in the decentralized market, the clearing price resulting from bid strategies based on the learning algorithm first decreases and then increases, which is also a response to the surplus of electricity resources.

Table 2: The system performance of different market structures at 60% PV penetration

	Self-consumption	Profits ($)			Average Percentage traded
		Consumer	Prosumer	Total	
Centralized – Distribution rule	75.43%	0	118.68	118.68	/
Centralized – SDR mechanism	75.43%	41.77	76.91	118.68	/
Decentralized – Random bidding	42.31%	23.91	59.71	83.62	46%
Decentralized – Learning algorithm	43.64%	24.54	73.96	98.50	42%

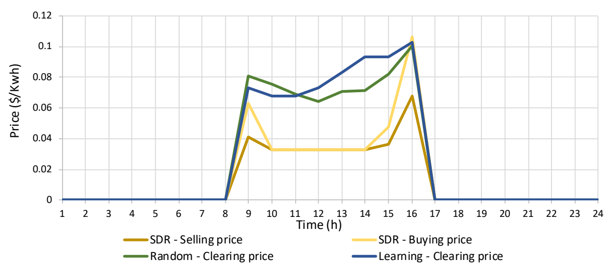

Figure 5: Internal market price of different market structures at 60% PV penetration

5 Conclusions

P2P energy trading plays a significant role in increasing the self-consumption of the local energy system. It can also involve consumers and prosumers in the local energy market. In different market structures, namely centralized and decentralized markets, P2P energy trading provides great economic advantages to market participants to encourage their involvement. The centralized market-based approach seems to have greater advantages as it leads to higher overall system self-consumption and profits. However, participants in the centralized market are considered as price takers and may not be fully incentivized to participate the market actively. Otherwise, participants can make decisions and bid in the decentralized market. Bid strategies based on the learning algorithm in the decentralized market show better performance compared to the random method, but this relies on participants learning from their bidding history. Overall, this study provide insights for evaluating the impact of different P2P energy trading market structures on the performance of the local energy system.

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References

Chiu, W.-Y., Hu, C.-W., & Chiu, K.-Y. (2022). Renewable Energy Bidding Strategies Using Multiagent Q-Learning in Double-Sided Auctions. IEEE Systems Journal, 16(1), 985–996.

Iazzolino, G., Sorrentino, N., Menniti, D., Pinnarelli, A., De Carolis, M., & Mendicino, L. (2022). Energy communities and key features emerged from business models review. Energy Policy, 165, 112929.

Kumar, D. S., Quan, H., Wen, K. Y., & Srinivasan, D. (2021). Probabilistic risk and severity analysis of power systems with high penetration of photovoltaics. Solar Energy, 230, 1156–1164.

Lin, J., Pipattanasomporn, M., & Rahman, S. (2019). Comparative analysis of auction mechanisms and bidding strategies for P2P solar transactive energy markets. Applied Energy, 255, 113687.

Liu, N., Yu, X., Wang, C., Li, C., Ma, L., & Lei, J. (2017). Energy-Sharing Model With Price-Based Demand Response for Microgrids of Peer-to-Peer Prosumers. IEEE Transactions on Power Systems, 32(5), 3569–3583.

Long, C., Wu, J., Zhang, C., Thomas, L., Cheng, M., & Jenkins, N. (2017). Peer-to-peer energy trading in a community microgrid. 2017 IEEE Power & Energy Society General Meeting, 1–5.

Mengelkamp, E., Staudt, P., Garttner, J., & Weinhardt, C. (2017). Trading on local energy markets: A comparison of market designs and bidding strategies. 2017 14th International Conference on the European Energy Market (EEM), 1–6.

Muhsen, H., Allahham, A., Al-Halhouli, A., Al-Mahmodi, M., Alkhraibat, A., & Hamdan, M. (2022). Business Model of Peer-to-Peer Energy Trading: A Review of Literature. Sustainability, 14(3), 1616.

Nicolaisen, J., Petrov, V., & Tesfatsion, L. (2001). Market power and efficiency in a computational electricity market with discriminatory double-auction pricing. IEEE Transactions on Evolutionary Computation, 5(5), 504–523.

Reis, I. F. G., Gonçalves, I., Lopes, M. A. R., & Antunes, C. H. (2020). A multi-agent system approach to exploit demand-side flexibility in an energy community. Utilities Policy, 67, 101114.

Salvia, M., Reckien, D., Pietrapertosa, F., Eckersley, P., Spyridaki, N.-A., Krook-Riekkola, A., Olazabal, M., De Gregorio Hurtado, S., Simoes, S. G., Geneletti, D., Viguié, V., Fokaides, P. A., Ioannou, B. I., Flamos, A., Csete, M. S., Buzasi, A., Orru, H., de Boer, C., Foley, A., … Heidrich, O. (2021). Will climate mitigation ambitions lead to carbon neutrality? An analysis of the local-level plans of 327 cities in the EU. Renewable and Sustainable Energy Reviews, 135, 110253.

Soto, E. A., Bosman, L. B., Wollega, E., & Leon-Salas, W. D. (2021). Peer-to-peer energy trading: A review of the literature. Applied Energy, 283, 116268.

Yu, Q., Meeuw, A., & Wortmann, F. (2018). Design and implementation of a blockchain multi-energy system. Energy Informatics, 1(S1), 17.

Zade, M., Lumpp, S. D., Tzscheutschler, P., & Wagner, U. (2022). Satisfying user preferences in community-based local energy markets—Auction-based clearing approaches. Applied Energy, 306, 118004.

Zhang, C., Wu, J., Zhou, Y., Cheng, M., & Long, C. (2018). Peer-to-Peer energy trading in a Microgrid. Applied Energy, 220, 1–12.

Zheng, B. (2022). A peer-to-peer energy trading market embedded with residential shared energy storage units. Applied Energy.

Zhou, B., Meng, Y., Huang, W., Wang, H., Deng, L., Huang, S., & Wei, J. (2021). Multi-energy net load forecasting for integrated local energy systems with heterogeneous prosumers. International Journal of Electrical Power & Energy Systems, 126, 106542.

Zhou, Y., Wu, J., & Long, C. (2018). Evaluation of peer-to-peer energy sharing mechanisms based on a multiagent simulation framework. Applied Energy, 222, 993–1022.

Zhou, Y., Wu, J., Song, G., & Long, C. (2020). Framework design and optimal bidding strategy for ancillary service provision from a peer-to-peer energy trading community. Applied Energy, 278, 115671.

Towards Principles For a Data-Driven Business Model Innovation Process – A Design Science Case Study

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Transforming an existing business model into a data-driven one is challenging. Tools, methods and processes can support organisations in that innovation. This paper presents a three-year interventionist case study with an automotive company, where we investigated how an innovation process towards data-driven business models should be designed. We analysed data from interviews, notes from company meetings and workshops, as well as learnings from supporting seven different data initiatives within the organisation. As a result, we present requirements that decision-makers have regarding a process and principles that guide the process design. The principles are not specific to data-driven business model innovation. However, at the level of operationalising the process, activities and actionable tools need to be specific to the goal of a business model innovation: how data and analytics can be used for new services and business models.

Keywords:
business model innovation process, interventionist case study, data-driven business models, design science research, Bled eConference

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1 Introduction

Developments in data-driven technologies, as well as the availability of large data sets, hold the opportunity for developing new products, services, and business models (Günther et al. 2017), so-called data-driven business models (DDBMs) (Hartmann et al. 2016). This transformation toward a DDBM is particularly challenging for offline-established organisations (Schüritz et al. 2017b), i.e., organisations with an established business model that does not (yet) substantially rely on data analytics-enabled services or products. Therefore, research has started to design tools and methods as support for developing DDBMs (Fruhwirth et al. 2020b), e.g., supporting idea generation (Kühne and Böhmann 2019), performing financial evaluations (Zolnowski et al. 2017) or identifying risks (Fruhwirth et al. 2021). While these approaches investigate specific aspects of DDBM innovation, such as idea generation, evaluation, or risk management, organisations also need support over the innovation activities via a structured management process (Terrenghi 2019). Further, the knowledge of such a holistic process is still fragmented, specifically missing a sequence of activities and connection of tools (Fruhwirth et al. 2020b). Moreover, there is a lack of knowledge in designing such processes. Research has recently started to develop frameworks to guide the development of a DDBM (e.g., Rashed et al. 2022). Nevertheless, they need to be adapted to the organisational requirements, connected to innovation tools and converted into a structured process. Therefore, we answer the following research question: *What process allows us to develop data-driven business models in offline-established organisations systematically?*

2 Background

Business models can be understood as "stories that explain how enterprises work" (Magretta 2002) and describe how organisations create, deliver and capture value (Osterwalder and Pigneur 2010). Business model innovation (BMI) appears "when two or more elements of a business model are reinvented to deliver value in a new way" (Lindgardt et al. 2009). BMI can be seen as a process, i.e., "the activity of designing – that is, creating, implementing and validating – a new BM [business model]" (Massa and Tucci 2013). Processes serve as a guideline to structure BMI activities in organisations (Wirtz and Daiser 2018). A process comprises idealised phases, such as idea generation or implementation (Wirtz 2011). Each phase is associated with certain activities and generates distinct outcomes (Terrenghi 2019), and tools and methods support these activities (Bouwman et al. 2020). As research often tends to focus on parts of processes, e.g., providing single tools, the knowledge about how phases, activities, and tools are connected is still fragmented (Fruhwirth et al. 2020b). Therefore, research on business model innovation processes increased recently (Andreini et al. 2022), such as a process model to align value creation and value capture in BMI. Nevertheless, little attention has been paid to how to desig such processes. Concretely, we know of only Geissdoerfer (2019) and Simmert et al. (2019), who designed a process for sustainable business model innovation and continuous business model improvement, respectively.

Data-driven business models (DDBMs), in particular, have a conceptual focus on value creation from data (Guggenberger et al. 2020). In a DDBM, data is used as a key resource (Hartmann et al. 2016). Data analytics methods are applied to discover insights from data (Kühne and Böhmann 2019) that are delivered as data-based features, products, or services and support customers in decision-making (Schüritz et al. 2019) and enable the generation of new revenue streams (Schüritz et al. 2017a). Existing literature provides a comprehensive set of typologies of DDBMs (Dehnert et al. 2021), often based on the business models of start-ups (e.g., Hartmann et al. 2016; Schmidt et al. 2018), thus, neglecting offline-established organisations (Fruhwirth et al. 2020b).

Further, academia has paid little attention to the dynamic aspects of DDBMs (Wiener et al. 2020), particularly their design and realisation (Rashed and Drews 2021). One exception is the study of Lange et al. (2021), who found that DDBMs are realised iteratively along four periods (experimentation, minimum viable product, minimum marketable product and scaling). Although tools and methods should support organisations along that process (Fruhwirth et al. 2020b), current research mainly focuses on supporting idea generation through canvases (e.g., Hunke et al. 2021; Kayser et al. 2019; Kühne and Böhmann 2019). Further, there is a need for repeatable processes and the connection of tools and methods (Fruhwirth et al. 2020b). Existing high-level process approaches are based on expert interviews (Hunke et al. 2017) or literature reviews (Lange and Drews 2020). Rashed et al. (2022) recently provided a reference framework with six enablers and related activities that guide the design and realisation of DDBMs. Such models guide activities but are not yet embedded in a manageable process and do not connect tools to an overarching procedure (Fruhwirth et al. 2020b).

3 Research Design

Our overarching research approach is an interventionist case study (Korhonen et al. 2021; Yin 2009) with one automotive company (masked due to confidentiality as *Comp*) following principles of design science research. *Comp* is one of the world's leading organisations in engineering and testing of automotive systems, operating in a B2B context, with more than 10.000 employees. *Comp* has a knowledge-intensive business, where innovations are often triggered bottom-up. The automotive industry is undergoing a significant transformation due to data-driven technologies like autonomous driving that offer opportunities for new revenue streams with DDBMs (Seiberth and Gründinger 2018). Thus, the question of *Comp* is how to evolve its profitable business model by leveraging new technologies such as big data analytics and artificial intelligence.

We conducted this case study over three years, from 2018 to 2021. In this case study, we developed individual tools, methods, and an overall process to support *Comp's* DDBM initiatives. Note that the scope of the presented paper is not on the individual stages, activities, or tools but on the overall process and structured support during a DDBM innovation. Further, the scope of this research is on DDBMs on a unit or service level of *Comp* that are proposed in addition to their existing business models. This research can be labelled as an interventionist case study since we actively collaborated with representatives of *Comp* and were involved in different stages of DDBM innovation initiatives. This approach allowed us to access meaningful research data (Korhonen et al. 2021). Aside from 28 semi-structured interviews, this study includes 97 documented meetings and workshops with 73 representatives of *Comp*. Further, one researcher actively participated in seven DDBM initiatives at *Comp*. As design outcomes, we derived design requirements, design principles and design features for such a process.

Design requirements describe what users need and expect from a process. To identify requirements, we conducted 17 interviews with employees responsible for data-driven innovations and 11 interviews with employees responsible for BMI at *Comp*. Further, we collected tacit knowledge about BMI practices and considerations for DDBMs by participating in 97 meetings and workshops over three years. We took notes and had access to additional internal materials (e.g., presentations). We analysed our data following a Qualitative Content Analysis (Mayring 2015): we applied an open coding approach to identify relevant statements, grouped similar statements to codes, and structured the codes to requirements.

Design principles capture the knowledge from the design process and describe salient characteristics of the design that are transferable to other solutions for the same problem (i.e., other business model innovation processes) (Sein et al. 2011). Design principles also show how the requirements link to the specific implementation, i.e., the design features (Meth et al. 2015). We extracted our design principles through reflection and abstraction from our design requirements and features (Gregor et al. 2013).

Design features address specific aspects of the requirements (Maedche et al. 2021) and structure the description of the process design. We crafted design features by addressing the requirements and synthesising best practices at *Comp*. and grounded them in the BMI literature. Further, we conducted a structured literature review (Fruhwirth et al. 2020b), leading to an initial toolbox. One researcher actively participated in DDBM innovations at *Comp*, where we developed DDBM-specific tools. Supporting seven DDBM initiatives in specific activities enabled us to generate learnings on the activity and tool level.

4 Design Requirements

DR1: *A DDBM innovation process should increase the speed of innovation,* i.e., the time to market from an idea to launching a DDBM. Increasing speed is especially important for DDBMs, as they move faster with shorter life cycles compared to traditional product-oriented businesses. One manager at *Comp* mentioned: *"Time to market will be quite important with data. We will only be successful […] if we are really fast in development."* (Manager Data Science). In contrast to traditional products with extensive release and approval processes, DDBMs must go to market with a semi-finished solution – a "minimum marketable product" (Lange et al. 2021). Customer (decision) problems that can be addressed by a data service emerge over time through customer interactions and insights from data analytics.

DR2: *A DDBM innovation process should guide management (investment) decisions.* A successful DDBM innovation requires commitment from management to provide sufficient resources (Rashed et al. 2022). As innovating a DDBM is associated with many uncertainties, resources must be allocated reasonably. Therefore, criteria are needed to inform and objectify decisions, as one manager highlighted: *"It [the process] must support decision-making, it must provide orientation and clear yes/no decisions, provide clear statements."* (Product Manager Data Solutions). One important aspect of decision-making is to identify risks (Tesch and Brillinger 2017), e.g., if critical information could be shared through a data-based value proposition (Fruhwirth et al. 2021).

DR3: *A DDBM innovation process should have an iterative character and follow an effectuation logic* to address the uncertainties in innovating a DDBM. Effectuation focuses on taking action in the market to generate new insights by a trial and error logic (Sosna et al. 2010; Tesch et al. 2017). One common approach for early customer feedback is a Minimum Viable Product (MVP), as one manager reported: *In digital innovations, you have to create an MVP and go into testing at about 50 per cent maturity. Before that, the substance for validation was missing. In the data-driven environment, MVP approaches are much more prominent."* (Manager Digital Services).

DR4: *A DDBM innovation process should be simple and adaptive.* It should focus on the minimal necessary elements that also a prerequisite that the process will be used by all target users, as one manager highlighted: *"It must be simple to make a new topic understandable for a department. Everyone should have the know-how to use the process correctly."* (Project Manager). DDBM innovation requires adaptive approaches (Lange et al. 2021) in contrast to traditional structured processes, e.g., for product development.

DR5: *A DDBM innovation process should educate its users* and establish a mindset (e.g., customer orientation and data thinking). Thus, a process should also provide guidance and how-to instructions and equip its users with the competencies to innovate DDBMs, as one manager exemplary mentioned: *"A process can be supportive if you plan to establish the thinking that is inherent in the process anyway. Keyword: process plus education."* (Project Manager) One example of such educative topics was fostering customer-centricity, which is critical in DDBMs, as value is closely co-created with the customer (Schüritz et al. 2019).

DR6: *A DDBM innovation process should provide actionable how-to instructions for its users.* We found that the how-to of certain activities, such as defining a data product and its potential benefits, is often unclear for non-data domain experts. For instance, one manager mentioned that *"a process should provide a clear roadmap from grasping first ideas up to calculating an ROI with checklists, best practices, examples, and suggestions for business model tools."* (Manager Software).

5 Design Principles and Features

We describe our process design, as shown in Figure 1, guided by our three design principles: structure the process by investment decisions, support cyclic convergent and divergent thinking and enable organisational learning. We implemented the design principles via seven design features.

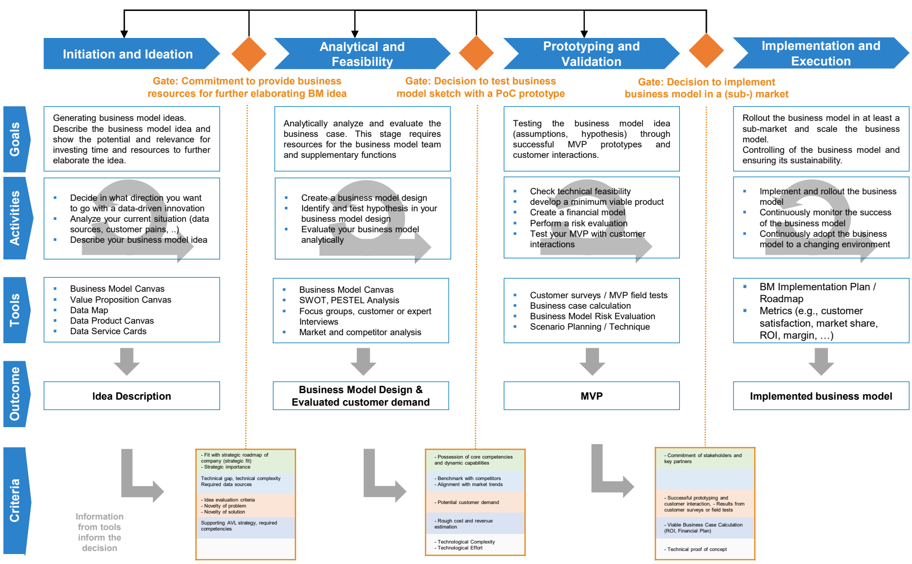

Figure 1: Overview of our process design with instantiated design features (DFs).

5.1 DP1: Structuring the Process by Decision Points

A process should be structured along with management investment decisions that are informed by a set of decision criteria. These criteria determine the information that needs to be collected in each phase to inform the decisions. Based on these criteria, the precedent phase can be defined with its activities and supporting tools. Recommended tools guide and support the data collection process. The following features implement this principle.

DF1.1 - Definition of phases and gates: The DDBM innovation process is structured along four phases and intermediate gates: initiation and ideation, analytical feasibility, prototyping and validation, implementation and execution. We based these phases on the review work of Wirtz and Daiser (2018), who identified seven generic phases of a business model innovation process based on a systematic literature review. We merged phases between two gates and dropped the decision-making phase due to our gate structure.

DF1.2 - Support decision-making by actionable criteria: Decision criteria inform and objectify the management decision if they further invest in a business model initiative (Tesch et al. 2017). We identified decision criteria from six categories based on our case and the literature: customer demand, market and competition, organisation and strategy, data and technology, financial rationales, and risks. The criteria are operationalised via evaluation questions and a response scale for each criterion in a closed form (in terms of a binary "yes" or "no", or in the form of Likert items) (Gilsing et al. 2020). Data-specific examples for such criteria are data ownership or risks associated with data sharing.

DF1.3 – Define an outcome for each phase: From our case study, we learned that it is important to have a clearly defined outcome, documented in a coherent form, at the end of each phase. This is, in particular, important when a portfolio of DDBM innovations has to be managed. For instance, the goal for the idea generation phase is to have a fully elaborated idea with a description of the key elements of a DDBM. We used this requirement to develop the Data Product Canvas (Fruhwirth et al. 2020a) as a template. The main elements are a description of the customer, benefits, problems addressed, a vision for the data analytics solution, required data sources and data analytics methods.

5.2 DP2: Support Cyclic Divergent and Convergent Thinking

Every phase in BMI has alternating activities that require divergent (i.e., exploring multiple options) and convergent thinking (i.e., deciding and going for one option). These two types of thinking and related activities are iterated until a target outcome is achieved. For instance, in the idea generation phase, activities encompass generating multiple DDBM ideas (divergent thinking) and filtering and deciding on one promising opportunity (convergent thinking). We implemented this design principle via the following two features.

DF2.1 – Definition of iterative activities for each phase: The process suggests activities for each phase that lead to the defined outcomes. The activities are iterated and alternated until the target outcome is achieved (e.g., identifying and validating a meaningful customer need). In our interventionist case study with *Comp,* we ran through an iterative cycle for testing the hypothesis in a DDBM, as suggested, for instance, by Bland et al. (2020) and added it to the process. This involved alternating activities of identifying potential data sources, generating insights from the data via data analytics and exploring customer needs.

DF2.2 – Suggestions from a toolbox: Each activity of a phase is supported by suggestions from a toolbox. In workshops of our case study, we combined several tools from the literature to support idea generation. First, we used a classification matrix (e.g., Breitfuß et al. 2019) to guide the direction of the ideation workshops (i.e., what type of DDBM should be investigated). A Data Map (e.g., Kayser et al. 2019) then supports identifying, structuring, and documenting data sources as input for idea generation workshops. A card deck (Breitfuß et al. 2023) provides basic information on DDBMs for non-data experts and supports the creative process in idea-generation workshops. Finally, the Data Product Canvas (Fruhwirth et al. 2020a) is used to structure idea generation workshops and describe and communicate a DDBM idea.

5.3 DP3: Enable Organisational Learning

A process should enable organisational learning by providing best practices. A process is based on both generic knowledge from the literature (e.g., phases of BMI) and organisation-specific best practices and tacit knowledge. Further, a process is a vehicle of change to establish desired procedures and ways of thinking. Organisations and their employees can learn by using and continuously updating the process. We implemented this principle based on two features.

DF3.1 – Include best practices: Our process design for DDBM incorporates best practices and learnings from previous DDBM innovations (i.e., critical aspects to consider or how to execute an activity). For instance, for evaluating a DDBM with the help of a SWOT analysis, we added guiding questions that were asked in previous DDBM innovations, such as: Are we too dependent on certain external data sources/providers? What happens if we have no access to the data any more? Are we handling critical customer data where a data breach would have serious consequences (e.g., threatening our reputation)?

DF3.2 – Provide a method of use for tools: For each tool, we defined a goal, an explanation, a template, and suggestions for a combination with other tools. Further we provided an illustrative example of how the tool could be used or was used in a previous initiative. As we found that it was often unclear how a tool should be used, we added step-by-step descriptions of how to use each tool. For instance, for the Data Product Canvas (Fruhwirth et al. 2020a), we found it useful to start with the customer problems, then think about a vision for the data service, consider required data sources and analytics activities, and then iterate.

6 Discussion

In this study, we investigated a DDBM innovation process through a case study from two perspectives: First, what are the requirements and expectations of the management regarding a process? And second, what are the inherent principles that guide the design of such a process? We found three salient principles that map to the characteristics of our case study. Structuring a process along gates and investment decision points reflects the hierarchical control structures and the need for investment steering of traditional B2B organisations (Rummel et al. 2022). Support cyclic convergent and divergent thinking reflect the agile and iterative nature of digital innovations (Ghezzi and Cavallo 2020). Enabling organisational learning reflects the need for a knowledge-intensive business where innovations often happen decentralised and bottom-up (Burnes et al. 2003). Thus, our principles are not specific to DDBMs; they can be transferred to other types of business models in similar contextual settings. Nevertheless, on the activities and tools level, the process is very specific for DDBMs, as the tools and activities bring in the necessary knowledge and specifics of DDBMs.

We showed that a process design should be structured along with (investment) decision points and informing criteria. This principle relates to a linear BMI process approach (Andreini et al. 2022) and reflects traditional organisations' management steering and hierarchical control structure (Rummel et al. 2022). However, specific decision points are missing in current BMI processes. Tesch et al. (2017) empirically investigated decision points and decision criteria, Lange et al. (2021) further add that incumbent organisations use Stage-Gates for a stop-or-go decision during DDBM innovation.

Further, a process design should support cyclic convergent and divergent thinking within each phase. This principle relates to the recursive BMI process approach (Andreini et al. 2022) and reflects the iterative and agile nature of digital innovations in general (Ghezzi and Cavallo 2020; Rummel et al. 2022). This principle relates to topical approaches such as Design Thinking and Lean Start-Up for BMI (Brown 2008; Ries 2011; Rummel et al. 2022). Existing process designs from the literature do not explicitly differentiate between convergent and divergent thinking. However, Hunke et al. (2017) already visualise convergent and divergent thinking aspects in their process. Fruhwirth et al. (2020b) also suggest structuring BMI tools by convergent and divergent thinking.

Nevertheless, there is a tension between these two design principles, i.e., the required iterative and flexible character (within each phase) with iterative divergent and convergent activities and the strict Stage-Gate logic (at the gates between the phases). Cooper and Sommer (2016) found that IT and manufacturing firms recently combined agile development and Stage-Gate approaches for product development, the so-called Agile-Stage-Gate hybrid model. Rummel et al. (2022) further found that manufacturing firms with a B2B business model use hybrid agile and Stage-Gate models for their BMI process. Thus, these empirical studies underpin the relevance of this two design principles.

A BMI process should also enable organisational learning. This principle reflects that innovations in knowledge-intensive organisations (such as *Comp*) often happen bottom-up and that knowledge about new business models is emerging over time in organisations. In our case study, we observed that DDBM innovations happen bottom-up in the units based on customer interactions, as domain experts are closer to the customer problem that can be addressed with data analytics. Therefore, generated learnings and insights about DDBMs need to be transferred to the organisational system. The domain experts also need the skills and tools to develop DDBMs successfully. Thus, by incorporating best practices and learning, a process can be the vehicle of knowledge transfer from individuals to the organisation and vice-versa (Sosna et al. 2010). The need for a high level of learning is crucial in fast-moving environments based on digital technologies (Burnes et al. 2003), such as data analytics. Thus, this literature stream underpins the relevance of our third design principle.

On a tools and activity level, our process is very specific to DDBMs. Tools and methods support the activities within each phase and bring in the knowledge and specifics for DDBMs. By suggesting DDBM-specific activities, tools and methods – and showing how they are interlinked - organisations and individuals can learn about the characteristics of this new type of business model. Recent literature has investigated DDBM-specific activities during BMI (Lange and Drews 2020; Rashed and Drews 2021). Nevertheless, there is a need for further research in several areas of tool support for DDBMs. First, further research should identify DDBM-specific decision criteria and evaluate DDBM-specific risks. Second, as research recently started to empirically investigate the realisation of DDBMs (i.e., prototyping and implementation; e.g., Lange et al. 2021; Rashed and Drews 2021), these insights should be transferred to tools and processes.

Finally, our research is not without limitations. All our design outcomes are based on a single case. While we aimed to generalise our results through design principles and reflected in the discussion how these appear in other, similar processes, future research should build on the principles and reflect on their usefulness in helping design a DDBM innovation process. Second, we did not rigorously evaluate the process. Future research could conduct interviews to evaluate our design principles. It should also investigate how comparative and experimental research complement case study work. This could show how our process improves the performance and outcome of DDBM innovations in organisations. It could further measure the effectiveness of the process in terms of velocity (i.e., time from the first idea to the execution of the DDBM) and economic impact (i.e., the success rate of innovations).

7 Conclusion

This paper provides three contributions to the literature: First, we showed that the design of a BMI process could be viewed from two perspectives: what the users expect from a process (requirements) and how to design such a process (principles and features). Our principles align with recent literature and point to other disciplines, such as psychology (with convergent and divergent thinking) and (organisational) learning. Second, we showed that a BMI process can be operationalised by defining outcomes, activities and tools for each phase, as shown in Figure 1. Third, our results show that the activity and tool level bring the specifics of DDBMs to a BMI process. Further, we provide an integrated perspective on how different tools and methods are interlinked.

Acknowledgements

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References

Andreini, D., Bettinelli, C., Foss, N. J., and Mismetti, M. 2022. "Business model innovation: a review of the process-based literature," *Journal of Management and Governance* (26:4), pp. 1089-1121 (doi: 10.1007/s10997-021-09590-w).

Bland, D. J., Osterwalder, A., Smith, A., and Papadakos, T. 2020. *Testing business ideas*: *Strategyzer.com/test*, Hoboken, New Jersey: John Wiley & Sons, Inc.

Bouwman, H., Reuver, M. de, Heikkilä, M., and Fielt, E. 2020. "Business model tooling: where research and practice meet," *Electronic Markets* (30:3), pp. 413-419 (doi: 10.1007/s12525-020-00424-5).

Breitfuß, G., Fruhwirth, M., Pammer-Schindler, V., Stern, H., and Dennerlein, S. 2019. "The Data-Driven Business Value Matrix: A Classification Scheme for Data-Driven Business Models," in *32nd Bled eConference Humanizing Technology for a Sustainable Society*, A. Pucihar (ed.), pp. 803-820.

Breitfuß, G., Santa-Maria, T., Fruhwirth, M., and Disch, L. 2023. "Use Your Data: Design and Evaluation of a Card-Based Ideation Tool for Data-Driven Services," *Proceedings of the 56th Hawaii International Conference on System Sciences*, pp. 5176-5185.

Brown, T. 2008. "Design Thinking," *Harvard Business Review* (56:4).

Burnes, B., Cooper, C., and West, P. 2003. "Organisational learning: the new management paradigm?" *Management Decision* (41:5), pp. 452-464 (doi: 10.1108/00251740310479304]).

Cooper, R. G., and Sommer, A. F. 2016. "Agile-Stage-Gate: New idea-to-launch method for manufactured new products is faster, more responsive," *Industrial Marketing Management* (59), pp. 167-180 (doi: 10.1016/j.indmarman.2016.10.006).

Dehnert, M., Gleiss, A., and Frederik, R. 2021. "What makes a data-driven business model? A consolidated taxonomy," *Proceedings of the Twenty-Ninth European Conference on Information Systems (ECIS 2021).*

Fruhwirth, M., Breitfuß, G., and Pammer-Schindler, V. 2020a. "The Data Product Canvas: A Visual Collaborative Tool for Designing Data-Driven Business Models," in *33rd Bled eConference Enabling Technology for a Sustainable Society*, A. Pucihar, M. K. Borštnar, R. Bons, H. Cripps, A. Sheombar and D. Vidmar (eds.), Online. June 28-29 2020, pp. 515-528.

Fruhwirth, M., Pammer-Schindler, V., and Thalmann, S. 2021. "A Network-based Tool for Identifying Knowledge Risks in Data-Driven Business Models," in *Proceedings of the 54th Annual Hawaii International Conference on System Sciences*, T. Bui (ed.), pp. 5218-5227.

Fruhwirth, M., Ropposch, C., and Pammer-Schindler, V. 2020b. "Supporting Data-Driven Business Model Innovations: A structured literature review on tools and methods," *Journal of Business Models* (8:1), 7-25.

Geissdoerfer, M. 2019. *Sustainable business model innovation: Process, challenges and implementation.*

Ghezzi, A., and Cavallo, A. 2020. "Agile Business Model Innovation in Digital Entrepreneurship: Lean Startup Approaches," *Journal of Business Research* (110), pp. 519-537 (doi: 10.1016/j.jbusres.2018.06.013).

Gilsing, R., Turetken, O., Ozkan, Baris, Adali, Onat Ege, and Grefen, P. 2020. "A method for qualitative evaluation of service-dominant business models," *Proceedings of the Twenty-Eight European Conference on Information Systems (ECIS) - A Virtual AIS Conference.*

Guggenberger, M. T., Möller, F., Boualouch, K., and Otto, B. 2020. "Towards a Unifying Understanding of Digital Business Models," *Twenty-Third Pacific Asia Conference on Information Systems, Dubai, UAE, 2020.*

Günther, W. A., Rezazade Mehrizi, M. H., Huysman, M., and Feldberg, F. 2017. "Debating big data: A literature review on realizing value from big data," *The Journal of Strategic Information Systems* (26:3), pp. 191-209 (doi: 10.1016/j.jsis.2017.07.003).

Hartmann, P. M., Zaki, M., Feldmann, N., and Neely, A. 2016. "Capturing value from big data – a taxonomy of data-driven business models used by start-up firms," *International Journal of Operations & Production Management* (36:10), pp. 1382-1406 (doi: 10.1108/IJOPM-02-2014-0098).

Hunke, F., Seebacher, S., Schüritz, R., and Illi, A. 2017. "Towards a Process Model for Data-Driven Business Model Innovation," *Proceedings of the 19th IEEE Conference on Business Informatics (CBI)*, pp. 150-157.

Hunke, F., Thomsen, H., and Satzger, G. 2021. "Investigating Modular Reuse as an Underlying Mechanism of Conceptualization during Service Design – the Case of Key Activity Orchestration," in *Proceedings of the 54th Annual Hawaii International Conference on System Sciences*, T. Bui (ed.).

Kayser, L., Mueller, R. M., and Kronsbein, T. 2019. "Data Collection Map: A Canvas for Shared Data Awareness in Data-Driven Innovation Projects," *2019 Pre-ICIS SIGDSA Symposium on Inspiring mindset for Innovation with Business Analytics and Data Science, Munich 2019.*

Korhonen, T., Selos, E., Laine, T., and Suomala, P. 2021. "Exploring the programmability of management accounting work for increasing automation: an interventionist case study," *Accounting, Auditing & Accountability Journal* (34:2), pp. 253-280 (doi: 10.1108/AAAJ-12-2016-2809).

Kühne, B., and Böhmann, T. 2019. "Data-Driven Business Models: Building the Bridge Between Data and Value," in *Proceedings of the 27th European Conference on Information Systems - Information Systems for a Sharing Society*, J. Vom Brocke, S. Gregor and O. Müller (eds.), Stockholm and Uppsala, Sweden.

Lange, H. E., and Drews, P. 2020. "From Ideation to Realization: Essential Steps and Activities for Realizing Data-Driven Business Models," *22nd IEEE International Conference on Business Informatics (CBI) Workshops, Antwerp, 2020*.

Lange, H. E., Drews, P., and Höft, M. 2021. "Realization of Data-Driven Business Models in Incumbent Companies: An Exploratory Study Based on the Resource-Based View," *Proceedings of the Forty-Second International Conference on Information Systems, Austin 2021*.

Lindgardt, Z., Reeves, M., Stalk, G., and Deimler, M. S. 2009. "Business Model Innovation: When the Game Gets Tough, Change the Game," Boston Consulting Group.

Maedche, A., Gregor, S., and Parsons, J. 2021. "Mapping Design Contributions in Information Systems Research: The Design Research Activity Framework.," *Communications of the Association for Information Systems* ((forthcoming), in Press).

Magretta, J. 2002. "Why Business Models Matter," *Harvard Business Review* (80:5), pp. 86-92.

Massa, L., and Tucci, C. L. 2013. "Business model innovation," in *The Oxford handbook of innovation management*, M. Dodgson, D. M. Gann and N. Phillips (eds.), Oxford: Oxford Univ. Press, pp. 420-441.

Mayring, P. 2015. *Qualitative Inhaltsanalyse*: *Grundlagen und Techniken*, Weinheim: Beltz.

Meth, H., Mueller, B., and Maedche, A. 2015. "Designing a Requirement Mining System," *Journal of the Association for Information Systems* (16:9), pp. 799-837 (doi: 10.17705/1jais.00408).

Osterwalder, A., and Pigneur, Y. 2010. *Business Model Generation*: *A Handbook for Visionaries, Game Changers, and Challengers*, Hoboken, New Jersey: John Wiley & Sons.

Rashed, F., and Drews, P. 2021. "Pathways of Data-driven Business Model Design and Realization: A Qualitative Research Study," in *Proceedings of the 54th Annual Hawaii International Conference on System Sciences*, T. Bui (ed.), 5676-5685 (doi: 10.24251/HICSS.2021.689).

Rashed, F., Drews, P., and Zaki, M. 2022. "A Reference Model for Data-Driven Business Model Innovation Initiatives in Incumbent Firms," *Proceedings of the Thirtieth European Conference on Information Systems (ECIS 2022), Timişoara, Romania*.

Ries. 2011. *The lean startup*: *How today's entrepreneurs use continuous innovation to create radically successful business*, New York: Currency.

Rummel, F., Hüsig, S., and Steinhauser, S. 2022. "Two archetypes of business model innovation processes for manufacturing firms in the context of digital transformation," *R&D Management* (52:4), pp. 685-703 (doi: 10.1111/radm.12514).

Schmidt, J., Drews, P., and Schirmer, I. 2018. "Charting the Emerging Financial Services Ecosystem of Fintechs and Banks: Six Types of Data-Driven Business Models in the Fintech Sector," *Proceedings of the 51st Hawaii International Conference on System Sciences*, pp. 5004-5013.

Schüritz, R., Farrell, K., Wixom, B. H., and Satzger, G. 2019. "Value Co-Creation in Data-Driven Services: Towards a Deeper Understanding of the Joint Sphere," *Proceedings of the Fortieth International Conference on Information Systems (ICIS), Munich*.

Schüritz, R., Seebacher, S., and Dorner, R. 2017a. "Capturing Value from Data: Revenue Models for Data-Driven Services," in *Proceedings of the 50th Hawaii International Conference on System Sciences*, T. Bui (ed.), Waikoloa Village, Hawaii, USA, pp. 5348-5357.

Schüritz, R., Seebacher, S., Satzger, G., and Schwarz, L. 2017b. "Datatization as the Next Frontier of Servitization: Understanding the Challenges for Transforming Organizations," *Proceedings of the Thirty-Eighth International Conference on Information Systems (ICIS), Seoul*.

Seiberth, G., and Gründinger, W. 2018. "Data-driven business models in connected cars, mobility services and beyond," *BVDW Research*, available at https://bvdw.org/datadrivenbusinessmodels/.

Sein, M. K., Henfridsson, O., Purao, S., Rossi, M., Lindgren, R., Sein, Henfridsson, Purao, Rossi, and Lindgren. 2011. "Action Design Research," *Management Information Systems Quarterly* (35:1), pp. 37-56 (doi: 10.2307/23043488).

Simmert, B., Ebel, P. A., Peters, C., Bittner, E. A. C., and Leimeister, J. M. 2019. "Conquering the Challenge of Continuous Business Model Improvement," *Business & Information Systems Engineering* (61:4), pp. 451-468 (doi: 10.1007/s12599-018-0556-y).

Sosna, M., Trevinyo-Rodríguez, R. N., and Velamuri, S. R. 2010. "Business Model Innovation through Trial-and-Error Learning," *Long Range Planning* (43:2-3), pp. 383-407 (doi: 10.1016/j.lrp.2010.02.003).

Terrenghi, N. 2019. *Design, Implement, Repeat: Essays on Business Model Management in Offline-Born Organizations*.

Tesch, J., and Brillinger, A.-S. 2017. "The Evaluation Aspect of Digital Business Model Innovation: A Literature Review on Tools and Methodologies," in *Proceedings of the 25th European Conference on Information Systems*, I. Ramos, V. Tuunainen and H. Krcmar (eds.), Guimarães, Portugal, pp. 2250-2268.

Tesch, J., Brillinger, A.-S., and Bilgeri, D. 2017. "Internet of Things Business Model Innovation and the Stage-Gate Process: An Exploratory Analysis," *International Journal of Innovation Management* (21:5), 1740002-1 - 1740002-17 (doi: 10.1142/S1363919617400023).

Wiener, M., Saunders, C., and Marabelli, M. 2020. "Big-data business models: A critical literature review and multiperspective research framework: A Critical Literature Review and Multi-Perspective Research Framework," *Journal of Information Technology* (35:1), pp. 66-91 (doi: 10.1177/0268396219896811).

Winterhalter, S., Weiblen, T., Wecht, C. H., and Gassmann, O. 2017. "Business model innovation processes in large corporations: Insights from BASF," *Journal of Business Strategy* (38:2), pp. 62-75 (doi: 10.1108/JBS-10-2016-0116).

Wirtz, B. W. 2011. *Business Model Management: Design - Instruments - Success Factors*, Gabler.

Wirtz, B. W., and Daiser, P. 2018. "Business Model Innovation Processes: A Systematic Literature Review," *Journal of Business Models* (6:1), pp. 40-58.

Yin, R. K. 2009. *Case study research: Design and methods*, Los Angeles: SAGE.

Zolnowski, A., Anke, J., and Gudat, J. 2017. "Towards a Cost-Benefit-Analysis of Data-Driven Business Models," in *Proceedings der 13. Internationalen Tagung Wirtschafstinformatik (WI 2017)*, J. M. Leimeister and W. Brenner (eds.), pp. 181-195.

FUTURE COMPETENCES FOR THE EUROPEAN SOFTWARE SECTOR: A MIXED-METHOD APPROACH

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The shortage for ICT personal in the EU is large and expected to increase. The aim of this paper is to disseminates information from the ESSA alliances needs analysis. The needs analysis research was to contribute to a better understanding of the roles and competences needed, so that education curricula can be better aligned to evolving market demand,by answering the research question: *Which competence gaps do we need to bridge in order to meet the future need for sufficiently qualified personnel in the EU Software sector?* In this research, a mixed method approach was executed by ESSA-partners in twelve European countries, to map the current and future needs for competences in the EU. The analyses shows changes in demand regarding technical skills, e.g. low-code and a stronger focus on soft skills like communication and critical thinking. Besides this, the research showed educational institutes would do well to develop their curricula in a practical way by integration of real live cases and work together with organizations.

Keywords:
software sector,
skills,
future,
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competences,
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1 Introduction

Current education and training programs are unable to meet the rising demand for properly skilled staff in the European software industry (Saabeel et al., 2022). Several studies highlight the alarming figures concerning the increasing shortages of ICT professionals in a growing number of different roles with related skills requirements (European Commission, 2019; European Commission, 2020, Beckett & Daberkow 2019). To close this growing skills gap, Europe needs a new strategy for software skills that can accelerate workforce upskilling and reskilling (European Commission, 2017; Saabeel et al., 2022). Technological developments have changed the way software and ICT infrastructure are being designed, delivered, and managed (ESSA, 2021a). This enables the development of more services using new types of technologies such as cloud computing, AI, Machine Learning and Blockchain. Moreover, technological developments have increased the automation of aspects such as testing, deployment, management of new releases and introduced new approaches to working in teams to create software and services, like DevOps (ESSA, 2021a). This calls for shorter and more efficient education cycles. However, the pace of technological change makes it difficult for education and training providers to keep up and adapt their curriculums to the changing software skills demand of the market. Vocational education is seen as one solution to this problem as it provides an appropriate format for more flexible learning pathways and better connection with industry and employer needs (Aertsen & Saabeel, 2022).

The European Software Skills Alliance (ESSA) has the objective to close the gap between the demand and need of software skills in Europe. This consortium of both academia and practitioners have worked on a needs analysis in the sector during this second phase of this four year project. The needs analysis aimed to contribute to the timely anticipation of the expected future scarcity of sufficient and properly trained staff in the EU software sector. The ESSA-partners worked with the following research question:

- *Which competence gaps do we need to bridge in order to meet the future need for sufficiently qualified personnel in the EU Software sector?*

To be able to answer this research question, two sub-questions are answered:

- *What are the current profiles and competences needed in the European software industry?*
- *What are the future profiles and competences needed in the European software industry?*

The structure of this paper is as follows: In section 2 the methodology and its substantiation are described. In section 3, the findings of the ESSA's needs analysis are presented. The 4th section provides a description of the conclusions and finally in section 5 the limitations of this research and recommendations for further research are discussed.

2 Methodology

This chapter outlines the methodology used to investigate the current and future demand for ICT software development skills. To better understand the fast-changing software services environment and competences needed both quantitative and qualitative data is collected by the ESSA partners. Specifically, as "different methods have the potential to enrich our understanding of business problems and questions" (Molina-Azorin, 2016). Thus, the study employed a mixed-method approach, comprised of a literature review (in which both practice-based and scientific articles are included), focus groups and a job vacancy analysis. 21 European partner organizations, both academic and non-academic from 8 different countries, were involved in this study. The purpose of the study was to provide a comprehensive and accurate understanding of the current and future demand for ICT software development skills. Triangulation was used to validate the findings of the literature review with the results of the questionnaire, job vacancy analysis, and focus groups (ESSA, 2021). The literature review provided guidelines for the survey and the focus groups as it specified the foundation for the roles in ICT software development that are important.

The process and methods followed to identify gaps in the market need and provide recommendations is shown in figure 1. For the current demand, the primary data is found in labour market reports, as these reports focus on the types and numbers of skilled workers that are needed. Complementary to the labour market reports, during the expert group meetings the need for skilled workers and the way organizations fill these needs is discussed. Furthermore, the current need of ICT software development skills is also analysed with data collected by a questionnaire. As a validation we collected and analysed job vacancies to determine if the competences mentioned in the text match the preliminary findings from our other data.

To also look forward to future ICT software development skills, the focus groups gathered data on the experts’ views on the future skills needed.

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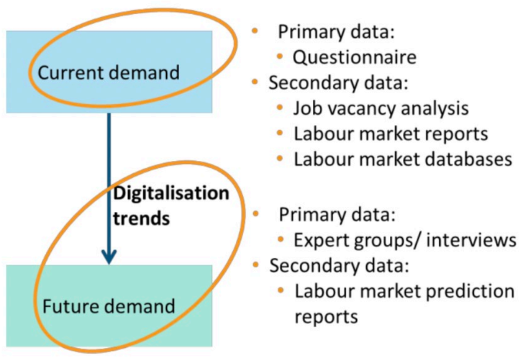

Figure 1: Research Process and methods

An overview of the data collected is shown in table 1. Below we briefly discuss each of the data collection methods.

Table 1: Quantitative characteristics data collection (ESSA, 2021)

Data collection in numbers	
Academic literature study	18 selected top papers for detailed analysis
Labour market desk research	63 national labour market reports
	14 national labour market databases
	905 job vacancies, 20 countries
Demand questionnaire	301 respondents, 21 countries
Expert groups in 9 different countries	10 national expert groups, 118 experts
	1 European expert group, 14 experts

Literature review

Scientific papers

In the systematic review, of the ESSA's (2021) needs analysis a Webster and Watson (2002) approach has been adopted. In an iterative approach four researchers together with their teams from four different countries and universities have comprised the following search terms: 'Software engineering ', 'software skills', 'Digital transformation', 'Industry 4.0', 'knowledge', 'software education', 'future', 'programming', 'computational thinking', 'logic'. These terms ware used to search in the following databases: Scopus, ACM, IEEE, Arxiv and the AIS Library. Only papers published from 2018 onward and peer-reviewed, are included in the analyses.

The initial 84 papers identified through the primary database searches, are analysed based on the abstract and title. This provided 44 Articles focused on software development competences and also provided a future orientation of needed skills (Scopus: 7, Acm: 10, IEEE: 6, Arxic: 11, AIS Library: 10).

All papers were discussed by all researchers to determine to which extent the papers were focused on the topic of software development skills. Based on this full paper analysis, 18 papers (see table 2) were included in our study (Scopus: 3, Acm: 2, IEEE: 3, Arxic: 4, AIS Library: 6). Complementary to the systematic review, a snowball-method has been adopted to review older papers, 1 has been included into the research because it contained some insights relevant for the research aims.

Table 2: Included papers and short characteristic or most revealing insight (ESSA, 2021)

Authors	Insights
Albino & Souza (2019)	Description of the gaps (skills, commitment) of firms going through a digital transformation by a literature review.
Beckett & Daberkow (2019)	Evaluation of challenges determining current and future competences in software sector by literature review.
Cico et al. (2021)	Integrate technologies and practices from software industry in curricula.
Duan et al. (2020)	Framework for adopting digital work in organizations.
Engelbrecht et al. (2018)	Necessity of context and comprehensive competences (+is challenging).
Föll et al. (2018)	Job vacancies and literature used to identify skills demand. Competence Framework are useful to develop curricula.
Garousi et al. (2018)	Prioritise the gap between software engineering and market needs.
Günay et al. (2020)	Description of need for and how to develop domain-specific critical thinking in education.
Heintz & Manilla (2018)	Students re-engineer the problem-solving process of computers.
Hoover et al. (2019)	Integration of AI and machine learning in creative domains like arts to establish deep learning and enlarge the programming awareness.
Licorish & MacDonell (2016)	Dependence of role types/engagement of project members and necessary skills.
Quezada-Sarmiento et al. (2018)	Emphasis in education for developing creativity and innovativeness.
Reinhart & Genovese (2019)	Experiences of group students taught software engineering skills.
Ryan (2020)	Develop curricula beyond Industry needs (e.g. ethics, social skills).
Shaba et al. (2019)	Effects on organizations after implementing Industry 4.0 technology.
Thorat & Kshirsagar (2021)	Identifies loopholes in software education and gives possible solutions.
Schmidt (2020)	Students collaborate in engineering projects representative for real-life.
Zabavnik et al. (2019)	UML skills for the Automotive Industry. Avoiding mistakes is key.

Labor reports

In addition, researchers from 14 different countries collected and analysed 63 national labour market reports and 14 national labour market databases. On European level statistics by Eurostat were also used for analyses. We focused on collecting data regarding ICT labour markets, and more specifically software development roles on a national or European level. Records found include white papers, formal government policy documents and professional bodies reports (such as commissioned research 'state of the art' reviews regarding software trends and competences). The selected databases are provided and maintained by a national statistics office, by other government agencies and a private institute depending on national context.

Job vacancy analysis

A job vacancy analysis was conducted to validate the current demand for software roles and competences in the EU. The methods and strategies to gather the information was left to the twelve national research teams. During the period of two months this analysis was executed the research teams exchanged the methods and the strategies for gathering their data in project meetings, so adjustments and insights were shared. 905 job vacancies from 20 countries were included. The job vacancy data were analysed to identify the most in-demand software roles and the level of proficiency required for these jobs. This data is used as input for both the results and to validate the findings of the questionnaire and focus groups.

Questionnaire

A questionnaire was designed to collect data on the current and a perception of the future demand for ICT software development roles based on the project requirements and input from partners. The first phase was to invite partners to provide questions they considered relevant in the questionnaire. The first version of the questionnaire was drafted based on the requirements of the project and this input. This version was improved based on feedback from the partners. The next version was implemented in the EU Survey and tested by 17 people. The adjustments made based on this test resulted in the final version which was distributed via the partners of the consortium. 301 respondents have filled in this questionnaire, working in various industries in various roles (mainly HR and management). The questions were designed to collect data on the demand for software development roles, the proficiency required and possible upcoming roles. The questionnaire consisted of 4 parts, 1) 4 general questions on the country and type of organization in which the respondent works, 2) 7 questions about what are considered the most relevant ICT professional role profiles, 3) 5 questions on software skills that are not yet met in the organization, and 4) 11 questions on what the views of the organization are on training needs in relation to the identified roles and skills.

Focus groups

In 10 national focus groups, 118 experts participated. These meetings were held both online and offline in 2 to 3 hours sessions with 6 to 20 experts. In addition, one international focus group was held with 14 experts from different European countries. The focus groups were led by moderators who ensured the experts would feel free to discuss knowledge exchange and building new insights.

The experts were selected based on their insights into future ICT developments. There was a mix of experts from HR, ICT, people working in the software sector and the research field. Types of candidates who were involved were:

- Heads of HR departments of ICT companies (responsible for the staffing strategy);
- Managers of employment agencies or recruitment agencies specialising in ICT;
- CIOs of large companies (responsible for ICT strategy and sourcing).

The participants were asked to reflect on their practices regarding the future demands for software roles, competences, needs and ICT-training.

3 Findings

The results of the executed research components were analyzed, evaluated and discussed in international working groups, composed by method and overall across all research components. The most important findings based on all components of this mixed-method research are discussed and presented in this section.

During this data evaluation phase, it appeared that some of the valuable insights were not just about the roles or competences of the future of the software sector but were more about the learning process. For this reason, in this section the results are divided into three sections. The first two sections discuss the results to answer the two sub-questions (roles and competences). A third section is added which describes the insights and results on a more abstract level, the educational needs.

What roles are needed in the future?

1. Developers needed most.

Overall, we found that the role of developer is still the most important role for the software sector. More than half of all respondents are currently looking for extra developers. Both the current as predicted future demand for software developers is high. However, there is a shift toward a new kind of developers, like full stack developers and low code developers. Another important progress mentioned is that the importance of developers increases as they are more integrated in the regular organization (business) instead of working from a separate entity (IT department). Soft skills and knowledge of the business are therefore increasingly important for developers to be able to function.

2. Growing importance of the DevOps engineer

We found a growing attention for the DevOps expert role which can be explained by the need for better integration between software production and the rest of an organization. Most DevOps job vacancies are from large companies. The DevOps role integrates development, deployment and maintenance and is the developer in agile environments using e.g., continuous integration and continuous delivery.

3. Great need for solution designers

The outcomes of the analyses shows there is a great need for solution designers in various industries. Solution designers play a critical role in developing effective solutions for complex problems. The largest number of vacancies are found in respectively in the programming sector 24,8% followed by the consultancy branche (18,3%). Furthermore, we found that many companies are looking for solution designers with senior-level experience, making it challenging for entry-level designers to find suitable job opportunities.

What competences are needed for future software development roles?

1. Programming principles

It is not clear which new programming languages emerge or which of the current languages will last in the long run and are needed in the future. Therefore, it is difficult to determine which programming languages to include in a software training program to meet changing market requirements. A way to solve this problem is to make sure that software professionals have a solid foundation in understanding the underlying programming principles. This will help to adapt quicker to new languages and make software professionals more flexible and future proof.

2. Important profession related competences

Because of its importance, security needs to be an integral part of the whole cycle of designing, developing, deployment and maintenance. Although currently not considered highly important, it is expected that in the (near) future sustainability management and sustainable software development will become important. Besides these, also an understanding of the business and its needs (Business-IT-alignment) will continue to grow in importance. These types of profession related competences are rapidly becoming more important for software professionals and should therefore have a prominent place in educational programmes.

3. Interpersonal soft skills

People in software roles need interpersonal soft skills since many activities require collaboration. The most relevant skills found in our study are teamwork and general communication skills. During the focus group meetings, it was also often mentioned that the ability to communicate in English is increasingly important as it is often the standard language in software development projects. An additional benefit is that having good English language skills can increase job mobility which could benefit both the professionals as organizations searching for employees.

4. Personal soft skills are key

Across all aspects of this research, the growing importance of personal soft skills for people in software roles was clear. The most important seem to be critical thinking & analysis, problem solving and self-management. These soft skills are also truly transversal since these three skills are also the top three skills of which the World Economic Forum (2020) concludes that they will be increasingly in demand by 2025 in the total population of organizations. In other words: these skills are important for people in any working environment and certainly for software professionals.

Future educational needs

Based on the analyses of the transcripts of the expert group meetings we found that besides roles and competences there is also a need for educational processes to change. In Europe there seems to be a focus on educational programmes for entry-level software roles. However, given the large and growing demand for software professional reskilling and upskilling is essential. As time for training is limited, short and modular programmes focusing on new technology trends are necessary. Collaboration between businesses and educational providers is needed to bridge the gap between education and practice, for example through company academies. Especially large organizations can (and already do) organise their own tailormade educational programmes.

Participants of the expert meetings even went as far as stating that flexible, lifelong learning of software professionals should start ideally in primary school with a focus on programming logic and should continue throughout their careers to adapt to new situations and technologies. Providing micro credentials can enable professionals to build up their resumes.

4 Conclusions

Based on the needs analysis (ESSA, 2021)we conclude that the developer role is the most crucial and in-demand role. The shift towards new types of developers, such as full-stack and low-code developers, highlights the need for developers to possess soft skills and business knowledge. The growing attention towards DevOps engineering further emphasizes the need for better integration between software production and the rest of the organization, this is also true for the solution designer role.

Organizations face a challenge in finding applicants with the necessary competences, and employees often lack the opportunities to train themselves while on the job. The educational field needs to educate and train people to possess the right competences to fill these job vacancies. Based on the survey we also found that large organizations have a more significant need for people in software roles and implement solutions like a company academy to reskill and upskill personnel.

Furthermore, we found that soft skills are becoming increasingly important for software professionals. Personal soft skills like adaptability, resilience, and problem-solving abilities are key to succeed as a software professional. Interpersonal soft skills like teamwork and communication are foundational, and English language skills are crucial. Additionally, we found that project management and security management are profession-related skills that are also becoming more important.

The research indicates that time for training is limited, making upskilling a challenge, therefore initial education is crucial for reducing the competence gap in entry-level software roles. Collaboration between businesses and educational providers is needed to bridge the gap between education and practice. Besides this, training with micro credentials are seen as enabler to further close the competence gap and keep software professionals up to date.

5 Reflection and directions for further research

As with all research there are some limitations that need to be discussed. First, the literature review focused on a short period for publications and had a strict set of search criteria to limit the number of findings. This means that important relevant literature might have been missed. Second, during the expert meetings the questions started interesting discussions that often needed to be cut short due to time constraints which might mean we have missed additional needs. Third, the amount of data across the different methods made analysis very time consuming. Therefore, it was conducted by multiple researchers from different countries who then came together to combine their findings. However, it would have been better if parallel analyses of data were evaluated more often to get more alignment between the different researchers during their analysis process.

To counter these limitations, we recommend that this research is conducted on a yearly basis. Hereby it is possible to keep up with the technological developments and the fast-emerging roles and competences needed in the (near) future.

An important research question that remains unanswered in this study concerns the way in which the enormous and still growing shortage of ICT professionals can be reduced. To close the gap between supply and demand in the future, it is important to also identify the supply side of educational programs. This enables organizations to choose the right training strategy that can train people to become exactly these professionals that the market demands.

Recommendations for practice

Prioritize initial education to close the competence gap for entry-level software roles, as the limited time for training makes upskilling challenging.

Develop short, modular, and micro credentialing programs to help software professionals stay up to date with the newest technologies and trends. Integrate the development of soft skills and broader education for software professionals to become T-shaped and Pi-shaped professionals who can bridge the gap between different disciplines.

Encourage collaboration between businesses and educational providers to create better-tailored education and training programs that include real-life examples and environments for practice. And let businesses support the learning process by providing opportunities for software professionals to apply their skills to real-world problems. Just be aware of the risks of this collaboration like ethical contradictions or a superficial learning process due to a practical interest of business.

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References

Aertsen, P., & Saabeel, W. (2022). How to design Software Professionals Curricula. In *https://www.softwareskills.eu/*. European Software Skills Alliance (ESSA).

Albino, R. and Souza, C., "Information and Technology's role and digital transformation challenges: a systematic literature review" (2019). *CONF-IRM 2019 Proceedings*. 5 https://aisel.aisnet.org/confirm2019/5

Allmér, H. (2018). Servicescape for digital wellness services for young elderly. Åbo Akademi University Press, Turku, Finland.

Attig, C., Franke, T. (2020). Abandonment of personal quantification: a review and empirical study investigating reasons for wearable activity tracking attrition. Computers in Human Behavior, 102, 223-237.

Beckett, R., & Daberkow, T. (2019). Work 4.0 and the Identification of Complex Competence Sets. *MWAIS 2019 Proceedings*, 0–6. https://aisel.aisnet.org/mwais2019/33

Duan, L., Cui, S., Qiao, Y., & Yuan, B. (2020). Clustering based on supervised learning of exemplar discriminative information. *Ieee Transactions on Systems, Man, and Cybernetics: Systems*, *50*(12). https://doi.org/10.1109/TSMC.2018.2870549

Engelbrecht, L., Landes, D., & Sedelmaier, Y. (2018). A didactical concept for supporting reflection in software engineering education. *IEEE Global Engineering Education Conference (EDUCON)*

European Software Skills Alliance (ESSA). (2021). Europe's Most Needed Software Roles and Skills. In *https://www.softwareskills.eu/*.

European Commission (2017) Digital Skills and Jobs Conference – Digital Opportunities for Europe, https://digital-strategy.ec.europa.eu/en/library/digital-skills-and-jobs-conference-7-december-2017

European Commision (2019) Analysis of shortage and surplus occupations based on national and Eurostat Labour Force Survey data 2019, https://ec.europa.eu/social/main.jsp?catId=738&langId=en&pubId=8269&furtherPubs=yes

European Commision (2020) Analysis of shortage and surplus occupations 2020, https://op.europa.eu/en/publication-detail/-/publication/22189434-395d-11eb-b27b-01aa75ed71a1/language-en

Föll, P., Hauser, M., & Thiesse, F. (2018). Identifying the skills expected of IS graduates by industry: A text mining approach. *International Conference on Information Systems 2018, ICIS 2018*, 1-17

Garousi, V., Giray, G., Tüzün, E., Catal, C., & Felderer, M. (2019). The Journal of Systems and Software Aligning software engineering education with industrial needs: A meta-analysis. *The Journal of Systems and Software*, *156*, 65–83. htps://doi.org/10.1016/j.jss.2019.06.044

Günay, C., Doloc-Mihu, A., Barakat, R., Gluick, T., & Moore, C. . (2018). Improving Critical Thinking in Software Development via Interdisciplinary Projects at a Most Diverse College. *SIGITE 2020 - Proceedings of the 21st Annual Conference on Information Technology Education*

Heintz, F., & Mannila, L. (2018). Computational thinking for all: an experience report on scaling up teaching computational thinking to all students in a major city in sweden. *Acm Inroads*, *9*(2), 65–71. https://doi.org/10.1145/3159450.3159586

Hoover, A. K., Spryszynski, A., & Halper, M. (2019). Deep learning in the IT curriculum. *SIGITE 2019 - Proceedings of the 20th Annual Conference on Information Technology Education*, 49–54. https://doi.org/10.1145/3349266.3351406

Licorish, S. A., & MacDonell, S. G. (2021). Exploring software developers' work practices: Task differences, participation, engagement, and speed of task resolution. *Information and Management*, *54*(3), 364–382. https://doi.org/10.1016/j.im.2016.09.005

Molina-Azorin, J.F. (2016). Mixed methods research: An opportunity to improve our studies and our research skills. European Journal of Management and Business Economics, 25(2), pp. 37-38.

Reinhart, A., & Genovese, C. R. (2020). *Expanding the scope of statistical computing: Training statisticians to be software engineers*

Ryan, K. (2020). We should teach our students what industry doesn't want. *Proceedings - International Conference on Software Engineering*, 103–106. https://doi.org/10.1145/3377814.3381719

Saabeel, W., Aertsen, P., Martinez-Usero, J., & Montaldo, M. (2022). A Software Skills Strategy for Europe. In *https://www.softwareskills.eu/*. European Software Skills Alliance (ESSA).

Schmidt, J. Y., & 51st ACM SIGCSE Technical Symposium on Computer Science Education, SIGCSE 2020 51 2020 03 11 - 2020 03 14. (2020). Reviewing cs1 materials through a collaborative software engineering exercise: an experience report. *Annual Conference on Innovation and Technology in Computer Science Education, Iticse*, *379-385*, 379–385. https://doi.org/10.1145/3328778.3366932

Schmidt, J. Y., & 51st ACM SIGCSE Technical Symposium on Computer Science Education, SIGCSE 2020 51 2020 03 11 - 2020 03 14. (2020). Reviewing cs1 materials through a collaborative software engineering exercise: an experience report. *Annual Conference on Innovation and Technology in Computer Science Education, Iticse*, *379-385*, 379–385. https://doi.org/10.1145/3328778.3366932

Shaba, E., Guerci, M., Gilardi, S., & Bartezzaghi, E. (2019). Industry 4.0 technologies and organizational design - Evidence from 15 Italian cases. *Studi Organizzativi*, *1*, 9–37. https://doi.org/10.3280/so2019-001001

Thorat, S. A., & Kshirsagar, D. P. (2021). Developing logic building, problem solving, and debugging programming skills among students. *Journal of Engineering Education Transformations*, *34*(Special Issue), 402–406. https://doi.org/10.16920/jeet/2021/v34i0/157188

Webster, J., & Watson, R. T. (2002). Analyzing the past to prepare for the future: Writing a literature review. MIS quarterly, xiii-xxiii.

World Economic Forum (2020) The Future of Jobs Report 2020, http://www3.weforum.org/docs/WEF_Future_of_Jobs_2020.pdf.

Zabavnik, J., Riel, A., Marguč, M., & Rodič, M. (2019, July 3). Knowledge and skills requirements for the software design and testing of automotive applications. *SAAEI* . https://hal.archives-ouvertes.fr/hal-02335566

The Cross-Channel Effects of In-Store Customer Experience in the Case of Omnichannel Fashion Retailing in Finland

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Although omnichannel retailing has emerged as a popular research topic in academic research, there are still gaps in our understanding of this phenomenon. One such gap concerns omnichannel customer experience and particularly the cross-channel or spillover effects of how customer experience in one channel may affect customer behaviour not only in that specific channel but also in the other channels of the same retailer. In this study, we aim to address this gap by examining how customer experience in the offline channel affects customer behaviour in both the offline and the online channel, more specifically how in-store customer experience affects both brick-and-mortar store and online store visit intention. The study is conducted by using survey data from the customers of a Finnish fashion retailer on their recent brick-and-mortar store visit. We find that in-store customer experience does indeed positively affect not only brick-and-mortar store but also online store visit intention.

Keywords:
in-store customer experience, customer satisfaction, brick-and-mortar store visit intention, online store visit intention, omnichannel fashion retailing, Finland

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1 Introduction

Today, more and more retailers are engaging in so-called omnichannel retailing, which refers to the integration of multiple retail channels or other touchpoints between retailers, brands, and consumers in order to provide a single seamless and consistent customer experience (Rigby, 2011; Brynjolfsson et al., 2013; Verhoef et al., 2015; Akter et al., 2021). Thus, it is no surprise that omnichannel retailing has emerged as a popular research topic also in academic research (e.g., Cai & Lo, 2020; Gerea et al., 2021; Mishra et al., 2021; Asmare & Zewdie, 2022; Lopes et al., 2022; Nguyen et al., 2022; Timoumi et al., 2022). However, there are still substantial gaps in our present understanding of this phenomenon. One such gap concerns omnichannel customer experience and particularly the cross-channel or spillover effects of how customer experience in one channel may affect customer behaviour not only in that specific channel but also in the other channels of the same retailer (e.g., Gerea et al., 2021; Mishra et al., 2021; Timoumi et al., 2022). Such effects have not been examined in any prior study that we are aware of, although some prior studies have focused on related topics, such as the effects of online channel service failures on offline channel customer loyalty (Wang & Zhang, 2018) and the effects of online channel customer satisfaction on offline channel adoption (Teng et al., 2023). However, none of them has focused on customer experience from a holistic perspective, and most of them have focused only on the online-to-offline instead of offline-to-online effects.

In this study, we aim to address the aforementioned research gap by examining *how customer experience in the offline channel affects customer behaviour in both the offline and the online channel*, more specifically *how in-store customer experience affects both brick-and-mortar store and online store visit intention.* As with many other prior studies on omnichannel retailing (e.g., Lynch & Barnes, 2020; Truong, 2021; Riaz et al., 2022), the study is conducted in the case context of fashion retailing and in co-operation with a Finnish fashion retailer by first surveying its customers on their recent brick-and-mortar store visit and then analysing this collected data with partial least squares structural equation modelling (PLS-SEM).

After this introductory section, we briefly present the research model of the study in Section 2. The methodology and results of the study are reported in Sections 3 and 4, of which the results are discussed in more detail in Section 5. Finally, we conclude the paper with a brief discussion of the limitations of the study and some potential paths for future research in Section 6.

2 Research Model

We base our research model on the in-store customer experience (ISCX) scale by Bustamante and Rubio (2017), which is a holistic instrument for measuring customer experience in brick-and-mortar stores and has successfully been applied to various retail contexts in prior research (e.g., Bustamante & Rubio, 2017; Happ et al., 2021). The ISCX scale is based on the definition of customer experience by Verhoef et al. (2009) as a construct that "is holistic in nature and involves the customer's cognitive, affective, emotional, social, and physical responses to the retailer". As such, overall in-store customer experience is hypothesised to be constituted of four components (Bustamante & Rubio, 2017): cognitive experience (i.e., the capability of marketing stimuli to make a customer think and reflect, arouse curiosity, awaken creativity, inspire, etc.), affective experience (i.e., the capability of marketing stimuli to provoke emotions in a customer), social experience (i.e., the relationship a customer establishes with the store as a social system by interacting with the employees or other customers), and physical experience (i.e., the physiological responses of a customer in his or her interaction with the environment). However, when applying the ISCX scale to our research model, we make two modifications. First, of its four components, we omit social and physical experience and focus only on cognitive and affective experience, which have traditionally been found as the most important components of customer experience in prior research (Alan et al., 2016) and were also found as the most important components of overall in-store customer experience in the study by Bustamante and Rubio (2017). Second, we decompose affective experience, which in the ISCX scale focuses only on positive affective experience, into two components: positive affective experience and negative affective experience. This is in line with the prevailing view of positive and negative affect as two distinct affective dimensions rather than as bipolar endpoints of a single affective dimension (e.g., Watson & Tellgren, 1985; Watson et al., 1988). Of these three components, in line with the study by Bustamante and Rubio (2017), we hypothesise cognitive experience and positive affective experience to have a positive effect on overall in-store customer experience and negative affective experience to have a negative effect on overall in-store customer experience.

Finally, as already mentioned in the introduction, we add brick-and-mortar (B&M) store and online store visit intention as outcomes of overall in-store customer experience in the research model. The decision to focus on these two constructs is based on the fact that store (re)visit intention has traditionally been considered one of the main manifestations of store loyalty (Bloemer & de Ruyter, 1998), thus making it a very relevant business metric for the retailers who are running the stores. In addition, because customer satisfaction has been found to at least partially mediate the effects of customer experience in general (e.g., Brakus et al., 2009; Klaus & Maklan, 2013) and in-store customer experience in particular (Bustamante & Rubio, 2017) on customer or store loyalty, we also add it as a mediator in the research model, hypothesising that overall in-store customer experience will positively affect brick-and-mortar store and online store visit intention both directly and indirectly via customer satisfaction. The whole resulting research model is illustrated in Figure 1.

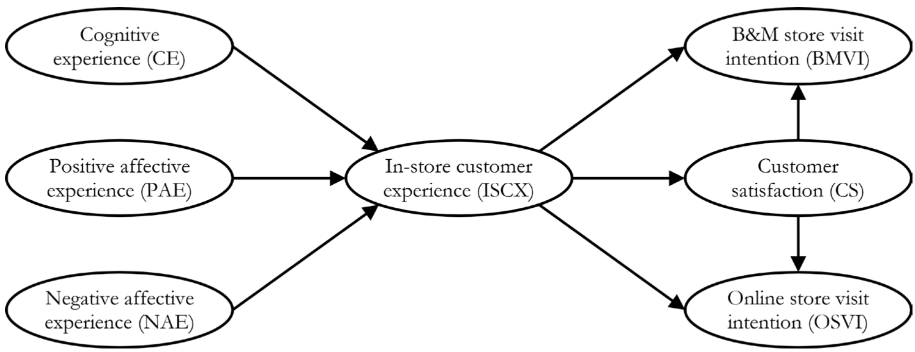

Figure 1: Research model

3 Methodology

The study was conducted in co-operation with a Finnish fashion company, which will be referred to as company X in the remainder of the paper. The company has its own clothing brand, a factory, and multiple brick-and-mortar stores around Finland. However, in this study, we focused on only one of those brick-and-mortar stores, which was the factory outlet. In addition, the company has an online store. The brick-and-mortar stores and the online store are closely integrated (e.g., they are branded consistently and there is the option to pick up the purchases made in the online store from the brick-and-mortar stores), thus making the company a suitable case company for this study on omnichannel retailing.

We collected the data for the study between May 2022 and September 2022 by using both a pen-and-paper survey and an online survey conducted with the LimeSurvey service. Both the surveys were anonymous, had identical questionnaires, and were targeted at the customers of company X who were currently visiting or had recently visited its brick-and-mortar store. The surveys were promoted in two ways. First, we placed promotional boards in the brick-and-mortar store, in which customers were invited to respond to the survey either by using the pen-and-paper questionnaires at the store or by accessing the online questionnaire via a QR code or web address that was printed on the boards. Second, the salespeople at the brick-and-mortar store placed promotional leaflets into the shopping bags of people who had made a purchase at the store, in which customers were invited to respond to the survey by accessing the online questionnaire via a QR code or web address that was printed on the leaflets. In both the promotional boards and the promotional leaflets, customers were also informed about the opportunity to take part in a prize drawing of one 50 € gift card after completing the survey. This was considered a suitable incentive in terms of not causing any bias to the results but still promoting the response rate.

In the survey, customers were first inquired about their general background information and then more specifically about their visit to the brick-and-mortar store, which also contained the items for measuring the seven constructs in the research model. All the constructs were measured reflectively by multiple items: cognitive experience, positive affective experience, negative affective experience, overall in-store customer experience, and customer satisfaction with three items each and brick-and-mortar store and online store visit intention with two items each. The wordings of these 19 items are reported in Appendix A. The items for measuring cognitive experience, positive affective experience, and overall in-store customer experience were adapted from the study by Bustamante and Rubio (2017), whereas the items for measuring negative affective experience were adapted from the study by Richins (1997) and the items for measuring brick-and-mortar store and online store visit intention were adapted from the behavioural intention measures by Fishbein and Ajzen (2010). The measurement scale for all these items was the traditional five-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, and 5 = strongly agree). In turn, the items measuring customer satisfaction were adapted from the American Customer Satisfaction Index (ACSI) by Fornell et al. (1996) and the Extended Performance Satisfaction Index

(EPSI) by Selivanova et al. (2002), which are both based on the Swedish Customer Satisfaction Barometer (SCSB) by Fornell (1992). The measurement scale for these items was a modified five-point Likert scale (1 = extremely dissatisfied, 2 = dissatisfied, 3 = neither satisfied nor dissatisfied, 4 = satisfied, and 5 = extremely satisfied). Finally, we also used five control variables in the study: gender, age, information on whether the respondent had made a purchase during the visit, and information about the average visiting frequency to the brick-and-mortar store and the online store of company X. Of these, the first three variables were used to control all the endogenous constructs in the research model (i.e., overall in-store customer experience, customer satisfaction, brick-and-mortar store visit intention, and online store visit intention), whereas brick-and-mortar store visiting frequency was used to control only brick-and-mortar store visit intention and online store visiting frequency was used to control only online store visit intention. In order to avoid forced responses, responding to all the items in the survey was voluntary, and not responding to a particular item resulted in a missing value.

Due to the limited sample size, the collected data was analysed with variance-based structural equation modelling (VB-SEM), more specifically partial least squares structural equation modelling (PLS-SEM) by using the SmartPLS 4.0.8.8 software by Ringle et al. (2022). When conducting PLS-SEM, we followed the recent guidelines by Hair et al. (2022). For example, we used mode A as the indicator weighting mode, path weighting as the weighting scheme, +1 as the initial weights, and $< 10^{-7}$ as the stop criterion in model estimation, whereas the statistical significance of the model estimates was tested by using bootstrapping with 10,000 subsamples. As the threshold for statistical significance, we used $p < 0.05$, but we also took into account the results that were statistically almost significant at $p < 0.10$ due to the limited sample size. Because of their small percentage, the potential missing values were handled simply by using mean replacement.

4 Results

In total, we received 101 valid responses to the survey, of which 40 (39.6%) originated from the pen-and-paper survey and 61 (60.4%) originated from the online survey. The descriptive statistics of the whole sample in terms of the gender, age, and socioeconomic status of the respondents are reported in Table 1. In addition, Table 1 reports whether the respondents had made a purchase during their visit as well as their average brick-and-mortar store and online store visiting frequency. As can be seen, most of the respondents (74.3%) were women, which was expected when considering our case context of fashion retailing. The age of the respondents ranged from 15 to 72 years, with a mean of 39.9 years and a standard deviation of 14.6 years. In terms of socioeconomic status, most of the respondents were either employees (72.3%) or students (22.8%). Most of the respondents (76.2%) had also made a purchase during their visit and almost all of them (96.0%) had visited the brick-and-mortar store prior to their present visit. In contrast, the online store was visited slightly less frequently, and there was also a substantial share of respondents (15.8%) who had never visited it.

Table 1: Descriptive statistics of the sample (N = 101)

	N	%		N	%
Gender			**Made a purchase during the visit**		
Man	26	25.7	Yes	77	76.2
Woman	75	74.3	No	20	19.8
Age			No response	4	4.0
15–29 years	26	25.7	**B&M store visiting frequency**		
30–39 years	29	28.7	At least monthly	20	19.8
40–49 years	20	19.8	At least yearly	48	47.5
50–59 years	11	10.9	Less frequently than yearly	29	28.7
60 years or over	15	14.9	Has never visited	2	2.0
Socioeconomic status			No response	2	2.0
Student	23	22.8	**Online store visiting frequency**		
Employee	73	72.3	At least monthly	21	20.8
Self-employed	5	5.0	At least yearly	32	31.7
Unemployed or unable to work	3	3.0	Less frequently than yearly	29	28.7
Pensioner	7	6.9	Has never visited	16	15.8
Stay-at-home parent	1	1.0	No response	3	3.0

In the following three subsections, we first assess the estimated model in terms of the reliability and validity of its constructs and indicators. Finally, we report the model estimates.

4.1 Construct Reliability and Validity

Construct reliability was assessed from the perspective of internal consistency by using the composite reliability (CR) of the constructs (Fornell & Larcker, 1981), which is commonly expected to be at least 0.7 (Nunally & Bernstein, 1994). The CR of each construct is reported in the first column of Table 2, showing that all the constructs met this criterion. In turn, construct validity was assessed from the perspectives of convergent and discriminant validity by using the two criteria by Fornell and Larcker (1981). They are both based on the average variance extracted (AVE) of the constructs, which is the average proportion of variance that a construct explains in its indicators. The first criterion concerning convergent validity expects each construct to have an AVE of at least 0.5. This means that, on average, each construct should explain at least half of the variance in its indicators. The AVE of each construct is reported in the second column of Table 2, showing that all the constructs met this criterion. The second criterion concerning discriminant validity expects each construct to have a square root of AVE that is at least equal to its absolute correlations with the other constructs in the model. This means that, on average, each construct should share at least an equal proportion of variance with its indicators to what it shares with the other constructs. The square root of AVE of each construct (on-diagonal) and the correlations between all the constructs in the model (off-diagonal) are reported in the remaining columns of Table 2, showing that this criterion was also met by all the constructs. Additional support for discriminant validity was also provided by the heterotrait-monotrait (HTMT) ratios of the aforementioned correlations, which all met the criterion of being less than 0.90 (Henseler et al., 2015).

Table 2: Construct-level statistics

	CR	AVE	Square roots of AVE and the correlations between the constructs						
			CE	PAE	NAE	ISCX	CS	BMVI	OSVI
CE	0.870	0.690	0.831						
PAE	0.871	0.693	0.681	0.832					
NAE	0.884	0.718	-0.120	-0.362	0.847				
ISCX	0.921	0.795	0.347	0.516	-0.397	0.892			
CS	0.929	0.815	0.386	0.611	-0.517	0.616	0.903		
BMVI	0.935	0.878	0.274	0.322	-0.234	0.695	0.400	0.937	
OSVI	0.928	0.865	0.245	0.298	-0.085	0.376	0.385	0.459	0.930

4.2 Indicator Reliability and Validity

Indicator reliability and validity were assessed by using the standardised loadings of the indicators, which are reported in Appendix A together with the means and standard deviations (SD) of the indicator scores as well as the percentages of missing values. In the typical case of each indicator loading on only one construct, the standardised loading of each indicator is commonly expected to be statistically significant and at least 0.707 (Fornell & Larcker, 1981). This is equivalent to the standardised residual of each indicator being at least 0.5, meaning that at least half of the variance in each indicator is explained by the construct on which it loads. As can be seen, all the indicators met this criterion.

4.3 Model Estimates

The results of model estimation in terms of the standardised effect sizes and their statistical significance as well as the proportions of explained variance (R^2) are reported in Figure 2 (and in Appendix B for the effects of the control variables). As can be seen, positive affective experience and negative affective experience were both found to have a statistically significant effect on overall in-store customer experience, with the effect of positive affective experience being positive and the effect of negative affective experience being negative. In contrast, the effect of cognitive experience on overall in-store customer experience was found to be statistically not significant. In turn, overall in-store customer experience was found to have a statistically significant effect on customer satisfaction, a statistically significant direct effect on brick-and-mortar store visit intention, and a statistically almost significant direct effect on online store visit intention. These effects were all positive, and especially the effect of overall in-store customer experience on brick-and-mortar store visit intention was found to be very strong. Finally, customer satisfaction was found to have a statistically not significant effect on brick-and-mortar store visit intention and a statistically almost significant and positive effect on online store visit intention.

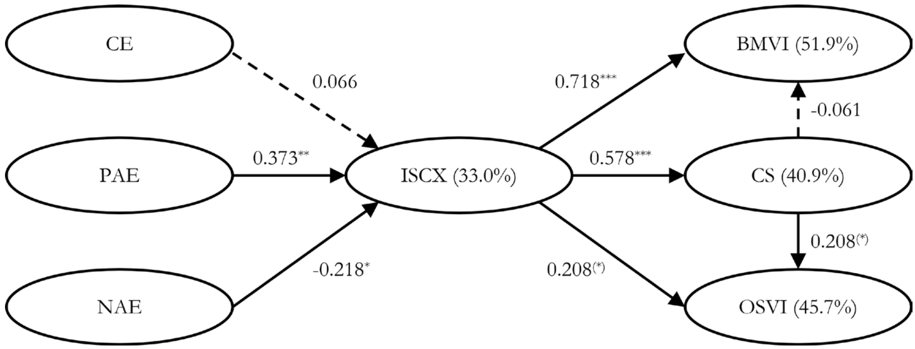

Figure 2: Model estimates (* = p < 0.001, ** = p < 0.01, * = p < 0.05, (*) = p < 0.10)**

In addition to the aforementioned direct effects, we also examined the indirect effects of overall in-store customer experience on brick-and-mortar store visit intention and online store visit intention via customer satisfaction as well as the total effects of overall in-store customer experience on brick-and-mortar store visit intention and online store visit intention that take into account both the direct and the indirect effects. Of these, the indirect effects of overall in-store customer experience on both brick-and-mortar store visit intention (-0.035) and online store visit intention (0.120) were found to be statistically not significant, whereas the total effect of overall in-store customer experience on both brick-and-mortar store visit intention (0.682***) and online store visit intention (0.328***) were found to be statistically significant and positive.

The effects of the control variables were found to be mostly statistically not significant. The exceptions were the statistically significant and positive effect of having made a purchase during the visit on customer satisfaction, the statistically almost significant and positive effect of past brick-and-mortar store visiting frequency on future brick-and-mortar store visit intention, and the statistically significant and positive effect of past online store visiting frequency on future online store visit intention. In total, the model was able to explain 33.0% of the variance in overall in-store customer experience, 40.9% of the variance in customer satisfaction, 51.9% of the variance in brick-and-mortar store visit intention, and 45.7% of the variance in online store visit intention. The variance inflation factor (VIF) values of all the constructs and control variables were found to be less than three, thus indicating no multicollinearity issues (Hair et al., 2018).

5 Discussion and Conclusion

In this study, we examined the effect of in-store customer experience on brick-and-mortar store and online store visit intention while also considering the role of customer satisfaction as a mediator. All in all, we made three main findings. First and foremost, we found that in-store customer experience does indeed affect positively not only brick-and-mortar store but also online store visit intention, especially when considering the total effect of in-store customer experience on online store visit intention that takes into account both the direct effect and the indirect effect via customer satisfaction. Thus, at least in our case context of fashion retailing, there seems to be a positive cross-channel or spillover effect for the outcomes of customer experience from offline to online channels. Second, our findings provide some support for the role of customer satisfaction as a mediator for the effect of in-store customer experience on online store visit intention because although the indirect effect of in-store customer experience on online store visit intention via customer satisfaction was found to be statistically not significant in our sample, this effect was still strong enough to result in the total effect of in-store customer experience on online store visit intention becoming statistically significant despite the statistically not significant direct effect of in-store customer experience on online store visit intention. In contrast, our findings provide no support for the role of customer satisfaction as a mediator for the effect of in-store customer experience on brick-and-mortar store visit intention due to the statistically not significant and very weak indirect effect of in-store customer experience on brick-and-mortar store visit intention via customer satisfaction. In other words, in-store customer experience alone seems to determine brick-and-mortar store visit intention regardless of the resulting customer satisfaction. This finding conflicts with the study by Bustamante and Rubio (2017), who found store satisfaction to mediate the effect of in-store customer experience on store loyalty. The conflict may be explained by their different operationalisation of store loyalty, which did not focus only on store (re)visit intention but also on aspects like word-of-mouth behaviour. Third, we found overall in-store customer experience to be affected more strongly by positive than negative affective experience but not at all by cognitive experience as it is hypothesised in the study by Bustamante and Rubio (2017). Of these, the former finding is in line, for example, with the prior study by Makkonen et al. (2019), who found outcomes like customer satisfaction, repurchase intention, and recommendation intention to be affected more strongly by positive than negative emotions in the context of online shopping. In turn, the latter finding may be explained by our more hedonic and less utilitarian case context of fashion retailing (e.g., Kemppainen et al., 2021), in which affective rather than cognitive experience is likely to be more dominant in determining overall customer experience.

From a theoretical perspective, the findings of the study promote our understanding of the cross-channel or spillover effects of customer experience and its outcomes in omnichannel retailing, which is a topic that has been largely overlooked in prior research. For example, as already discussed in the introduction, although some prior studies have focused on related topics, none of them has focused on customer experience from a holistic perspective by comprehensively considering its various (e.g., cognitive and affective) components, and most of them have focused only on the online-to-offline instead of offline-to-online effects. In turn, from a practical perspective, the findings of the study highlight the importance of holistic channel and customer experience management in omnichannel retailing. Such holistic management can be considered important because the aforementioned cross-channel or spillover effects pose both substantial opportunities and substantial threats for omnichannel retailers. On one hand, the effects pose opportunities because good customer experience in one channel is likely to result in positive outcomes not only in that particular channel but in other channels as well. Thus, it always pays off for omnichannel retailers to invest in the improvement of customer experience in all their channels because even if some channels may be seen as strategically less important, the resulting positive outcomes are likely to spill over and promote the success of also the strategically more important channels. On the other hand, the effects pose threats because bad customer experience in one channel is likely to result in negative outcomes not only in that particular channel but in other channels as well. Thus, omnichannel retailers should never neglect customer experience in any of their channels because even if some channels may once again be seen as strategically less important, the resulting negative outcomes are likely to spill over and spoil the success of also the strategically more important channels. In summary, in omnichannel retailing, the customer experience of all channels always counts.

6 Limitations and Future Research

We see this study to have four main limitations. First, the study was conducted in the case context of fashion retailing, which may limit the generalisability of its findings to other retail contexts. Second, the sample size of the study was relatively small, although still sufficiently large for identifying several statistically significant effects between the constructs in our research model. The sample size was mainly limited by our methodological choice of focusing on the customers of only one case company and on their very recent visits, of which the latter is reflected by the fact that 85 out of the 101 respondents (84.2%) completed the survey on the same day of their visit. Thus, we believe that what we may have lost in data quantity, we have more than gained in data quality in terms of minimising recall bias and the effects of confounding factors that may have resulted from having multiple case companies in the study. Third, when measuring in-store customer experience, we focused only on cognitive and affective experience while omitting social and physical experience, which may explain our rather modest R^2 of overall in-store customer experience (33.0%), although it cannot be seen to compromise our findings concerning the effects of overall in-store customer experience on its outcomes. Fourth, of the potential outcomes of in-store customer experience, we focused only on customer satisfaction as well as on visit intentions as manifestations of store loyalty. Obviously, also many other constructs could have been chosen as outcomes in our research model.

We see that future research should address the aforementioned limitations by replicating the study in other case contexts than fashion retailing by using larger samples and even more holistic measures of in-store customer experience while also considering other potential outcomes of in-store customer experience, such as customer value, customer commitment, customer engagement, or willingness-to-pay. In addition, it is essential to examine the cross-channel or spillover effects not only from brick-and-mortar stores to online stores but also vice versa and between other commonly used channels in omnichannel retailing.

References

Akter, S., Hossain, T. M. T., & Strong, C. (2021). What omnichannel really means? Journal of Strategic Marketing, 29(7), 567–573.

Alan, A. K., Kabadayi, E. T., & Yilmaz, C. (2016). Cognitive and affective constituents of the consumption experience in retail service settings: Effects on store loyalty. Service Business, 10(4), 715–735.

Asmare, A., & Zewdie, S. (2022). Omnichannel retailing strategy: A systematic review. International Review of Retail, Distribution and Consumer Research, 32(1), 59–79.

Bloemer, J., & de Ruyter, K. (1998). On the relationship between store image, store satisfaction and store loyalty. European Journal of Marketing, 32(5/6), 499–513.

Brakus, J. J., Schmitt, B. H., & Zarantonello, L. (2009). Brand experience: What is it? How is it measured? Does it affect loyalty? Journal of Marketing, 73(3), 52–68.

Brynjolfsson, E., Hu, Y. J., & Rahman, M. S. (2013). Competing in the age of omnichannel retailing. MIT Sloan Management Review, 54(4), 23–29.

Bustamante, J. C., & Rubio, N. (2017). Measuring customer experience in physical retail environments. Journal of Service Management, 28(5), 884–913.

Cai, Y.-J., & Lo, C. K. Y. (2020). Omni-channel management in the new retailing era: A systematic review and future research agenda. International Journal of Production Economics, 229, 107729.

Fishbein, M., & Ajzen, I. (2010). Predicting and Changing Behavior: The Reasoned Action Approach. New York, NY: Psychology Press.

Fornell, C. (1992). A national customer satisfaction barometer: The Swedish experience. Journal of Marketing, 56(1), 6–21.

Fornell, C., Johnson, M. D., Anderson, E. W., Cha, J., & Bryant, B. E. (1996). The American Customer Satisfaction Index: Nature, purpose, and findings. Journal of Marketing, 60(4), 7–18.

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. Journal of Marketing Research, 18(1), 39–50.

Gerea, C., Gonzalez-Lopez, F., & Herskovic, V. (2021). Omnichannel customer experience and management: An integrative review and research agenda. Sustainability, 13(5), 2824.

Hair, J. F., Jr., Black, W. C., Babin, B. J., & Anderson, R. E. (2018). Multivariate Data Analysis (8th ed.). Andover, United Kingdom: Cengage.

Hair, J. F., Jr., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2022). A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM) (3rd ed.). Thousand Oaks, CA: SAGE.

Happ, E., Scholl-Grissemann, U., Peters, M., & Schnitzer, M. (2021). Insights into customer experience in sports retail stores. International Journal of Sports Marketing and Sponsorship, 22(2), 312–329.

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. Journal of the Academy of Marketing Science, 43(1), 115–135.

Kemppainen, T., Frank, L., Makkonen, M., & Hyvönen, O.-I. (2021). Barriers to responsible consumption in e-commerce: Evidence from fashion shoppers. In A. Pucihar, M. Kljajić Borštnar, R. Bons, H. Cripps, A. Sheombar & D. Vidmar (Eds.), Proceedings of the 34th Bled eConference (pp. 323–335). Maribor, Slovenia: University of Maribor Press.

Klaus, P., & Maklan, S. (2013). Towards a better measure of customer experience. International Journal of Market Research, 55(2), 227–246.

Lopes, J. M., Sousa, A., Calçada, E., & Oliveira, J. (2022). A citation and co-citation bibliometric analysis of omnichannel marketing research. Management Review Quarterly, 72(4), 1017–1050.

Lynch, S., & Barnes, L. (2020). Omnichannel fashion retailing: Examining the customer decision-making journey. Journal of Fashion Marketing and Management, 24(3), 471–493.

Makkonen, M., Riekkinen, J., Frank, L., & Jussila, J. (2019). The effects of positive and negative emotions during online shopping episodes on consumer satisfaction, repurchase intention, and recommendation intention. In A. Pucihar, M. Kljajić Borštnar, R. Bons, J. Seitz, H. Cripps &

D. Vidmar (Eds.), Proceedings of the 32nd Bled eConference (pp. 931–953). Maribor, Slovenia: University of Maribor Press.

Mishra, R., Singh, R. K., & Koles, B. (2021). Consumer decision-making in omnichannel retailing: Literature review and future research agenda. International Journal of Consumer Studies, 45(2), 147–174.

Nguyen, A., McClelland, R., Thuan, N. H., & Hoang, T. G. (2022). Omnichannel marketing: Structured review, synthesis, and future directions. International Review of Retail, Distribution and Consumer Research, 32(3), 221–265.

Nunnally, J. C., & Bernstein, I. H. (1994). Psychometric Theory (3rd ed.). New York, NY: McGraw-Hill.

Riaz, H., Baig, U., Meidute-Kavaliauskiene, I., & Ahmed, H. (2022). Factors effecting omnichannel customer experience: Evidence from fashion retail. Information, 13(1), 12.

Richins, M. L. (1997). Measuring emotions in the consumption experience. Journal of Consumer Research, 24(2), 127–146.

Rigby, D. (2011). The future of shopping. Harvard Business Review, 89(12), 65–76.

Ringle, C. M., Wende, S., & Becker, J.-M. (2022). SmartPLS 4. Oststeinbek, Germany: SmartPLS GmbH. Available at http://www.smartpls.com

Selivanova, I., Hallissey, A., Letsios, A., & Eklöf, J. (2002). The EPSI rating initiative. European Quality, 9, 10–25.

Teng, H., Xia, Q., Shou, J., & Zhao, J. (2023). Positive or negative spillover? The influence of online channel satisfaction on offline channel adoption. Journal of Business Research, 154, 113332.

Timoumi, A., Gangwar, M., & Mantrala, M. K. (2022). Cross-channel effects of omnichannel retail marketing strategies: A review of extant data-driven research. Journal of Retailing, 98(1), 133–151.

Truong, T. H. H. (2021). The drivers of omni-channel shopping intention: A case study for fashion retailing sector in Danang, Vietnam. Journal of Asian Business and Economic Studies, 28(2), 143–159.

Verhoef, P. C., Kannan, P. K., & Inman, J. J. (2015). From multi-channel retailing to omni-channel retailing: Introduction to the special issue on multi-channel retailing. Journal of Retailing, 91(2), 174–181.

Verhoef, P. C., Lemon, K. N., Parasuraman, A., Roggeveen, A., Tsiros, M., & Schlesinger, L. A. (2009). Customer experience creation: Determinants, dynamics and management strategies. Journal of Retailing, 85(1), 31–41.

Wang, X., & Zhang, Q. (2018). Does online service failure matter to offline customer loyalty in the integrated multi-channel context? The moderating effect of brand strength. Journal of Service Theory and Practice, 28(6), 774–806.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. Journal of Personality and Social Psychology, 54(6), 1063–1070.

Watson, D., & Tellegen, A. (1985). Toward a consensual structure of mood. Psychological Bulletin, 98(2), 219–235.

Appendix A: Indicator-Level Statistics

Item	Wording	Mean	SD	Missing	Loading
	How satisfied were you with your visit to the B&M store of X…				
CS1	… overall?	4.673	0.568	0.0%	0.917***
CS2	… in relation to your expectations?	4.556	0.745	2.0%	0.916***
CS3	… in relation to your idea of an ideal store visit?	4.550	0.642	1.0%	0.875***
	Visiting the B&M store of X…				
CE1	… taught me interesting things.	3.176	0.973	9.9%	0.793***
CE2	… awoke my creativity.	3.469	1.015	5.0%	0.841***
CE3	… brought interesting ideas to my mind.	3.680	0.984	1.0%	0.857***
PAE1	… put me in a good mood.	4.327	0.801	0.0%	0.866***
PAE2	… made me feel happy.	3.760	0.971	5.0%	0.868***
PAE3	… made me feel optimistic.	3.615	0.863	5.0%	0.759***
NAE1	… put me in a bad mood.	1.465	0.962	2.0%	0.824***
NAE2	… made me feel frustrated.	1.747	1.137	2.0%	0.800***
NAE3	… made me feel discontented.	1.740	1.070	1.0%	0.913***
ISCX1	I enjoyed visiting the B&M store of X.	4.604	0.722	0.0%	0.888***
ISCX2	I enjoyed doing business at the B&M store of X.	4.707	0.593	2.0%	0.880***
ISCX3	I enjoyed spending time in the B&M store of X.	4.490	0.835	1.0%	0.907***
BMVI1	I intend to visit the B&M store of X in the future.	4.639	0.739	4.0%	0.947***
BMVI2	I plan to visit the B&M store of X in the future	4.469	0.888	3.0%	0.927***
OSVI1	I intend to visit the online store of X in the future	4.242	0.970	9.9%	0.936***
OSVI2	I plan to visit the online store of X in the future	4.132	0.968	9.9%	0.925***

*** = $p < 0.001$

Appendix B: Effects of the Control Variables

	ISCX	CS	BMVI	OSVI
Gender (0 = male and 1 = female)	-0.086	0.080	0.231	0.007
Age (in years)	-0.023	0.002	-0.004	-0.039
Made a purchase during the visit (0 = no and 1 = yes)	0.270	0.435*	-0.040	-0.229
B&M store visiting frequency (1 = has never visited, 2 = less frequently than yearly, 3 = at least yearly, and 4 = at least monthly)	–	–	0.155(*)	–
Online store visiting frequency (1 = has never visited, 2 = less frequently than yearly, 3 = at least yearly, and 4 = at least monthly)	–	–	–	0.525***

*** = $p < 0.001$, ** = $p < 0.01$, * = $p < 0.05$, (*) = $p < 0.10$

THE ROLE OF ANTICIPATED GUILT AND ITS NEUTRALISATION IN EXPLAINING RESPONSIBLE ONLINE SHOPPING

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Although responsible consumption has been the target of growing interest in academic research, the antecedents of responsible online shopping remain poorly understood. In this study, we address this gap in prior research by focusing on the role of anticipated guilt in explaining responsible online shopping. By using data from 479 Finnish consumers, we aim to answer two research questions: (1) how strong an antecedent of responsible online shopping intention is anticipated guilt in relation to other potential antecedents and (2) how efficiently can consumers regulate their resulting feelings of guilt by using different kinds of neutralisation techniques? We find anticipated guilt to be a strong antecedent of responsible online shopping intention and the denial of responsibility, the denial of injury, and the appeal to higher loyalties to be the most efficient neutralisation techniques for consumers to regulate their feelings of guilt that result from not engaging in responsible online shopping.

Keywords:
responsible online shopping, anticipated guilt, neutralisation techniques, theory of planned behaviour, online survey, structural equation modelling, Finland

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1 Introduction

Sustainable development, which is commonly defined as development that meets the needs of the present without compromising the ability of future generations to meet their needs (United Nations, 1987), has become one of the main goals of most modern societies. One central component of sustainable development is responsible consumption (Jain et al., 2022), which refers to consumption that has a less negative or more positive impact on the environment, society, self, and others (Ulusoy, 2016). Although responsible consumption has been the target of growing interest also in academic research (cf. Webb et al., 2008; Gupta & Agrawal, 2018; Jain et al., 2022), few prior studies have focused on it in the context of online shopping, which can be seen as surprising when considering its widespread adoption among modern consumers. More specifically, no prior studies that we are aware of have holistically examined the antecedents of responsible online shopping in terms of what actually causes consumers to make or not to make responsible consumption choices when shopping online.

In this study, we aim to address this gap in prior research by focusing on the role of anticipated guilt in explaining responsible online shopping. Anticipated guilt refers to the feelings of guilt that arise from contemplating a potential deviation from one's standards (Rawlings, 1970), and it has been used in marketing research to explain various aspects of consumer behaviour (Antonetti & Baines, 2015), including sustainable and responsible consumer behaviour (e.g., Onwezen et al. 2013, 2014a, 2014b; Antonetti & Maklan, 2014a, 2014b; Theotokis & Manganari, 2015; Lindenmeier et al., 2017). Thus, it can be assumed to play an important role also in explaining responsible online shopping. More specifically, we focus on answering two research questions: (1) how strong an antecedent of responsible online shopping intention is anticipated guilt in relation to other potential antecedents and (2) how efficiently can consumers regulate their resulting feelings of guilt by using different kinds of neutralisation techniques? As our data, we use the responses from 479 Finnish consumers, which were collected with an online survey and are analysed with structural equation modelling (SEM).

After this introductory section, we briefly present the research model of the study in Section 2. The methodology and results of the study are reported in Sections 3 and 4, of which the results are discussed in more detail in Section 5. Finally, we conclude the paper with a brief discussion of the limitations of the study and some potential paths for future research in Section 6.

2 Research Model

In order to examine the strength of anticipated guilt as an antecedent of responsible online shopping intention in relation to other potential antecedents, we apply the theory of planned behaviour (TPB) by Ajzen (1985, 1991), which is an extension of the theory of reasoned action (TRA) by Fishbein and Ajzen (1975, 1980) and one of the most commonly applied theories for explaining human behaviour in a variety of contexts (Fishbein & Ajzen, 2010). Some examples of these are the acceptance and use of various kinds of information technologies (IT) and information systems (IS) (e.g., Makkonen et al., 2010, 2012a, 2012b; Kari & Makkonen, 2014; Weigel et al., 2014), online shopping (e.g., Pavlou & Fygenson, 2006), sustainable and responsible consumption (e.g., Onwezen et al., 2013, 2014b; Han & Stoel, 2017), and even sustainable online shopping (Yang et al., 2018). In TPB, an individual's intention to engage in a particular behaviour is hypothesised to be explained by three antecedents (Fishbein & Ajzen, 2010): the attitude toward the behaviour (i.e., an individual's positive or negative evaluations of engaging in the behaviour), the subjective norm toward the behaviour (i.e., an individual's perception of social pressure to engage or not engage in the behaviour), and the perceived behavioural control over the behaviour (i.e., an individual's sense of capability, control, and self-efficacy to engage in the behaviour). In our research model, in line with the studies by Onwezen et al. (2014a, 2014b), we add anticipated guilt as the fourth antecedent of behavioural intention in order to compare its explanatory power with the three original antecedents of TPB. We hypothesise each of these four antecedents to have a positive effect on responsible online shopping intention, meaning that the more positive the attitude, the stronger the subjective norm and perceived behavioural control, and the more guilt an individual feels from not engaging in responsible online shopping, the stronger his or her responsible online shopping intention is hypothesised to be.

In turn, in order to examine how efficiently consumers can regulate the feelings of guilt that result from not engaging in responsible online shopping, we apply the neutralisation theory by Sykes and Matza (1957), which was originally developed for the context of juvenile delinquency to explain how individuals are able to justify and deflect the feelings of guilt that result from deviant behaviour by using different kinds of neutralisation techniques. More recently, it has been applied to also various other contexts, such as employee IS security policy violations (Siponen & Vance, 2010), software piracy (Siponen et al., 2012), shadow IT use (Silic et al., 2017), employee unauthorised computer access (Lin et al., 2018), and digital media piracy (Riekkinen, 2018) in IS, as well as inappropriate consumer behaviour (Strutton et al., 1994), fair trade (Chatzidakis et al., 2007), sustainable consumption (Antonetti & Maklan, 2014b; Gruber & Schlegelmilch, 2014), and immoral and unethical consumption (McGregor, 2008) in marketing. Originally, Sykes and Matza (1957) proposed five neutralisation techniques: the denial of responsibility (i.e., claiming not to be responsible for the deviant behaviour), the denial of injury (i.e., claiming that the deviant behaviour caused no injury), the denial of victim (i.e., claiming that the deviant behaviour was rightful when considering the circumstances), the condemnation of the condemners (i.e., claiming that those who condemn the deviant behaviour engage themselves in similar behaviour), and the appeal to higher loyalties (i.e., claiming that the deviant behaviour was due to actualising a higher-order ideal or value). Later, also other neutralisation techniques have been proposed, of which the most prominent are the metaphor of the ledger (i.e., claiming that the prior good behaviour counterbalances the present bad behaviour) by Klockars (1974) and the defence of necessity (i.e., claiming that the deviant behaviour was necessary) by Minor (1981). These all except for the denial of victim have been found to be used by consumers in the context of sustainable consumption in the study by Gruber and Schlegelmilch (2014), which is why we assume them to be used by consumers also in the closely related context of responsible consumption. Thus, in our research model, we add these six neutralisation techniques, which are the same ones that have been used also in the studies by Siponen and Vance (2010), Silic et al. (2017), and Lin et al. (2018), as antecedents of anticipated guilt, hypothesising them to have a negative effect on it. The resulting research model is illustrated in Figure 1.

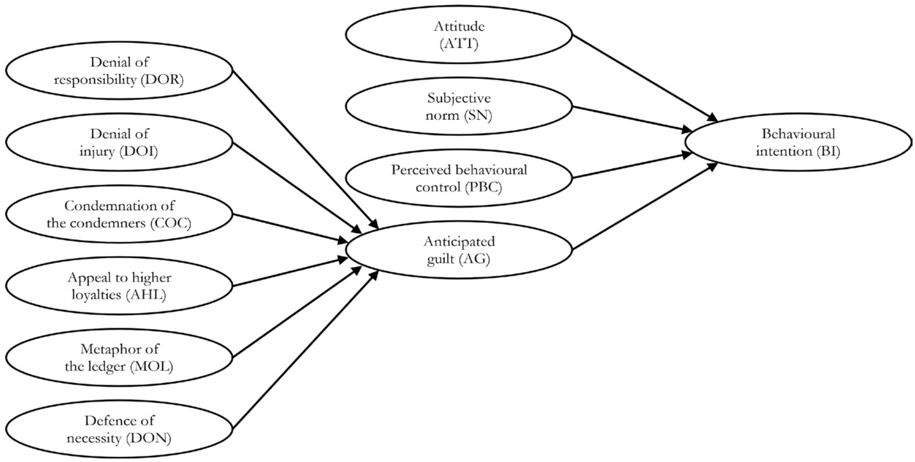

Figure 1: Research model

3 Methodology

We collected the data for testing the research model from Finnish consumers between February 2023 and March 2023 with an online survey that was conducted by using the LimeSurvey service. The respondents for the survey were recruited by promoting the survey on social media and via the various communication channels of Finnish universities and student associations. As an incentive for responding, all the respondents who completed the survey were able to take part in a prize drawing of ten gift boxes, which were worth about 25 € each.

Before measuring the constructs of the research model, responsible online shopping was first defined for the respondents as making consumption choices that take various ecological and ethical values (e.g., sustainable development and fair trade) into account while shopping online. Of the constructs, responsible online shopping intention, attitude, subjective norm, perceived behavioural control, and anticipated guilt were measured reflectively by three items each, whereas the six neutralisation techniques were measured reflectively by only two items each in order to avoid respondent fatigue. The wordings of these items are reported in Appendix A. The items for measuring responsible online shopping intention, attitude, subjective norm, and perceived behavioural control were adapted from the examples by Fishbein and Ajzen (2010), whereas the items for measuring anticipated guilt were adapted from the guilt inventory by Kugler and Jones (1992) as exemplified by

Onwezen et al. (2013, 2014a, 2014b). In turn, the items for measuring the six neutralisation techniques were developed for this study based on the format by Siponen and Vance (2010) and the contextualisations by Gruber and Schlegelmilch (2014), who examined the meaning of these neutralisation techniques to consumers in the context of sustainable consumption. A seven-point semantic differential scale ranging from -3 to +3 was used for measuring attitude, whereas the traditional five-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, and 5 = strongly agree) was used for measuring all the other constructs.

In addition, we used three control variables to control the effects of gender, age, and social desirability bias on responsible online shopping intention and anticipated guilt. Of these, gender and age were each measured with a single item, whereas social desirability bias was measured with the ten items and the measurement procedure proposed by Kuokkanen (2017), in which the item scores are transformed into a single continuous social desirability bias variable ranging from one (minimum social desirability bias) to five (maximum social desirability bias). In order to avoid forced responses, responding to all the items in the survey was voluntary, and not responding to a particular item resulted in a missing value.

The data was analysed with covariance-based structural equation modelling (CB-SEM) by using the Mplus 8.8 software (Muthén & Muthén, 2023) and following the guidelines by Gefen et al. (2011) for SEM in administrative and social science research. As the model estimator, we used the robust maximum likelihood (MLR) estimator, which is able to handle also non-normal data. The potential missing values were handled by using the full information maximum likelihood (FIML) estimator, which uses all the available data in model estimation. As the threshold for statistical significance, we used $p < 0.05$.

4 Results

In total, we received 479 valid responses to the online survey. The descriptive statistics of this sample in terms of the gender, age, yearly personal taxable income, socioeconomic status, and average online shopping frequency of the respondents are reported in Table 1. As can be seen, most of the respondents were women, students, and relatively young, which was not surprising when considering our recruitment of the respondents. More specifically, the age of the respondents ranged from 19 to 75 years, with a mean of 28.4 years and a standard deviation of 9.2 years. However, most of the respondents (68.7%) were relatively active online shoppers who shopped online at least monthly on average.

Table 1: Descriptive statistics of the sample (N = 479)

	N	%		N	%
Gender			**Socioeconomic status**		
Man	88	18.4	Student	341	71.2
Woman	365	76.2	Employee or self-employed	132	27.6
Other	26	5.4	Unemployed or unable to work	10	2.1
Age			Pensioner	5	1.0
Under 25 years	206	43.0	Other	4	0.8
25–49 years	253	52.8	**Online shopping frequency**		
50 years or over	20	4.2	At least weekly	31	6.5
Yearly personal taxable income			At least monthly	298	62.2
Under 15,000 €	286	59.7	At least yearly	140	29.2
15,000–29,999 €	71	14.8	Less frequently than yearly	8	1.7
30,000 € or over	98	20.5	Has never shopped online	1	0.2
No response	24	5.0	No response	1	0.2

In the following three subsections, we first evaluate the estimated model in terms of the reliability and validity of its constructs and indicators as well as its goodness-of-fit with the data. Finally, we report the model estimates.

4.1 Construct Reliability and Validity

Construct reliability was evaluated from the perspective of internal consistency by using the composite reliability (CR) of the constructs (Fornell & Larcker, 1981), which is commonly expected to be at least 0.7 (Nunally & Bernstein, 1994). The CR of each construct is reported in the first column of Table 2, showing that all the constructs met this criterion.

Table 2: Construct-level statistics

	CR	AVE	Square roots of AVE and the correlations between the constructs										
			BI	**ATT**	**SN**	**PBC**	**AG**	**DOR**	**DOI**	**COC**	**AHL**	**MOL**	**DON**
BI	0.917	0.787	0.887										
ATT	0.829	0.618	0.434	0.786									
SN	0.940	0.840	0.341	0.272	0.916								
PBC	0.835	0.635	0.312	0.211	0.140	0.797							
AG	0.838	0.634	0.443	0.205	0.118	0.030	0.796						
DOR	0.932	0.874	-0.239	-0.290	-0.103	-0.117	-0.335	0.935					
DOI	0.890	0.801	-0.265	-0.269	-0.148	0.032	-0.467	0.474	0.895				
COC	0.874	0.777	-0.174	-0.235	-0.032	-0.032	-0.268	0.548	0.443	0.881			
AHL	0.886	0.795	-0.204	-0.162	-0.199	-0.146	-0.293	0.271	0.224	0.319	0.892		
MOL	0.787	0.650	-0.112	-0.119	-0.077	0.060	-0.191	0.413	0.493	0.540	0.283	0.806	
DON	0.850	0.739	-0.008	0.074	0.006	-0.196	0.021	0.145	0.034	0.061	0.350	0.140	0.860

In turn, construct validity was evaluated from the perspectives of convergent and discriminant validity by using the two criteria by Fornell and Larcker (1981). They are both based on the average variance extracted (AVE) of the constructs, which is the average proportion of variance that a construct explains in its indicators. The first criterion concerning convergent validity expects each construct to have an AVE of at least 0.5. This means that, on average, each construct should explain at least half of the variance in its indicators. The AVE of each construct is reported in the second column of Table 2, showing that all the constructs met this criterion. In turn, the second criterion concerning discriminant validity expects each construct to have a square root of AVE that is at least equal to its absolute correlations with the other constructs in the model. This means that, on average, each construct should share at least an equal proportion of variance with its indicators compared to what it shares with the other constructs. The square root of AVE of each construct (on-diagonal) and the correlations between all the constructs in the model (off-diagonal) are reported in the remaining columns of Table 2, showing that this criterion was also met by all the constructs.

4.2 Indicator Reliability and Validity

Indicator reliability and validity were evaluated by using the standardised loadings of the indicators, which are reported in Appendix B together with the means and standard deviations (SD) of the indicator scores as well as the percentages of missing values. In the typical case of each indicator loading on only one construct, the standardised loading of each indicator is commonly expected to be statistically significant and at least 0.707 (Fornell & Larcker, 1981). This is equivalent to the standardised residual of each indicator being at least 0.5, meaning that at least half of the variance in each indicator is explained by the construct on which it loads. As can be seen, this criterion was met by all the indicators except for PBC3. However, because the slightly lower loading of this indicator was not found to compromise the reliability or validity of the perceived behavioural control construct (cf. Section 4.1), we decided to retain it in the model.

4.3 Model Fit and Model Estimates

The results of model estimation in terms of the standardised effect sizes and their statistical significance, the proportions of explained variance (R^2), and model fit are reported in Figure 2 (and in Appendix C for the effects of the control variables). Model fit was evaluated by using the χ^2 test of model fit and four model fit indices recommended by Hu and Bentler (1999): the comparative fit index (CFI), the Tucker-Lewis index (TLI), the root mean square error of approximation (RMSEA), and the standardised root mean square residual (SRMR). Of these, the χ^2 test of model fit rejected the null hypothesis of the model fitting the data, which is common in the case of large samples (Bentler & Bonett, 1980), whereas the values of the four model fit indices all met the cut-off criteria recommended by Hu and Bentler (1999): CFI $\geq$ 0.95, TLI $\geq$ 0.95, RMSEA $\leq$ 0.06, and SRMR $\leq$ 0.08. Thus, we consider the overall fit of the model acceptable. We also found no signs of multicollinearity or common method bias in the model. For example, the variance inflation factor (VIF) values calculated from the factor scores were all less than three (Hair et al., 2018), and the Harman's single factor test (Podsakoff et al., 2003) suggested a very bad fit with the data ($\chi^2(324) = 4{,}754.140$, $p < 0.001$, CFI = 0.261, TLI = 0.199, RMSEA = 0.169, SRMR = 0.147).

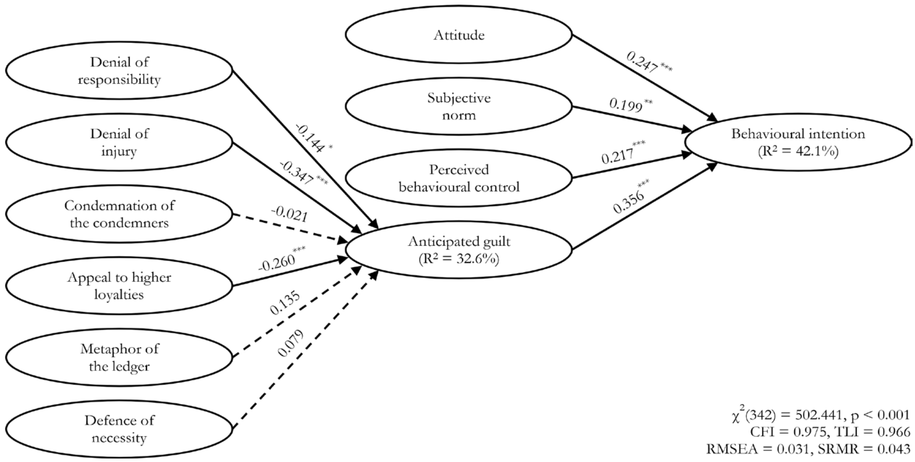

Figure 2: Model fit and model estimates (* = p < 0.001, ** = p < 0.01, * = p < 0.05)**

Of the three original antecedents of TPB, attitude, subjective norm, and perceived behavioural control were all found to have statistically significant and positive effects on responsible online shopping intention. Similarly, the effect of anticipated guilt on responsible online shopping intention was found to be statistically significant, positive, and even slightly stronger than the effects of the three original antecedents of TPB based on the point estimates of the effect sizes reported in Figure 2. However, the overlapping 95% confidence intervals of the estimated effect sizes of attitude ([0.122, 0.372]), subjective norm ([0.070, 0.327]), perceived behavioural control ([0.098, 0.335]), and anticipated guilt ([0.222, 0.489]) suggested that the differences in the strengths of all the effects were statistically not significant. In turn, of the six neutralisation techniques, the denial of responsibility, the denial of injury, and the appeal to higher loyalties were found to have statistically significant and negative effects on anticipated guilt, whereas the effects of the condemnation of the condemners, the metaphor of the ledger, and the defence of necessity were found to be statistically not significant. The effects of the control variables were found to be mostly statistically not significant, with the exception that age was found to have a statistically significant and negative effect on responsible online shopping intention and being a man was found to have a statistically significant and negative effect on anticipated guilt. In total, the model was able to explain 42.1% of the variance in responsible online shopping intention and 32.6% of the variance in anticipated guilt. Without anticipated guilt, the model would have been able to explain only 35.3% of the variance in responsible online shopping intention, so its addition resulted in a 6.8 percentage point promotion in explanatory power.

5 Discussion and Conclusion

In this study, we examined the role of anticipated guilt in explaining responsible online shopping intention by focusing on answering two research questions: (1) how strong an antecedent of responsible online shopping intention is anticipated guilt in relation to other potential antecedents and (2) how efficiently can consumers regulate their resulting feelings of guilt by using different kinds of neutralisation techniques? In terms of the first research question, we found that anticipated guilt is indeed a strong antecedent of responsible online shopping intention, although not necessarily stronger than the three original antecedents of TPB. However, its addition to the research model was able to substantially promote explanatory power in comparison to the basic TPB model, thus highlighting the role of anticipated guilt as an important additional antecedent of responsible online shopping intention. This promotion was consistent with the meta-analysis by Rivis et al. (2009), which found that adding different types of anticipated affect as an additional antecedent in the basic TPB model tends to promote the explained variance in behavioural intention by about five percentage points.

In terms of the second research question, we found that neutralisation techniques are indeed an efficient way for consumers to regulate their feelings of guilt that result from not engaging in responsible online shopping. In total, the six neutralisation techniques in the research model were able to explain almost one-third of the variation in anticipated guilt, which can be seen as a substantial proportion, especially when considering that the neutralisation techniques are not assumed to act as the main antecedents of anticipated guilt but only to regulate the feelings of guilt that are caused by other antecedents, such as the dissonance between behavioural norms and one's behaviour. Of these six neutralisation techniques, the most efficient ones were found to be the denial of responsibility, the denial of injury, and the appeal to higher loyalties. In other words, consumers can most effectively regulate their feelings of guilt that result from not engaging in responsible online shopping by justifying their behaviour with the fact that they cannot really change anything with their own consumption choices alone, that this does not cause actual injury to anybody, and that they have to consider also other values or criteria (e.g., price) when making their consumption choices. Of these, especially the last justification seemed to be used very often by consumers based on the high mean scores of the corresponding indicators reported in Appendix B. When comparing these findings with those of prior studies that have examined the effectiveness of individual neutralisation techniques, they seem to support the suggestion by Silic et al. (2017) that the effectiveness of specific neutralisation techniques varies considerably between contexts. For example, Silic et al. (2017) found the metaphor of the ledger to be the only neutralisation technique that affects the use intention and actual use of shadow IT, whereas Siponen et al. (2012) found the condemnation of the condemners and the appeal to higher loyalties to be the only two neutralisation techniques that affect software piracy intention. These are both very different findings from those of our study.

From a theoretical perspective, this study makes three main contributions. First, from the perspective of responsible consumption, the study promotes a more holistic understanding of the antecedents of responsible online shopping, in this case particularly anticipated guilt and the regulation of the feelings of guilt by using different kinds of neutralisation techniques. Second, from the perspective of TPB, the study responds to the calls by Richard et al. (1996) and Rivis et al. (2009) for more research on the role of different types of anticipated affect as additional antecedents for explaining behavioural intention and actual behaviour. Third, from the perspective of the neutralisation theory, the study continues the work of Chatzidakis et al. (2007) as well as Gruber and Schlegelmilch (2014) concerning the application of neutralisation techniques to explain responsible and sustainable consumption as well as the integration of neutralisation techniques with other prominent theories for explaining human behaviour, such as TPB.

In turn, from a practical perspective, the main contribution of the study is the implication that the most efficient way for businesses and society to promote responsible online shopping is not only to manipulate the attitudes, subjective norms, and perceived behavioural control of consumers but also to expose them to stronger feelings of guilt. This may be achieved not only by using different kinds of guilt appeals in consumer communication (cf. Turner & Rains, 2021) but also by restraining the use of different kinds of neutralisation techniques among consumers. Here, the most relevant neutralisation techniques are obviously the denial of responsibility, the denial of injury, and the appeal to higher loyalties, which were found to be the most effective ones in our study. Of these, the use of the first two neutralisation techniques may potentially be restrained, for example, by providing consumers with more metrics on both the positive and the negative consequences of their consumption choices. This could help consumers to perceive that even the consumption choices of one person do have measurable consequences, thus undermining the main arguments behind the denial of responsibility and injury. These metrics could also be further coupled with goal setting, which together were found to result in an even stronger promotion of sustainable online shopping in the study by Kanay et al. (2021). In turn, the use of the appeal to higher loyalties may potentially be restrained by making responsible consumption choices more affordable or otherwise more accessible to average consumers. This way consumers would not be forced to choose between responsibility and other values or priorities, such as providing for one's family by choosing a cheaper but less responsible product or service, thus once again undermining the main argument behind this neutralisation technique.

6 Limitations and Future Research

We see this study to have three main limitations. First, although our sample was relatively heterogenous in demographic terms, it was biased toward women and younger consumers, which may limit the generalisability of our findings. Second, our research model focused only on the role of anticipated guilt as an antecedent of responsible online shopping intention and not, for example, on the potential cross-over effects between attitude, subjective norm, perceived behavioural control, and anticipated guilt, which have been proposed in some prior studies (e.g., Onwezen et al., 2013, 2014a, 2014b; Turel, 2016), or on the effects of anticipated guilt on actual responsible online shopping behaviour. Third, of the different neutralisation techniques, our research model focused only on the six neutralisation techniques that have been used also in the studies by Siponen and Vance (2010), Silic et al. (2017), and Lin et al. (2018) instead of others, such as the claim of relative acceptability and the claim of individuality by Henry and Eaton (1999), justification by comparison by Cromwell and Thurman (2003), and the claim of entitlement by Coleman (2005). Both these two latter limitations cannot be seen to compromise the findings of this study per se. However, addressing them could help to provide an even more complete understanding of the role of anticipated guilt and neutralisation techniques in explaining responsible online shopping. In addition to addressing the aforementioned limitations, future research could focus on examining responsible online shopping in some more specific product or service contexts instead of only in general. One example of such context is fashion retailing, on which some prior research has already been conducted (e.g., Kemppainen et al., 2021, 2022). Other potential paths for future research could be to examine also the role of other types of anticipated affect, such as anticipated anxiety, shame, and worry (cf. Rivis et al., 2009), the role of positive and negative emotions more generally (e.g., Makkonen et al., 2019b), or the role individual values (e.g., Makkonen et al., 2019a) in explaining responsible online shopping.

References

Ajzen, I. (1985). From intentions to actions: A theory of planned behavior. In J. Kuhl & J. Beckman (Eds.), Action Control: From Cognition to Behavior (pp. 11–39). Heidelberg, Germany: Springer.

Ajzen, I. (1991). The theory of planned behavior. Organizational Behavior and Human Decision Processes, 50(2), 179–211.

Ajzen, I., & Fishbein, M. (1980). Understanding Attitudes and Predicting Social Behavior, Englewood Cliffs, NJ: Prentice-Hall.

Antonetti, P., & Baines, P. (2015). Guilt in marketing research: An elicitation–consumption perspective and research agenda. International Journal of Management Reviews, 17(3), 333–355.

Antonetti, P., & Maklan, S. (2014a). Exploring postconsumption guilt and pride in the context of sustainability. Psychology & Marketing, 31(9), 717–735.

Antonetti, P., & Maklan, S. (2014b). Feelings that make a difference: How guilt and pride convince consumers of the effectiveness of sustainable consumption choices. Journal of Business Ethics, 124(1), 117–134.

Bentler, P. M., & Bonett, D. G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. Psychological Bulletin, 88(3), 588–606.

Chatzidakis, A., Hibbert, S., & Smith, A. P. (2007). Why people don't take their concerns about fair trade to the supermarket: The role of neutralisation. Journal of Business Ethics, 74(1), 89–100.

Coleman, J. W. (2005). The Criminal Elite: Understanding White-Collar Crime (6th ed.). New York, NY: Worth Publishers.

Cromwell, P., & Thurman, Q. (2003). The devil made me do it: Use of neutralizations by shoplifters. Deviant Behavior, 24(6), 535–550.

Fishbein, M., & Ajzen, I. (1975). Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research. Reading, MA: Addison-Wesley.

Fishbein, M., & Ajzen, I. (2010). Predicting and Changing Behavior: The Reasoned Action Approach. New York, NY: Psychology Press.

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. Journal of Marketing Research, 18(1), 39–50.

Gefen, D., Rigdon, E. E., & Straub, D. (2011). Editor's comments: An update and extension to SEM guidelines for administrative and social science research. MIS Quarterly, 35(2), iii–xiv.

Gruber, V., & Schlegelmilch, B. B. (2014). How techniques of neutralization legitimize norm- and attitude-inconsistent consumer behavior. Journal of Business Ethics, 121(1), 29–45.

Gupta, S., & Agrawal, R. (2018). Environmentally responsible consumption: Construct definition, scale development, and validation. Corporate Social Responsibility and Environmental Management, 25(4), 523–536.

Hair, J. F., Jr., Black, W. C., Babin, B. J., & Anderson, R. E. (2018). Multivariate Data Analysis (8th ed.). Andover, United Kingdom: Cengage.

Han, T.-I., & Stoel, L. (2017). Explaining socially responsible consumer behavior: A meta-analytic review of theory of planned behavior. Journal of International Consumer Marketing, 29(2), 91–103.

Henry, S., & Eaton, R. (1999). Degrees of Deviance: Student Accounts of Their Deviant Behavior (2nd ed.). Salem, WI: Sheffield Publishing.

Hu, L.-t., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling, 6(1), 1–55.

Jain, V. K., Dahiya, A., Tyagi, V., & Sharma, P. (2022). Development and validation of scale to measure responsible consumption. Asia-Pacific Journal of Business Administration.

Kanay, A., Hilton, D., Charalambides, L., Corrégé, J. B., Inaudi, E., Waroquier, L., & Cézéra, S. (2021). Making the carbon basket count: Goal setting promotes sustainable consumption in a simulated online supermarket. Journal of Economic Psychology, 83, 102348.

Kari, T., & Makkonen, M. (2014). Explaining the usage intentions of exergames. In Proceedings of the 35th International Conference on Information Systems. Atlanta, GA: Association for Information Systems.

Kemppainen, T., Frank, L., & Luhtanen, V. (2022). What is meaningful for responsible shoppers in online fashion retail? In P. Bednar, A. S. Islind, H. Vallo Hult, A. Nolte, M. Rajanen, F. Zaghloul, A. Ravarini & A. M. Braccin (Eds.), Proceedings of the 8th International Workshop on Socio-Technical Perspective in IS Development. CEUR Workshop Proceedings 3239.

Kemppainen, T., Frank, L., Makkonen, M., & Hyvönen, O.-I. (2021). Barriers to responsible consumption in e-commerce: Evidence from fashion shoppers. In A. Pucihar, M. Kljajić Borštnar, R. Bons, H. Cripps, A. Sheombar & D. Vidmar (Eds.), Proceedings of the 34th Bled eConference (pp. 323–335). Maribor, Slovenia: University of Maribor Press.

Klockars, C. B. (1974). The Professional Fence. New York, NY: Free Press.

Kugler, K., & Jones, W. H. (1992). On conceptualizing and assessing guilt. Journal of Personality and Social Psychology, 62(2), 318–327.

Kuokkanen, H. (2017). Fictitious consumer responsibility? Quantifying social desirability bias in corporate social responsibility surveys. Palgrave Communications, 3, 16106.

Lin, T.-C., Hsu, J. S.-C., Wang, Y.-C., & Wu, S. (2018). Examining the antecedents of employee unauthorized computer access. Journal of Statistics & Management Systems, 21(3), 493–517.

Lindenmeier, J., Lwin, M., Andersch, H., Phau, I., & Seemann, A.-K. (2017). Anticipated consumer guilt: An investigation into its antecedents and consequences for fair-trade consumption. Journal of Macromarketing, 37(4), 444–459.

Makkonen, M., Frank, L., Kari, T., & Moilanen, P. (2012a). Examining the usage intentions of exercise monitoring devices: The usage of pedometers and route trackers in Finland. In U. Lechner, D. Wigand & A. Pucihar (Eds.), Proceedings of the 25th Bled eConference (pp. 439–453). Kranj, Slovenia: Moderna organizacija.

Makkonen, M., Frank, L., Kari, T., & Moilanen, P. (2012b). Explaining the usage intentions of exercise monitoring devices: The usage of heart rate monitors in Finland. In Proceedings of the 18th Americas Conference on Information Systems. Atlanta, GA: Association for Information Systems.

Makkonen, M., Frank, L., & Kemppainen, T. (2019a). The effects of individual values on online shopping spending. In A. Pucihar, M. Kljajić Borštnar, R. Bons, J. Seitz, H. Cripps & D. Vidmar (Eds.), Proceedings of the 32nd Bled eConference (pp. 969–994). Maribor, Slovenia: University of Maribor Press.

Makkonen, M., Halttunen, V., & Frank, L. (2010). Applying the theory of planned behaviour to explain the usage intentions of music download stores: Gender and age differences. In P. Kommers, T. Issa & P. Isaías (Eds.), Proceedings of the IADIS International Conference on Internet Technologies & Society 2010 (pp. 22–32). IADIS Press.

Makkonen, M., Riekkinen, J., Frank, L., & Jussila, J. (2019b). The effects of positive and negative emotions during online shopping episodes on consumer satisfaction, repurchase intention, and recommendation intention. In A. Pucihar, M. Kljajić Borštnar, R. Bons, J. Seitz, H. Cripps &

D. Vidmar (Eds.), Proceedings of the 32nd Bled eConference (pp. 931–953). Maribor, Slovenia: University of Maribor Press.

McGregor, S. L. T. (2008). Conceptualizing immoral and unethical consumption using neutralization theory. Family and Consumer Sciences Research Journal, 36(3), 261–276.

Minor, W. W. (1981). Techniques of neutralization: A reconceptualization and empirical examination. Journal of Research in Crime and Delinquency, 18(2), 295–318.

Muthén, L. K., & Muthén, B. O. (2023). Mplus Home Page. Available at https://www.statmodel.com

Nunnally, J. C., & Bernstein, I. H. (1994). Psychometric Theory (3rd ed.). New York, NY: McGraw-Hill.

Onwezen, M. C., Antonides, G., & Bartels, J. (2013). The Norm Activation Model: An exploration of the functions of anticipated pride and guilt in pro-environmental behaviour. Journal of Economic Psychology, 39, 141–153.

Onwezen, M. C., Bartels, J., & Antonides, G. (2014a). Environmentally friendly consumer choices: Cultural differences in the self-regulatory function of anticipated pride and guilt. Journal of Environmental Psychology, 40, 239–248.

Onwezen, M. C., Bartels, J., & Antonides, G. (2014b). The self-regulatory function of anticipated pride and guilt in a sustainable and healthy consumption context. European Journal of Social Psychology, 44(1), 53–68.

Pavlou, P. A., & Fygenson, M. (2006). Understanding and predicting electronic commerce adoption: An extension of the theory of planned behavior. MIS Quarterly, 30(1), 115–143.

Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. Journal of Applied Psychology, 88(5), 879–903.

Rawlings, E. I. (1970). Reactive guilt and anticipatory guilt in altruistic behavior. In J. Macaulay & L. Berkowitz (Eds.), Altruism and Helping Behavior (pp. 163–177). New York, NY: Academic Press.

Richard, R., van der Pligt, J., & de Vries, N. (1996). Anticipated affect and behavioral choice. Basic and Applied Social Psychology, 18(2), 111–129.

Riekkinen, J. (2018). Streaming Era Digital Media Piracy: An Integration of Three Theoretical Perspectives (Doctoral dissertation, University of Jyväskylä). Jyväskylä Studies in Computing 277.

Rivis, A., Sheeran, P., & Armitage, C. J. (2009). Expanding the affective and normative components of the theory of planned behavior: A meta-analysis of anticipated affect and moral norms. Journal of Applied Social Psychology, 39(12), 2985–3019.

Silic, M., Barlow, J. B., & Back, A. (2017). A new perspective on neutralization and deterrence: Predicting shadow IT usage. Information & Management, 54(8), 1023–1037.

Siponen, M., & Vance, A. (2010). Neutralization: New insights into the problem of employee information systems security policy violations. MIS Quarterly, 34(3), 487–502.

Siponen, M., Vance, A., & Willison, R. (2012). New insights into the problem of software piracy: The effects of neutralization, shame, and moral beliefs. Information & Management, 49(7–8), 334–341.

Strutton, D., Vitell, S. J., & Pelton, L. E. (1994). How consumers may justify inappropriate behavior in market settings: An application on the techniques of neutralization. Journal of Business Research, 30(3), 253–260.

Sykes, G. M., & Matza, D. (1957). Techniques of neutralization: A theory of delinquency. American Sociological Review, 22(6), 664–670.

Theotokis, A., & Manganari, E. (2015). The impact of choice architecture on sustainable consumer behavior: The role of guilt. Journal of Business Ethics, 131(2), 423–437.

Turel, O. (2016). Untangling the complex role of guilt in rational decisions to discontinue the use of a hedonic information system. European Journal of Information Systems, 25(5), 432–447.

Turner, M., & Rains, S. (2021). Guilt appeals in persuasive communication: A meta-analytic review. Communication Studies, 72(4), 684–700.

Ulusoy, E. (2016). Experiential responsible consumption. Journal of Business Research, 69(1), 284–297.

United Nations (1987). Report of the World Commission on Environment and Development: Our Common Future. Available at https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

Webb, D. J., Mohr, L. A., & Harris, K. E. (2008). A re-examination of socially responsible consumption and its measurement. Journal of Business Research, 61(2), 91–98.

Weigel, F. K., Hazen, B. T., Cegielski, C. G., & Hall, D. J. (2014). Diffusion of innovations and the theory of planned behavior in information systems research: A meta-analysis. Communications of the Association for Information Systems, 34(1), 31.

Yang, S., Li, L., & Zhang, J. (2018). Understanding consumers' sustainable consumption intention at China's Double-11 online shopping festival: An extended theory of planned behavior model. Sustainability, 10(6), 1801.

Appendix A: Item Wordings

Item	Wording
BI1	In future, I intend to make responsible choices when shopping online.
BI2	In future, I plan to make responsible choices when shopping online.
BI3	In future, I will make responsible choices when shopping online.
SN1	People who are important to me think that I should make responsible choices when shopping online.
SN2	People who are important to me think that it would be good if I made responsible choices when shopping online.
SN3	People who are important to me would want that I make responsible choices when shopping online.
PBC1	If I want to, it is possible for me to make responsible choices when shopping online.
PBC2	I am able to make responsible choices when shopping online if I want to.
PBC3	It is up to me whether or not I make responsible choices online when shopping online.
	I find the idea of me making responsible choices when shopping online…
ATT1	… negative vs. positive.
ATT2	… harmful vs. beneficial.
ATT3	… unpleasant vs. pleasant.
	If I do not make responsible consumption choices when shopping online, I feel…
AG1	… guilty.
AG2	… remorseful.
AG3	… bad.
	I find that is OK for me not to make responsible consumption choices when shopping online because…
DOR1	… one person cannot really trigger any change with his or her choices.
DOR2	… one person cannot really change anything with his or her choices.
DOI1	… it causes no actual harm to anybody.
DOI2	… it caused no actual damage to anybody.
COC1	… people who call for responsibility from others sometimes do the same.
COC2	… people who call for responsibility from others do not always themselves make responsible choices.
AHL1	… I have to consider also other values or criteria (e.g., price) when making my choices.
AHL2	… I have to take into account also other values or criteria (e.g., price) when making my choices.
MOL1	… I have already made enough responsible choices earlier in my life.
MOL2	… the responsible choices that I have made earlier in my life compensate for it.
DON1	… the lack of responsible alternatives sometimes makes it necessary.
DON2	… responsible alternatives are not always available.

Appendix B: Indicator-Level Statistics

Item	Mean	SD	Missing	Loading	Item	Mean	SD	Missing	Loading
BI1	4.232	0.807	2.7%	0.935***	**DOR1**	2.160	1.176	0.8%	0.919***
BI2	4.292	0.862	1.5%	0.855***	**DOR2**	2.101	1.134	0.6%	0.950***
BI3	4.195	0.792	3.8%	0.869***	**DOI1**	1.886	0.983	0.8%	0.861***
ATT1	2.385	0.970	1.3%	0.807***	**DOI2**	1.943	1.007	1.0%	0.928***
ATT2	2.316	1.070	1.7%	0.760***	**COC1**	2.629	1.239	6.7%	0.830***
ATT3	1.928	1.275	1.7%	0.790***	**COC2**	2.456	1.219	4.4%	0.930***
SN1	3.558	1.067	15.4%	0.911***	**AHL1**	4.326	0.790	0.6%	0.911***
SN2	3.777	1.021	13.8%	0.910***	**AHL2**	4.224	0.878	0.4%	0.872***
SN3	3.640	1.046	17.1%	0.928***	**MOL1**	2.025	1.019	1.3%	0.763***
PBC1	4.102	0.953	1.7%	0.855***	**MOL2**	1.834	0.969	0.6%	0.847***
PBC2	4.054	0.960	2.5%	0.901***	**DON1**	4.025	0.985	1.3%	0.863***
PBC3	3.996	1.006	0.8%	0.601***	**DON2**	4.032	1.004	1.9%	0.856***
AG1	3.504	1.215	2.7%	0.858***					
AG2	3.104	1.185	3.3%	0.722***					
AG3	3.305	1.255	2.9%	0.802***					

*** = $p < 0.001$

Appendix C: Effects of the Control Variables

Variable	BI	AG	Variable	BI	AG
Gender = man	-0.011	-0.180***	Age	-0.080*	-0.090
Gender = other	-0.058	0.010	Social desirability bias	0.074	-0.015

*** = $p < 0.001$, ** = $p < 0.01$, * = $p < 0.05$

Conceptualizing Information Systems as Biological Ecosystems - A ”New” Vocabulary for Speaking of Information Systems

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Biological ecosystems and related concepts are well known and have been used for a long time, also outside of the ecology context. In this conceptual paper, we explore the use of biological ecosystem concepts as a new lens to understand and analyze information systems. We propose that applying a frame of reference from a different discipline enriches information systems analysis in several ways, firstly through broadening the perspective of information systems, secondly by offering connections to phenomena and areas that were previously outside of the scope of the information system, and lastly through offering a new viewpoint on actors, roles and functions within an information system. Further research is needed to deepen our understanding of the information system ecosystem and apply this approach to other business activities.

Keywords:
biological ecosystem, ecosystem, information system, information system ecosystem, socio-technical system

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1 Introduction

Digital transformation represents a new chapter in the human-technology relationship, disrupting traditional structures, logics and models (McAfee & Brynjolfsson, 2017). One example of such changed logics and models are internet enabled platforms where companies leverage digital technologies and collaborate in order to create and deliver an increased value proposition (Cusumano et al., 2019; Libert et al., 2016; Parker et al., 2016). Such platforms are often described as digitally enabled ecosystems inhabited by people, organizations and resources (Parker et al., 2016; Fehrer et al., 2018). At the core of platform business models are information systems.

As information systems are very much a prerequisite and backbone of the ongoing digital transformation of organizations and society, their role and the way we think about them have not been excluded from being challenged, on the contrary. This has initiated a call from the information systems research community for a new or extended vocabulary in order to gain a richer understanding (Nischak et al., 2017; Benedict, 2018; Guggenberger et al., 2020). Alongside of the digital transformation, however not dependent on it, a discussion about ecosystems as a framework of understanding complex phenomena has emerged. This is very much related to an increased conversation on ecosystems from a biology and ecology perspective as climate issues have become more and more visible and critical. Ecosystem is about seeing wholeness and the term was originally coined by the English botanist Arthur G. Tansley (e.g., Tansley, 1935; Tansley, 1939) after suggestions from A. R. Clapham (Willis, 1997, p. 268). The concept of ecosystem has subsequently been developed and applied also in other fields outside of ecology. According to Adner (2017, p. 40) ecosystems can be explained as "the alignment structure of the multilateral set of partners that need to interact in order to focal value propositions to materialize". The use of the ecosystem concept within information systems research has increased over the years and several authors have stressed the ambiguity of the concept seeking to provide theoretical synthesis in order to increase relevance (Nischak et al., 2017; Benedict, 2018; Guggenberger et al., 2020).

The purpose of this paper is to explore the concept of information systems through the lens of biological ecosystems, in order to gain a richer picture of information systems as well as to contribute to the understanding of how biological ecosystems can be used as a blueprint to understand complex phenomena. We explore how concepts from biological ecosystems can be applied to the analysis of information systems, focusing on concepts describing ecosystem actors, environment and presumptions. Our proposed contribution is conceptual. More specifically, we aim at offering an alternative view; "to see something that has been identified in a new way", called *revising* by MacInnis (2011, p 138). MacInnis uses the metaphor of a person turning a kaleidoscope to reveal new perspectives to describe conceptual work of this type: we use a different frame of reference and view on a previously identified phenomenon. To do this, MacInnis suggests researchers can make use of novel metaphors – in our case biological ecosystem metaphors – and to seek new vantage points from other disciplines. Our work can also be understood through a design science lens. March and Smith (1995) state that constructs or concepts are one possible type of output or artifact from design science. The authors emphasize the importance and impact of terminology as tools for describing and thinking in a field. Hevner et al. (2004) outline seven guidelines for the design science research process. In line with these guidelines and within the scope of this article, we present a novel conceptualization, argue the relevance and contribution of our proposed vocabulary, offer a descriptive evaluation of it, and suggest steps for further research.

2 Ecosystems in business and information systems literature

Research has linked various aspects of biological and ecological theories to business contexts in various settings to compare, analyze and shed new light on current practices and business theories. Most frequently it has its ground in using the biological ecosystem as a metaphor or analogy to other contexts. Biological ecosystems and evolutionary perspectives in business studies have focused on innovation, entrepreneurial, knowledge, organizational, and industrial ecosystems (e.g., Ghazinoory et al., 2021; Kuckertz, 2019; Pilinkienė & Mačiulis, 2014; Blijleven et al., 2013). A heap of research has been made synthesizing innovation ecosystems and its analogy to biological ecosystems or ecology theories (Shaw and Allen, 2018; Geng and Côté, 2002). Mars et al. (2012) states that the ecosystem metaphor "is a useful tool for understanding and predicting the conditions that shape and influence organizational systems." (p. 279). Criticism towards using the term eco in innovation ecosystems has been voiced e.g. by Oh et al. (2016), where a flawed analogy to the biological ecosystem is debated. The dangers of using the analogy for innovation research is that the ecosystems are designed rather than evolved in this case, and include a variety of definitions and variations that may confuse. Ritala and

Almpanopoulou (2017) instead defend the analogy and discuss some of the critique by Oh et al. (2016) suggesting that the term may be needed in understanding theory and practice. McMullen (2018) did a thought-experiment by deconstructing certain concepts in business and compared it to biological terms to shed new light on hybrid organizations. Some research has also focused on how business innovation ecosystems co-evolve and the role innovation has in them (Breslin et al., 2021), or looked at symbiotic relationships (Yoon et al., 2022). In the digital realm where other rules reign, problematization and discussion of the view of ecosystems has occurred (Márton, 2022). Briscoe and De Wilde (2009) imply that a digital ecosystem is to be regarded as a digital counterpart of biological ecosystems. They describe digital ecosystems as software systems that are robust, scalable, and self-organizing to meet users' demand for digital services. Romero and Vernadat (2016) emphasize that an Executive Information System (EIS) contains a digital ecosystem where many information systems, sometimes hundreds, are included. There are several publications on ecosystems with a focus on information systems, information technology and information communication technology (ICT) (e.g. Anjum, 2023; Bash et al., 2008; Basole et al., 2015; Brummermann et al., 2011; Brummermann et al., 2012; Chamberlain & Said, 2022; Changjun & Hongbum, 2018; Diga & May, 2016; Karl et al., 2020; Schramm et al., 2012). While the ecosystem concept is commonly used, definitions vary greatly and are not established.

3 Information systems and biological ecosystems

3.1 Information systems as socio-technical systems and core concepts

Information systems collect, process, store and share information in order to support decision making and purposeful action in organizations. Information systems are frequently characterized as socio-technical systems consisting of technology and data (the technical sub-system), people and processes/tasks (the social sub-system); these separate components interact and together form a complex system (Figure 1). The socio-technical perspective enables a more nuanced understanding of both possibilities and problems surrounding organizational technology use. For example, investments into IT frequently fail. The reasons behind failure can be organizational or social rather than technical, or the reasons might be entanglements of technical and social reasons; socio-technical thinking is a useful framework for analysis in this context (Baxter and Sommerville, 2011). When working with complex real-world systems, using socio-technical approaches instead of traditional systems development methodologies is necessary (Wu et al., 2015). For actionable insights, socio-technical systems need to be modelled which has proven difficult due to e.g. the complexity of the systems, and the inter-disciplinary nature of socio-technical systems leading to a scattered research field. Consequently, methods for socio-technical analysis remain immature (ibid.) and central concepts underdeveloped (Millerand and Baker, 2010).

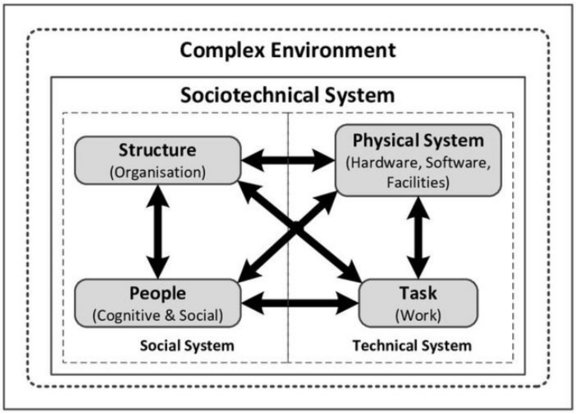

Figure 1: Sociotechnical system
Source: (Oosthuizen & Pretorious, 2016)

For example, when discussing the People component of socio-technical systems, the concept user is an established term to describe the individual who is making use of the system. The user concept has, however, been criticized e.g. for being narrow and simplistic, and for creating an artificial separation between users and developers (Lamb & Kling, 2003; Millerand & Baker, 2010). Within the Work System Framework, instead of 'users', the concepts of participants and customers are used to describe the people working with the system (Alter, 2004). Participants encompass those individuals who perform at least part of the target business process, and customers are people who receive benefit from the products or services produced. In another twist, Actor-Network theory makes use of the concepts actor and actant to denote both human and non-human elements participating in a network (Hanseth et al., 2004). In other words, by using different concepts and definitions for the people involved with the information system, we can examine the same phenomena from different viewpoints and gain new understanding. Hence, in section 4 of this paper we explore how concepts derived from biological ecosystems can be applied to information systems in order to gain novel insight. In the following section we overview a selection of biological ecosystem concepts.

3.2 Biological ecosystems and core concepts

In biology, an ecosystem includes all living things with their habitat within an area. An ecosystem has properties of self-organization, scalability, and sustainability. An ecosystem is self-regulating and consists of independent actors with selfish interests acting in an overall functioning environment. In addition to its internal integrity, an ecosystem can be affected by external factors. The word ecosystem consists of the two concepts ecology and system. Ecology, a nomenclature, includes an interaction between what lives, i.e., the biotic, and the non-living, i.e., the abiotic. A system is several parts that are connected to each other and that together form an ordered whole. In summary, the biological ecosystem consists of a biotic component, containing Organism and Function, and an abiotic component, containing Presumption and Habitat. The two components have interaction both between and within, furthermore they occupy a physical space (e.g., NE, 2023; Adner, 2017; Dhillon et al., 2013; Guggenberger et al., 2020; Nischak et al., 2017; Transley, 1939; Willis, 1997). There are different ways to describe the next order of principles in the biological ecosystem, one way is shown in figure 2. To clarify the meanings and content of an ecosystem, the Baltic Sea ecosystem is presented below.

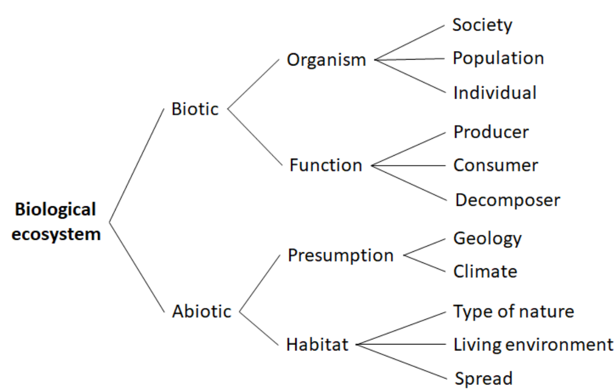

Figure 2: Principles of a biological ecosystems top three levels

The notion Biotic means living and can be divided into society, population and individual. A society contains all populations of different living species within a geographic area. In our example the society is all living species inhabiting the Baltic Sea. A population is a group of individuals belonging to the same species, living in the same area and interacting with each other. An example of a population in the Baltic Sea is a shoal of Baltic cods. An individual is the individual animal, for example an individual Baltic cod.

Organisms in an ecosystem can perform the functions or roles of producer, consumer and decomposer. These functions are key enablers for the circulation of energy within the ecosystem. A producer can, e.g., by using photosynthesis, transform energy into food, both for themselves, and for other organisms. In the Baltic Sea ecosystem, planktonic algae act as primary producers (John Nurminen Foundation, n.d.). Consumers are the animals and fungi that cannot produce their own food. The Baltic cod is a consumer in the Baltic Sea ecosystem. Decomposers break down dead plants and animals, and release energy back into circulation. Main decomposers in the Baltic Sea are various aerobic and anaerobic bacteria (Furman et al., n.d.).

Abiotic means nonliving and is dependent on Geology and Climate. In the Baltic Sea ecosystem, the abiotic are for example seabed, water and seacoast. Geology deals with the outer covering of the planet earth (the Lithosphere i.e., the earth's crust with the upper mantle). This casing covers soils and how they are composed and structured, to which over time is added development. Here it is possible to present stones, bedrock, sand and mud to mention a few.

Climate controls the weather and is a combination of physical average atmospheric conditions over a longer period for a geographic area. This includes, e.g. humidity, temperature and wind. The climate is naturally affected by e.g., the sun's radiation and the tilt of the earth's axis. It is also affected by human activities such as emissions of greenhouse gases and deforestation. A warmer climate leads, among other things, to increased water levels, stronger storms, and changing seasons.

A nature type has common flora and fauna within a geographically defined area. Examples of Swedish nature types are deciduous forest, coniferous forest, and mountains. The Baltic cod lives in brackish water. The biological habitat is the sum of the external circumstances that an individual needs in order to survive. The habitat for the Baltic cod is overfertilized, contains environmental toxins and suffers from overfishing of e.g., Baltic Herring. Spread is the geographical area within which a species is found; the Baltic cod exists only in the Baltic Sea.

4 Information systems as ecosystems

Considering the concepts of information systems and biological ecosystems side by side, some similarities emerge. Both information systems and biological ecosystems are inherently complex and challenging to understand. Information systems consist of multiple layers of technology, people and social structures, and biological ecosystems consist of multiple species and environmental factors. Changes in any of the separate components of the biological ecosystem or the information system impacts all parts of the system. Furthermore, the flow, exchange and transformation of energy is the focal function of an ecosystem - the flow, exchange and transformation (or refining) of data is central to the information system. Some concepts originating from biological ecosystems are already used in discussing information systems, especially holistic, behavioral concepts such as feedback loops, equifinality and adaptability. Even so, some authors suggest that the information systems discipline has done too little to understand the system nature of information systems, and in practice too often focusing on the technology as a tool (Alter, 2004). We suggest the use of ecosystems concepts by adapting terminology describing organisms, functions, presumptions and habitats as outlined in figure 2 to the information system. As a practical illustration we describe the concepts in the context of how the Ladok system is used by Linnaeus university in Sweden. Ladok (2023) is a Swedish national system that provides 40 Swedish universities with support in the study administrative work and is used by students, teachers and administrators. Ladok is used to store information about students' attendance, results and other data (Ladok, 2023).

The division made within ecosystems theory between biotic and abiotic subsystems bears a resemblance to the division often made within socio-technical systems and its social and technical subsystems, the biotic component corresponding to the social, and abiotic corresponding to the technical subsystem. Taking the analogy further, we explore the use of the biotic components organism and function and the abiotic components presumption and habitat to describe and understand an information system (Figure 3). Doing this, a new, enriched picture of the information system emerges, distinct from and complementary to previous socio-technical and system modelling approaches. We propose using the term organism in order to depict the character and nature of stakeholders/actors that use, contribute, as well as benefit from the data provided by the information system. When viewing Ladok through this lens, we can identify individual stakeholders, such as university teachers using the system to enter grades; intra-organizational stakeholders such as different faculty departments and educational programs using the system in order to achieve organizational goals; inter-organizational stakeholders such as funding and accreditation bodies using data from the system in order to validate and ensure quality.

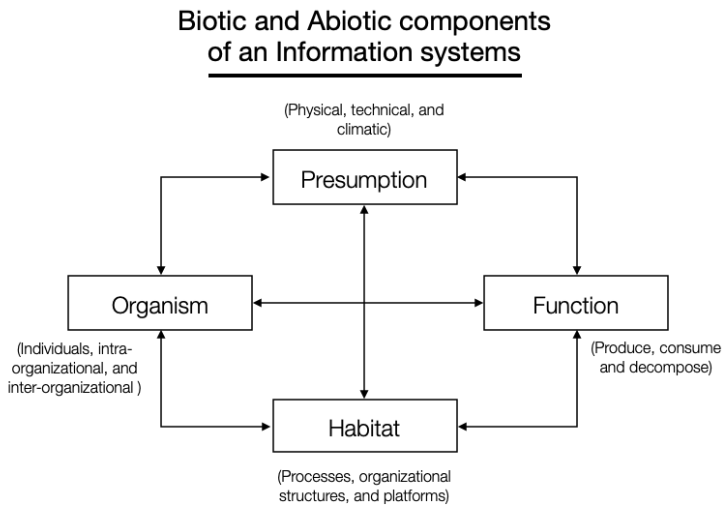

Figure 3: Components of the biotic and abiotic subsystems

The function component is defined as the activity areas or roles enabling the flow of data within the information system and consists of the activity roles: producer, consumer and decomposer. The activity role of producer depicts and concerns how data is put into the system; the activity role of consumer depicts how data is extracted from the system and presented; the activity role of decomposer depicts how existing data is refined, mined, combined and analyzed in ways that enable new understanding. The different stakeholders identified within the organism component each, concurrently or at different times, could hold the different roles of producer, consumer or decomposer of data. For example, an individual teacher is both a producer of data when registering course grades, and a consumer of data when accessing student course registrations ahead of an upcoming course. The biotic components of an information system provide a greater understanding of the who (organism) and why (functions) of information systems. Turning to the abiotic subsystem, here we investigate the conditions under which the information system operates. The presumption component consists of geology and climate and depict physical, technical and climactic aspects affecting the flow and use of data in the information system. Geology of the information system refers to the tangible infrastructural and technical aspects necessary for the information system to function, such as network infrastructure, hardware and software. Climate, on the other hand, refers to both tangible aspects (e.g. boundaries set by government, industry and organizational regulations and guidelines), as well as intangible aspects (e.g. strategies and culture on both an organizational and national level).

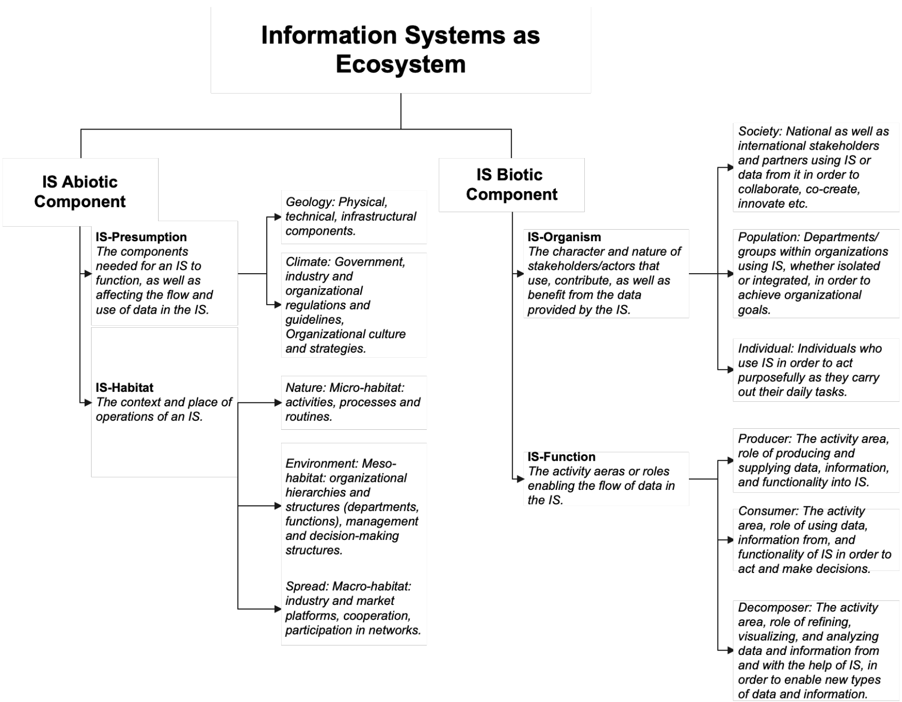

Figure 4: Principles of information system as an ecosystem, top three levels

The habitat component depicts the environments which constitute the context and place of operations of an information system. Firstly, there is the micro-habitat (type of nature) which constitutes organizational processes, routines, and activities where the information system is intended to provide support and be used. Information systems are typically used with the purpose to enforce, improve, or automate processes, related to the previously mentioned functions of producing, consuming, and decomposing data. In the Ladok example, there are the processes related to gathering and storing student credit data. A practical consideration is that processes with the same goal might be enacted differently at different faculties of the university, or at geographically separate campuses. Secondly, there is the meso-habitat (living environment), which constitutes organizational and decision-making structures and hierarchies, as well as interactions between different information systems. At the meso-habitat level the focal point of information systems is the support of, and alignment, with organizational or company-wide functions, strategies, and goals. Thirdly there is the macro-habitat (spread), which constitutes industry and market platforms, participation in networks etc. It is very much the external context in which information systems support the expanded organization, enabling cooperation, coopetition, and a sustainable competitive position. In our example, the Linnaeus university is a member of the Baltic University Program, a collaboration between 90 universities in the Baltic Sea region requiring the exchange of data between information systems to for example fulfil reporting requirements. The abiotic components provide a greater understanding of the what and where (habitat) as well as the how (presumptions) of an information system. They enable a rich picture of both the context and outcome of information systems, as well as the nature and character of needed infrastructure.

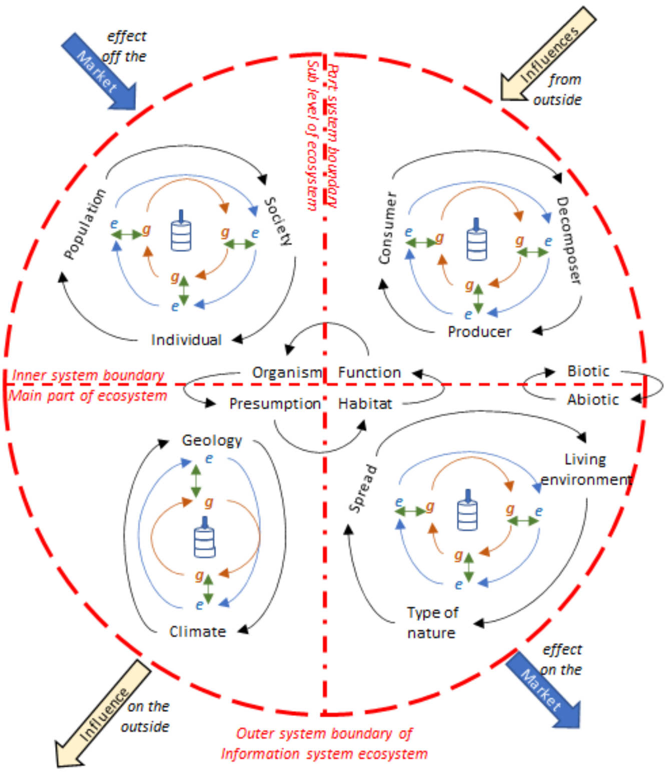

Figure 5: Three levels of circulation in information system ecosystem

When analyzing any system, a holistic view and investigating interdependence of the components are central (Figure 5). For example, while the organism component is useful to identify internal and external stakeholders, further insight is gained when considering how different stakeholders engage with the information system through the function component (producing, consuming and decomposing data). A deeper level of understanding is then gained when analyzing connections and interactions between sub-systems or components of the system at hand. The information system ecosystem has a system boundary providing an interface with an external environment. This environment affects and is affected by the ecosystem. The ecosystem with its biotic and abiotic components constitutes a constant, ongoing circulation, iteration, and/or feedback of data in and between all levels in an information system ecosystem. Data then becomes the heart of an information systems ecosystem. In figure 5 the example of Ladok is used to illustrate this complexity. The dashed line depicts outer, inner, and sub level boundaries. Furthermore, "e" stands for education and "g" for Ladok as a grading application.

5 Conclusion

We believe the biological ecosystem concepts give new insights as compared to traditional information systems analysis concepts. Ecosystem analysis goes beyond processes, taking into consideration also structures and hierarchies. For example, the concept Habitat gives a novel lens to analyze the boundary conditions impacting an information system, and by its division into three levels broadens the scope of the scrutiny both within the organization and beyond it. Further, in traditional systems analysis, tools such as data flow diagrams are used to model how data moves in the system, giving a necessary technical blueprint for how to build the system. The Function concepts, on the other hand, look at how and which data is needed in the socio-technical system for e.g. decision making, at the sources of the data, and at the usage of the data. The flow of data to and from stakeholders becomes a central focal point in the analysis, as all components of the system are analyzed in relation to the flow of data. We gain new understanding of the varied relations between stakeholders and data. Roles are not understood through the work tasks performed by the individual, or position in the organizational hierarchy, but as roles in relation to data. Using the biological ecosystem as a model forces a questioning of traditional information system concepts. It also means an extended and richer system perspective which is beneficial for the view of information systems. The ecosystem concepts give researchers and practitioners a new lens to use when studying, planning, designing or troubleshooting an information system.

In future research, we intend to further explore the notion of the information system ecosystem, and to carry out a more systematic evaluation of the framework, e.g. as a case study. As an additional evaluation of the proposed approach, a thorough review of and comparison to alternative information systems analysis frameworks and models is proposed. Finally, we intend to explore the use of the suggested framework in other business contexts, e.g. marketing.

References

Adner, R. (2017). Ecosystem as Structure: An Actionable Construct for Strategy. *Journal of Management*, volume 43, number 1, pages 39-58.

Alter, S. (2004). Desperately seeking systems thinking in the IS discipline. Proceedings of ICIS-25, *the International Conference on Information Systems*, Washington, DC, 757-769.

Anjum, B. (2023). A conversation with Grace IbukunOluwa Ufeoshi: Preparing African youth for the future of work in the IT ecosystem. *Ubiquity*, Doi:10.1145/3579372

Bash, C.E., Patel, C.D., Shah, A.J. & Sharma, R.K. (2008). The sustainable information technology ecosystem. *Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems*, p. 1126-1131

Basole, R.C., Park, H. & Barnett, B.C. (2015). Coopetition and convergence in the ICT ecosystem. *Telecommunications Policy*, 39:527-552

Baxter, G., & Sommerville, I. (2011). Socio-technical systems: From design methods to systems engineering. *Interacting with computers*, 23(1), 4-17.

Benedict, M., (2018), Modelling ecosystem in information systems – a typology approach. *Multikonferenz Wirtschaftsinformatik*, Lüneburg Germany, March 06-09, 2018, https://www.researchgate.net/publication/323218912

Blijleven, V., van Angeren, J., Jansen, S., & Brinkkemper, S. (2013, July). An evolutionary economics approach to ecosystem dynamics. In 2013 *7th IEEE International Conference on Digital Ecosystems and Technologies* (DEST) (pp. 19-24). IEEE

Breslin, D., Kask, J., Schlaile, M., & Abatecola, G. (2021). Developing a coevolutionary account of innovation ecosystems. *Industrial Marketing Management*, 98, 59-68.

Briscoe, G., & De Wilde, P. (2009). Digital Ecosystems: Evolving Service-Oriented Architectures. *Computer Science*. Retrieved from https://ai2-s2-pdfs.s3.amazonaws.com/04f0/33e8fe766d07025c3efe4f457bea7c0d69fb.pdf

Brummermann, H., Keunecke, M. & Scmid, K. (2011). Variability issues in the evolution of information system ecosystems. In *Proceedings of the 5th Workshop on Variability Modeling of Software-Intensive Systems* (pp. 159-164).

Brummermann, H., Keunecke, M. & Scmid, K. (2012). Formalizing distributed evolution of variability in information system ecosystems. In *Proceedings of the 6th Workshop on Variability Modeling of Software-Intensive Systems* (pp. 11-19).

Chamberlain, L.M. & Said, H. (2022). The early IT ecosystem: Re-envisioning dual credit, college access and affordability, and teachers as professionals. *Policy Futures in Education*. Doi:10.1177/14782103211066675

Changjun, L. & Hongbum, K. (2018). The evolutionary trajectory of an ICT ecosystem: A network analysis based on media users' data. *Information & Management*, 55:795-805

Cusumano, M.A., Gawer, A. & Yoffie, D.B. (2019). *Business of platforms, strategy in the age of digital competition, innovation, and power*. HarperCollins Publishers, New York.

Dhillon, S.K., Chiew, S.L., Leow, S.L., Sidhu, A.S., Shuhaimi, N.I., Leong, Y.M. & Chong, V.C. (2013). A model of digital biological ecosystem. *Systematics and biodiversity*, 11(4):425-435, Doi:10.1080/14772000.2013.856962

Diga, K. & May, J. (2016). The ICT ecosystem: The application, usefulness, and future of an evolving concept. *Information Technology for Development*, vol. 22, supplement 1, p. 1-6, Doi:10.1080/02681102.2016.1168218

Furman, E., Pihlajamäki, M., Välipakka, P. & Myrberg, K. (n.d.). The Baltic Sea. Environment and Ecology. *Finnish Environment Institute*, https://www.syke.fi/download/noname/%7B45C3C2FD-9301-43D7-803F-90460B436AE5%7D/99119

Geng, Y., & Côté, R. P. (2002). Scavengers and decomposers in an eco-industrial park. *The International Journal of Sustainable Development & World Ecology*, 9(4), 333-340.

Ghazinoory, S., Phillips, F., Afshari-Mofrad, M., & Bigdelou, N. (2021). Innovation lives in ecotones, not ecosystems. *Journal of Business Research*, 135, 572-580.

Guggenberger, T., Möller, F, Haarhaus, T & Gür, I. (2020). Ecosystem types in information systems. *ECIS 2020*, Marrakesh, Morocco, https://www.researchgate.net/publication/341188637

Hanseth, O., Aanestad, M., & Berg, M. (2004). Guest editors' introduction: Actor-network theory and information systems. What's so special?. *Information technology & people*, 17(2), 116-123.

Hevner, A.R., March, S.T., Park, J. & Ram, S., (2004). Design Science in Information System Research, *MIS Quartely*, vol 28 no 1 pp 75–105.

John Nurminen Foundation (n.d.). *Marine biodiversity*. https://johnnurmisensaatio.fi/en/the-baltic-sea/marine-biodiversity/

Karl, H., Kundisch, D., Meyer auf der Heide, F. & Wehrheim, H. (2020). A case for a new IT ecosystem: On-The-Fly computing. *Business Information System*, 62(6):467-481, Doi:10.1007/s12599-019-00627-x

Kuckertz, A. (2019). Let's take the entrepreneurial ecosystem metaphor seriously! *Journal of Business Venturing Insights*, 11, e00124.

Ladok, (2023), *Ladok*, https://ladok.se

Lamb, R., & Kling, R. (2003). Reconceptualizing users as social actors in information systems research. *MIS quarterly*, 197-236.

Libert, B., Beck, M., & Wind, J. (2016). *The network imperative, how to survive and grow in the age of digital business models*. Harvard business press, Boston.

MacInnis, D. J. (2011). A framework for conceptual contributions in marketing. *Journal of Marketing*, *75*(4), 136-154.

March, S.T. & Smith, G.F. (1995). Design and natural science research on information technology. *Decision Support Systems*, no 15 pp 251–266

Mars, M. M., Bronstein, J. L., & Lusch, R. F. (2012). The value of a metaphor: Organizations and ecosystems. *Organizational Dynamics*, 41(4), 271-280.

Márton, A. (2022). Steps toward a digital ecology: ecological principles for the study of digital ecosystems. *Journal of Information Technology*, 37(3), 250-265.

McAfee, A., and Brynjolfsson E., (2017). *Machine, platform, crowd, harnessing our digital future*. W.W. Norton & Company Inc., New York

McMullen, J. S. (2018). Organizational hybrids as biological hybrids: Insights for research on the relationship between social enterprise and the entrepreneurial ecosystem. *Journal of business venturing*, 33(5), 575-590.

Millerand, F., & Baker, K. S. (2010). Who are the users? Who are the developers? Webs of users and developers in the development process of a technical standard. *Information Systems Journal*, 20(2), 137-161.

NE. (2023). *Nationalencyklopedin* [Swedish encyclopedia], different keywords, https://www-ne-se.proxy.lnu.se/uppslagsverk/encyklopedi

Nischak, F., Hanelt, A., & Kolbe, L. M. (2017). Unraveling the interaction of information systems and ecosystems - A comprehensive classification of literature. *ICIS 2017 Proceedings*, 20.

Oh, D. S., Phillips, F., Park, S., & Lee, E. (2016). Innovation ecosystems: A critical examination. *Technovation*, 54, 1-6.

Oosthuizen, R., & Pretorius, L. (2016). Assessing the impact of new technology on complex sociotechnical systems. *South African Journal of Industrial Engineering*, 27(2), 15-29.

Parker, G. G., Van Alstyne, M. W., & Choudary, S. P. (2016). *Platform revolution: How networked markets are transforming the economy and how to make them work for you*. WW Norton & Company, New York.

Pilinkienė, V., & Mačiulis, P. (2014). Comparison of different ecosystem analogies: The main economic determinants and levels of impact. *Procedia-social and behavioral sciences*, 156, 365-370.

Ritala, P., & Almpanopoulou, A. (2017). In defense of 'eco'in innovation ecosystem. *Technovation*, 60, 39-42.

Romero, D., & Vernadat, F. (2016). Enterprise information systems state of the art: Past, present and future trends. *Computers in Industry*, 79, 3-13. Doi:10.1016/j.compind.2016.03.001

Schramm, W., Köstinger, H., Bayrhammer, K., Fiedler, M. & Grechenig, T. (2012). Developing a hospital information system ecosystem for creating new clinical collaboration methodologies, *IEEE-EMBS International Conference on Biomedical and Health Informatics*

Shaw, D. R., & Allen, T. (2018). Studying innovation ecosystems using ecology theory. *Technological Forecasting and Social Change*, 136, 88-102.

Tansley, A.G. (1935). The use and abuse of vegetational concepts and terms. *Ecology*, vol. 16, no. 3, pp. 284-307

Tansley, A.G. (1939). British ecology during the past quarter-century: the plant community and the ecosystem. *Journal of ecology*, vol. 27, no. 2, pp. 513-530

Willis, A.J. (1997). The ecosystem: An evolving concept viewed historically. *Functional Ecology*, vol., 11, no. 2, p. 268-271

Wu, P. P. Y., Fookes, C., Pitchforth, J., & Mengersen, K. (2015). A framework for model integration and holistic modelling of socio-technical systems. *Decision Support Systems*, 71, 14-27.

The Theory of Identity Management Extended to the Authentication of Identity Assertions

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At the 35th Bled eConference, a previously-published pragmatic metatheoretic model was articulated in the context of identity management. The present paper extends that theory to the authentication of the various categories of assertions that arise in identity management activities. The extended theory reflects the important distinction between the concepts of identity and entity. It deals with the fundamental categories, in which a particular data-record is claimed to relate to a particular physical entity or virtual identity; but it also encompasses claims about the properties of real-world things, and assertions that records in two different data-sets apply to the same (id)entity. The analysis has important implications for the practice of IS, and for IS researchers whose work is intended to influence IS practice.

Keywords:
IS practice,
assertion,
evidence,
property,
principal-agent

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1 Introduction

Organisations have encountered ongoing difficulties in the areas of identification and authentication, particularly where the entities in question are human beings. The topic of identity authentication is addressed in the technical information technology (IT) literature, although far less so in information systems (IS). On the other hand, authentication as a general concept and a family of business processes has attracted remarkably little attention. For example, of the 465 refereed papers from the Bled eConference accessible in the AIS electronic Library (AISeL), covering the last two decades, only 2 have the term 'authentication' in Title or Abstract. In AISeL as a whole, the corresponding count is only 38 of >17,000, and across the Basket of 8 IS journals, a mere 12 of >10,000 articles. Effective IS depend on a deep appreciation by IS designers of the nature of the relevant phenomena, and hence researchers need to pay far more attention to the topic.

IS professionals need to be supported by a model that is pragmatic, by which is meant that it is a fit to the needs of IS practitioners, but that also reflects insights from relevant aspects of philosophy. This paper builds on prior work in two areas. The first presents a pragmatic metatheoretic model to support IS, and the second examines the general concept of authentication. Together, these provide a suitable basis for an analysis of processes to authenticate assertions about identity.

The paper commences with a recapitulation of prior work that establishes the pragmatic metatheoretic model, and explains the generic concept of assertion authentication. The main body of the paper identifies and discusses specific categories of assertion in which identities and/or entities play a key role. Processes are then presented whereby the reliability of those kinds of assertions can be assessed. The effectiveness of those processes is shown to be dependent on evidence, and hence on the quality of the data on which reliance is placed. The application of these ideas to IS practice is argued to enable improvements in authentication design and operation. The need is shown for further work on their application to particular kinds of entities and identities and in particular contexts.

2 Prior Work

Organised activity involves dependence by parties on statements made by other parties. The longstanding maxim 'Trust, but verify' conveys that, in principle, all such statements on which dependence is placed need to be checked, but with effort invested proportionately to the harm that would arise from unjustified trust. Organisations need IS to be designed in a manner that reflects, supports and facilitates the checking of important statements. For that to be achieved, the model on which IS practice is founded needs to have an effective fit with the manner in which business enterprises, government agencies, not-for-profits and small businesses perceive the realities of their operational environment.

The first sub-section below summarises a model that is pragmatic, in that it supports understanding about and action in the world, yet has a firm foundation in relevant aspects of meta-theory, particularly ontology (the study of existence), epistemology (the study of knowledge), and axiology (the study of values). The second sub-section introduces a further area of prior work which examines the general notion of authentication. On these two foundations, the remainder of the paper builds an analysis of the authentication of assertions that involve identities and entities.

2.1 The Pragmatic Metatheoretic Model

Prior work reported at the Australasian Conference in Information Systems (ACIS) in Clarke (2021) presents a pragmatic metatheoretic model conceived in order to support both IS practice and that portion of IS research activity that is intended to be relevant to IS practice.

The foundational metatheoretic aspect is ontology, which is concerned with phenomena, and hence with the properties of things and events. The assumption adopted in the model is a conventional compromise between materialist and idealist notions, postulating that there are both material realities (the Real World) and internal mind-stuff (as that term is used by William Kingdon Clifford to refer to the intellectual or Abstract World – Coneybeare 1892): phenomena and their properties inhabit the Real World; whereas ideas are of the Abstract World.

The second aspect, epistemology, is the study of knowledge, and its sources, varieties and limits. Competing views are empiricism, which holds that knowledge is derived from sensory experience, and apriorism or rationalism, which considers that knowledge is or at least can be innate and/or derived from the human faculty of reason.

A pragmatic metatheoretic approach must support IS practitioners not only in contexts that are simple, stable and uncontroversial, but also where there is no expressible, singular, uncontested 'truth'. Some relatively closed systems, such as fly-by-wire, industrial control, and robotic assembly line management, can reasonably be treated as technical systems. In the large majority of IS, on the other hand, interaction among IT artefacts and people is intrinsic, and meaningful study of them requires the adoption of both a socio-technical perspective (Abbas & Michael 2022), and interpretivist or critical theory approaches to research. The epistemological commitment underlying the model is accordingly that knowledge depends on appropriately blending sensory experience, human imagination, and reasoning, and accommodating both tacit and codified knowledge.

A third important branch of philosophy, axiology, is less familiar. It is concerned with how value is imputed to things. Organised activities depend on people, artefacts, and effective interactions among them. IS also affect people, including those participating in the system (conventionally called 'users') and some who are not participants in the system, but are affected by it (usefully referred to as 'usees' – Berleur & Drumm 1991 p.388, Clarke 1992, Fischer-Huebner & Lindskog 2001, Baumer 2015). Examples of usees include people to whom records in shared industry databases refer, such as those for police suspects and tenants. Human values are accordingly central to the model.

In addition, IS involve various stakeholders, and value-conflicts are inherent. The approach adopted in the pragmatic metatheoretic model is that value is dependent on the observer, that there are generally multiple observers of any given phenomenon, and hence that IS must support the integration of multiple perspectives rather than assume that one necessarily dominates (Clarke & Davison 2020), and must continue to function where tension continues among two or more perspectives.

At the Bled eConference, in Clarke (2022), the pragmatic model was applied to identity management. A diagrammatic form of the full model is in Figure 1. The Properties of phenomena in the Real World can be sensed by humans and artefacts with varying reliability. Within the Abstract World, two levels are then distinguished. At the Conceptual-Model level, the Real-World phenomena are conceptualised by people, in many cases on behalf of organisations. In the remainder of this paper, capitalised terms are defined in the text, with the full set of definitions gathered into a Glossary, provided as Supplementary Material.

At the Data-Model level, the concepts are operationalised, enabling the Data-Items to represent the states of Properties of phenomena, in a manner that enables coherent collection, processing, management and use of the Data. At the Conceptual-Model level, Real-World Things and Events are represented as (Id)Entities and Transactions, and their Properties as Attibutes. Relationships exist among the various elements. These aspects of the model provide a useful formalisation of the way in which IS practitioners view the relevant parts of the surrounding world and the representations of that world expressed in their systems.

The compound and intentionally attention-attracting term (Id)Entity is used to refer to elements of the Conceptual Model that represent Real-World Things. An Entity corresponds with a Real-World Physical Thing, and an Identity with a Real-World Virtual Thing. Virtual Things lack the corporeal nature of a Physical Thing, but are treated as being real because they perform functions relevant to IS. Virtual Things include processes running inside computing devices, and human presentations or roles. For example, the role of CEO is an Identity that is usually performed by a single human Entity at any give time; but it is performed by different human Entities over time.

Virtual Things may have associations with Physical Things, e.g. a computer process with a computing device, a software-agent with a human principal, and a role with one or more humans. Some Physical Things have associations with multiple Virtual Things, and vice versa, and most associations are time-bounded.

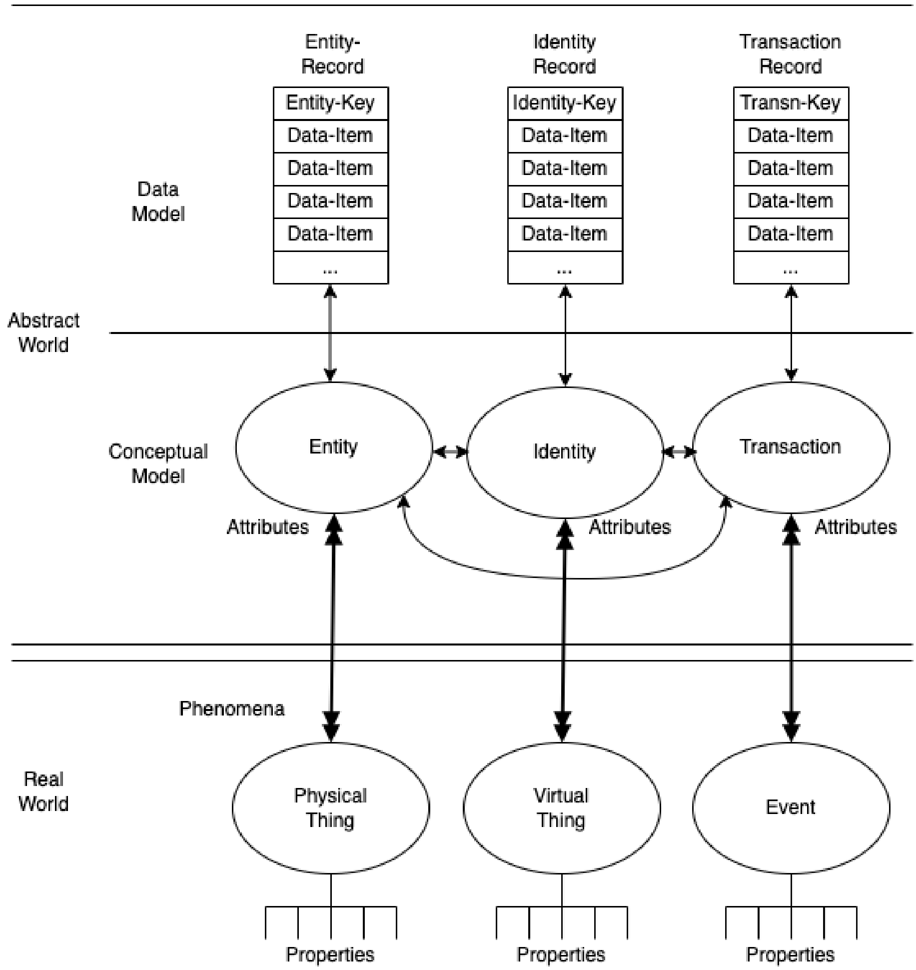

Figure 1: The Pragmatic Metatheoretic Model

Each element at the Conceptual Level has 'Attributes', which contain an 'Attribute-Value' for each instance. For example, the Entity shipping-containers has Attributes such as colour, owner and type (with Attribute-Values fot type such as refrigerated and half-height). A Relationship has the Attribute of cardinality, reflecting how many of each of the elements that it links can exist – typically zero, one or many.

At the operational, Data-Model level, a Data-Item is a storage-location in which a discrete 'Data-Item-Value' can be represented. For example, Entity-Attributes of cargo-containers may be expressed at the Data Model level as Data-Items and Data-

Item-Values of Colour = Orange, Owner = MSK (indicating Danish shipping-line Maersk), Type = Half-Height. A set of Data-Items that relate to the same (Id)Entity or Transaction make up a Record. Record-Keys are Data-Items or Data-Item groups that are capable of distinguishing which (Id)Entity-Instance a particular Record relates to. Record-Keys for Identities are called Identifiers, and Record-Keys for Entities are Entifiers.

Identification refers to the process whereby a Data-Record is associated with a particular Virtual Thing. It involves the acquisition of a Record-Key, that is to say an Identifier. The corresponding process is Entification, whereby a Data-Record is associated with a particular Physical Thing, involving the acquisition of an Entifier. Some computing devices, being a Physical Thing, have a unique number stored internally which can be reliably used as an Entifier; whereas each of the processes running within a device and communicating with remote devices is a Virtual Thing, for which a workable Identifer is the combination of IP-Address and Port-Number. For human beings, a customer-code is an Identifier, and a biometric is an Entifier.

The (Id)Entity and (Id)Entification distinctions were first proposed in 2001, and have been applied in about 25 articles within the Google Scholar catchment, which together have over 400 citations. However, despite the concept's importance, it has to date attracted far too little attention. This aspect of the pragmatic metatheoretic model represents a major contribution to practice and theory.
The basic features of the model can deal with passive Things, including natural objects (such as gems and dinosaur bones), animals, and artefacts (such as *objets d'art*, pallets, and stock-items). Further articulation is needed when dealing with active Things, including artefacts capable of action in the Real World (such as computing devices and robots), and human beings. The notion of identities of human entities, foundational to the discussion, has been treated elsewhere at length, both generally (e.g. Brown 2020) and specifically within IS (e.g. Clarke 1994b, Halperin & Backhouse 2008, Clarke 2008). In IS that extend beyond data-processing, to information production, to inferencing, to decision-making and even to action, values loom large, conflicts among value-sets occur, and designers must take much greater care.

2.2 Authentication Theory

The pragmatic metatheoretic model outlined in the previous section postulates a Real World comprising Things and Events, which have Properties. These can be sensed by humans and artefacts with varying reliability. Authentication is a process whereby that reliability can be assessed. This paper's purpose is to present an analysis of Authentication in contexts in which Identity or Entity plays a central role. No sufficiently general body of theory has been located in the IS or any other literature. As a basis for the analysis, this sub-section accordingly summarises prior work by the author on the generic notion of Authentication (Clarke 2023).

Dictionary definitions of 'assertion' refer to declarations or affirmations, and to the action of making such statements. In the present context:

> *An **Assertion** is an expression of knowledge about one of more elements of the pragmatic metatheoretic model.*

An Assertion may be made by a party, implied by context, inferred by a party, or postulated by a party. Assertions may be about:

1. Particular Phenomena in the Real World;
2. Particular elements of an Abstract World; or
3. Relationships between elements in both the Abstract and Real Worlds.

It is common in the IT industry for the process of establishing the reliability of an Assertion to be referred to as 'Verification', or sometimes 'Validation'. It is preferable to avoid those terms in favour of one that is consistent with the pragmatic model's recognition of the impracticality of the notion of humanly-accessible truth, and that interprets reliability in constructively loose terms:

> ***Authentication** is a process that establishes an appropriate degree of confidence in the reliability of an Assertion.*

In designing Authentication processes, organisations generally select a trade-off among key factors such as cost, reliability, and convenience for, and acceptability to, affected parties. This inevitably results in shortfalls in the quality of the

Authentication process. The term 'appropriate' has been included in the working definition above, to reflect the fact that the degree of confidence is compromised by, or balanced against, other factors.

Assertions in category (1) above, relating solely to the Real World, may be authenticated by empirical means, that is to say by observation of the Phenomena. Assertions in category (2), on the other hand, relate solely to the Abstract World. They may be authenticated against Data available in the Abstract World. Authentication processes for such Assertions may involve the application of reasoning, in order to infer additional Assertions.

Classical logic, such as the propositional calculus, is of limited use, because it only supports binary / true-or-false assertions. More useful logics support qualitative data on nominal and ordinal scales, and preferably on ordinal scales (such as the non-linear Richter scale for the intensity of earthquakes), interval scales (with equal distances between consecutive values, cf. Celsius for temperature), and most powerfully on ratio scales featuring a natural zero (cf. Kelvin for temperature – Stevens 1946).

Nomatter what approach is adopted, however, Authentication of Abstract-World Assertions cannot, alone, satisfy the criterion of 'establishing an appropriate degree of confidence', because it does nothing to test the relationship between Data and the Real World. The primary focus of Authentication processes needs to be on Assertions in category (3), straddling the two Worlds.
Authentication processes depend on evidence, for which dictionary definitions refer to observations adduced in support of a conclusion or statement. In the present context:

> ***Evidence*** *is Data that assists in determining the level of confidence in the reliability of an Assertion.*

An individual item of Evidence is usefully referred to as an Authenticator. A common form of Authenticator is a Document, in any form and expressed in any medium. Some Authenticators carry the imprimatur of an authority, such as a registrar or notary, and are referred to as Credentials. The term Token refers to a recording medium on which useful Data is stored, in the present context (Id)Entifiers, Authenticators and/or Credentials.

The preliminary sections of this paper have drawn on prior work to define a pragmatic metatheoretic model to support IS practice and practice-relevant research, and to establish basic theory in relation to Assertions and their Authentication. The following section applies those ideas to the specific context of assertions in which Entities and Identities figure prominently.

3 Assertions Relating to (Id)Entity

This section applies the theory of Authentication outlined above to Assertions that involve Entities or Identities. The first sub-section identifies the kinds of Assertion that are relevant. The later sub-sections discuss the process whereby such Assertions can be authenticated, and the nature of the Evidence that can be used in that process.

3.1 Introduction

The pragmatic metatheoretic model avoids the idea that an accessible truth exists, and articulates the relativistic notion of a degree of confidence in the reliability of Assertions. Reflecting this, a key term in the category descriptions below is defined as follows:

> ***Appropriately*** *means with a level of confidence commensurate with the reliance placed on the Assertion and the severity of the consequences if the reliance is misplaced*

This sub-section identifies a set of Assertion categories. Almost all of the IS and related literature on Authentication is concerned with a limited mainstream mode of thought in which the focus is on what are referred to here as (Id)Entity Assertions – categories (1) and (2) below.

(1) An Identity Assertion

An assertion of a relationship between a Virtual Thing and a Record takes one of the following forms:

- A particular Virtual Thing is appropriately associated with one or more Identity-Records
  'This client's profile information is displayed on the screen in front of me'
- The Data-Item-Values in a particular Identity-Record are appropriately associated with a particular Virtual Thing
  'This data on my screen relates to this software-agent'
- This Virtual Thing is the Virtual Thing with which this particular Identity-Record is appropriately associated
  'This corporation is the corporation we're doing business with'
  'This patient is the one to whom this medical record relates'

Expression of such Assertions is facilitated by the industry standard Security Assertion Markup Language (SAML), which includes an assertion-type called an 'authentication statement', which asserts that 'a particular remote Virtual Thing is appropriately associated with a particular Identity' (OASIS 2005).

(2) An Entity Assertion

An Assertion of a relationship between a Physical Thing and a Record takes one of the following forms:

- A particular Physical Thing is appropriately associated with one or more Entity-Records
  'This felon's profile information is displayed on the screen in front of me'
- The Data-Item-Values in a particular Entity-Record are appropriately associated with a particular Physical Thing
  'The data displayed on my screen relates to this particular stock-item'
- This Physical Thing is the Physical Thing with which this particular Entity-Record is appropriately associated
  'This is the shipping-container we were looking for'

'This person is Wanted Person No.1'

A contention of this paper is that a serious deficiency exists in the existing literature in the form of the conflation of Entity and Identity Assertions and their Authentication. An important example is the statement within the IT industry, frequently adopted in the research literature, that Authentication is based on 'what you know, what you have, and what you are'. See, for example, Elgarah & Falaleeva (2005), Witman (2006), Carpenter et al. (2008) and Hewitt (2009). The third category ('what you are') differs fundamentally from the other two.

A recent UNHCR plan reported on by Madon & Schoemaker (2021) calls for "a self-managed digital wallet [that] would allow refugees to store a variety of different forms of *identification* such as biometric registration, individual ID documentation, attestation card and already-existing authenticated paper documents that have been digitised and uploaded" (p.938, emphasis added). Authenticators for Identity Assertions (such as 'I have this Accredited Refugee Code') are combined into a single Token along with a biometric Authenticator for an Entity Assertion ('I am s/he'). Biometrics strikes through a person's multiple Identities to the Entity. Physical and Virtual Things differ enormously, as do the contexts, the impacts on values, and hence the design processes and the ethicality and public acceptability of those designs. It is therefore very important to distinguish between the two Assertion categories.

(3) A Simple Property Assertion

Assertion categories (3)-(5) are concerned with Properties. The descriptions here use the abbreviated form (Id)Entity to encompass both sub-categories. A straightforward Assertion takes the following form:

- A particular Data-Item-Value in a particular (Id)Entity Record is appropriately associated with, and reliably represents, a particular Property of a particular Thing
  'This person is old enough to enter the night club'
  'This customer is a frequent-buyer who qualifies for the loyalty discount'
  'There are 13 widgets in stock because the inventory system says there are'

This category of assertion is at an atomic level and of high granularity, and relates to a Property that is represented by a single Data-Item. More complex circumstances are the subject of the following category. The UNHCR plan discussed by Madon & Schoemaker (2021) includes in the envisaged "self-managed digital wallet [for] refugees" the inclusion of "education credentials" (p.938). The Token would therefore assist with the Authentication of Property Assertions (e.g. 'I have a High School Certificate from ...').

A Property Assertion is frequently assumed to be dependent on an accompanying (Id)Entity Assertion; but, subject to some conditions, it is feasible to perform Property Assertion Authentication without (Id)Entity, and may be far preferable to do so (e.g. for cost, confidentiality or privacy reasons).

To facilitate expression of Property Assertions, the industry standard SAML includes an assertion-type called an 'attribute statement', which asserts that a particular remote Virtual Thing has a particular Property (OASIS 2005).

(4) A Complex Property Assertion

A more complex assertion depends on an inference drawn from multiple Data-Items, and takes the following form:

- A particular Thing is inferred to have a particular Property, on the basis of multiple particular Data-Item-Values in one or more particular (Id)Entity Records, and on the assumption that those Data-Item-Values are appropriately associated with that Thing and reliably represent that Property
  'This borrower is behind on their loan repayments'
  'This welfare recipient has been overpaid because they understated their income'

Reliance on Property Assertions needs to be based on careful analysis, because each Assertion's reliability depends on data quality, and because of the wide array of quality factors that need to be satisfied to ensure that the level of confidence in the Assertion is appropriate – defined above as meaning 'commensurate with the reliance placed on the assertion and the severity of the consequences if the reliance is misplaced'.

Kambil & van Heck (1998) describe Authentication as one of the five 'Basic Trade Processes' in Online Auctions, used "to verify [1] the quality and [2] features of the product offered [both of which are Complex Property Assertions], [and] [3] the authenticity of the trading parties [a combination of Identity and Attribute Assertions] ..." (p.5). This was revisited in Fairchild et al. (2007), who argued that Authentication is "central to the design of multi-attribute markets [with the market operator performing] extensive pre-qualification of suppliers by intermediary to ensure the integrity of the auction process" (pp.291-292, involving both Identity Assertions and Complex Attribute Assertions).

However, where this category is evident in the IS literature, there is often a lack of clarity as to what the Assertion is, or Assertions are, whose reliability is being investigated. One example of simple mis-phrasing is "He pays for this transaction online using BankID to authenticate his payment" (Eaton et al. 2014), when what is meant is 'He authenticates himself to his bank as a person authorised to operate on that account', i.e. it is an Identity not a Value Assertion. Another is the expression 'authenticity of Internet-sourced information' (e.g. Haider 2008), which conflates source (an Identity Assertion) and content (a Fact Assertion).

(5) A Principal-Agent Assertion

A special case of a complex Property Assertion is of considerable commercial significance, and hence is dealt with here as a separate category. An Assertion relating one Thing's ability to act on behalf of another Thing takes the following form:

- A particular Thing has a particular Property, based on one or more particular Data-Item-Values in one or more particular (Id)Entity Records, which are appropriately associated with that Thing and which reliably convey that the particular Thing has the authority to act on behalf of another particular Thing
  'This human/legal-person/software-agent is the approved representative of this customer/client/accusee'

This Assertion-category involves a chain of Virtual and Physical Things, and hence requires multiple Authentication processes to be performed: "The claims of a business intermediary to be acting on behalf of another intermediary need to be subjected to testing. Moreover, the claims of a person to be acting on behalf of a business entity (which may itself be acting as an intermediary for another business entity) also need to be tested. Authentication needs to be undertaken of a particular attribute or credential that reflects the agency relationship, such as a power of attorney, or some other form of delegation of power to sign contracts" (Clarke 1999, p.9). A comprehensive study of Principal-Agent Authentication is in Basul & Muylle (2001).

(6) (Id)Entity Match Assertions

A further cluster of Assertion Categories are entirely within the Abstract World. Authentication of these categories is not merely valuable, but actually essential to the conduct of IS. They differ from the earlier categories, however, in that Authentication of these Assertions alone, while contributing to the level of confidence, does not satisfy all of the necessary conditions, and hence complementary Assertion Authentication processes are needed, to reliably link these Assertions within the Abstract World with Things in the Real World.

Match Assertions take one of the following forms:

- *This <u>Id</u>entity-Record is appropriately associated with this other <u>Id</u>entity-Record*
  Within a particular insurance company: 'This record in the Motor Vehicle Insurance database matches to this record in the Home & Contents database'
  In a government context, and subject to legal authority: 'The record containing this tax-file-identifier matches to the record containing this driver's licence number'
- *This <u>Entity</u>-Record is appropriately associated with this other <u>Entity</u>-Record*
  'This description of recovered stolen goods is of the same diamond necklace as this description of stolen goods'
  Subject to legal authority: 'This DNA sample data from { a crime-scene, a crash-site } is from the same person as is represented by this DNA sample data from a particular family history database'

- *This Identity-Record is appropriately associated with this Entity-Record*
  'This process is running in this computing device'
  In a law enforcement context: 'The record containing this client-number corresponds to this fingerprint-based criminal record'

The contexts in which matching of human Entities is undertaken often have potentially very serious consequences for the person concerned. This calls for a very high degree of confidence in the reliability of the Assertion.

3.2 The Authentication Process

Assertions are depended upon as a basis for inferencing, decision and action. They need to be authenticated, to protect against risks of error and fraud. Sources of poor quality include:

- Accidental mistakes; and
- Intentional mistakes, including:
- intentional false positives, e.g. masquerade or 'spoofing' to enable a person or process to exercise a power that should only be exercised by some other (Id)Entity; and
- intentional false negatives, e.g. avoidance, undermining or subversion of (Id)Entification.

Few sources have been located that identify criteria for evaluating the quality of Authentication processes. Zviran & Erlich (2006) identify as relevant factors: effectiveness, ease of implementation, ease of use, and user attitude and acceptance. Way & Yuan (2009) provide a more substantial list, comprising Accuracy, Robustness, User Acceptance, Accessibility, Feasibility, Applicability, Responsiveness, Non-reputability [sic: Non-Refutability] and Maintainability. Those authors also note different priorities for the criteria among stakeholders, which they categorise as Management, IT Support and Users. Both are useful contributions, but are mostly technical in their orientation. Most IS require a socio-technical approach, and hence additional considerations need to be factored in, such as transparency (from user and usee perspectives) and costs and risks (from the viewpoint not only of the system sponsor, but also of users and usees).

Quality is a substantially greater challenge where other parties are motivated to achieve false positives or false negatives. Safeguards are needed to limit the extent to which such parties may succeed in undermining authentication quality. Techniques such as channel encryption (in particular SSL/TLS) and one-time password schemes are applied to these purposes. Each safeguard has vulnerabilities, and is subject to threats. It is common to distinguish multiple quality-levels or 'strengths' of Authentication, such as unauthenticated, weakly authenticated, moderately authenticated and strongly authenticated. Business enterprises and most government agencies generally adopt risk-managed approaches, accepting lower levels of assurance in return for processes that are less expensive, more practical, easier to implement and use, and less intrusive.

3.3 Evidence in Support of the Authentication Process

In section 2.2, the concepts of Authenticators, Credentials and Tokens were introduced. These notions are much applied in the Authentication of Assertions involving (Id)Entity. The central form of such Assertions is category (1), an Identity Assertion, of the form:

- A particular Virtual Thing is appropriately associated with one or more Identity-Records

Each such association is achieved by means of an Identifier. The conventional term used in government circles for Authenticators designed to support Authentication of such Assertions is 'Proof of Identity' (PoI). This is a disingenuous term, implying infallibility of the Authenticator and the Authentication process that uses it. The notion of accessible truth in such complex circumstances lacks credibility. The appropriate term is accordingly Evidence of Identity (EoI).

Several different categories of Authenticator are used as EoI. The notions of 'what you know' (i.e. Data of some kind) and 'what you have' (a Credential or a Token containing one) are useful summaries. A reasonable degree of confidence in an Assertion of Identity can only be achieved, however, if:

- A Virtual Thing appropriately associated with that Identity can be relied upon to have access to suitable Evidence, to be willing to provide that Evidence, and to do so; and
- The party performing the Authentication (or the technology on which that party depends) has access to a copy of relevant Data, or some other means of being satisfied that the proffered Evidence supports the Assertion and is trustworthy.

Common examples of knowledge-based EoI are passwords and PINs. Further instantiations are private keys generated by (or sometimes issued to) individuals' own devices (workstations, mobile phones, tablets, smartcards, etc.), and one-time passwords, whether generated by a separate device issued to the relevant individual, or communicated to them at the appropriate time over a separate and secure transmission channel. Tokens are usefully applied to the storage of human-visible and/or machine-readable copies of (Id)Entifiers. The same Token may also be used as EoI, by containing one or more Authenticators, which may be Credentials. Forms of Tokens include sequentially-numbered tickets issued to people required to wait in a queue; a credit-card-sized plastic card carrying a chip, sometimes called a smartcard; machine-readable visual images (such as bar-codes and QR-codes); and machine-readable data-storage (such as a magnetic-stripe, solid-state memory in such artefacts as a thumbdrive or 'USB key', and transmissions from an RFID-tag).

In some circumstances, the provision of an Identifier may represent EoI. For example, if a Token is used, and not even the artefact or the individual is aware of the Data-Value that is their Identifier, but the authenticating party (or its technological artefact) knows that Data-Value, the Identifier itself can represent reliable EoI. Generally, however, an Identifier is not a secret, and most schemes use Data-Item(s) other than Identifiers.

The next Assertion category (2), an Entity Assertion, is of the form:

- A particular Physical Thing is appropriately associated with one or more Entity-Records

The Record-Key, in this case an Entifier, by definition reliably distinguishes that Entity-Instance from all other Instances of the same Entity. An Authenticator for this purpose, Evidence of Entity (EoE), differs from EoI, in that it is required to provide strong support for the proposition that the Physical Thing is a specific object, artefact or human.

An example is a Token installed in a device that provides the relevant Data to, and only to, the party doing the Authentication. Subject to careful design of the EoE creation, installation and storage, and of the communications protocols including transmission security features, a considerable degree of confidence can be designed into such a scheme. In the case of living things, a biometric measure may be used. Alternatively, a plant or an animal, including a human being, can be subjected to implantation of a Token in the same manner as installation of a Token into an artefact (Michael & Michael 2009).

Assertion categories (3) to (5) all involve Property Assertions. Simplifying:

- A particular Thing has a particular Property, based on one or more particular
  Data-Item-Values in one or more particular (Id)Entity Records

Two alternative approaches to the Authentication of Property Assertions are possible. Reliance may be placed on Evidence in such forms as Assertions containing sufficient detail that can be checked against one or more other sources (e.g. a claim of a qualification against a testamur, or against a database listing graduates).

The alternative approach is for the party performing the Authentication to rely on Data that they already hold. The relevant (Id)Entity Record may contain a directly-relevant Data-Item, such as a flag for 'Trade Customer' or 'Old-Age Pensioner', or for some category of disablement such as 'legally blind'. In other cases, it will be necessary for the organisation to apply logical processes to its Data to assess the claim. This applies, for example, to a claim of being owed a refund for a failed delivery; and to having reached a particular age or period of association with an organisation.

3.4 Data Quality's Role in the Authentication Process

Little material has been found that identifies criteria for data quality in support of Authentication processes. It is therefore necessary to got back to basic principles and work forward from there. Whether Data is a 'reliable representation' of the relevant phenomena depends on the factors listed in Table 1, comprising Data Quality factors (which are assessable at the time of creation and subsequently) and Information Quality factors (which are assessable only at the time of use).

The generic categorisation of quality factors in Table 1 needs to be applied to each circumstance. For example, an Identity Authenticator for a role may be vital to the signing of a large contract, in which case D7 (Temporal Applicability) looms as a high priority for careful checking. Another concern, causing people to be justifiably wary of government agencies sharing data, is that D3 (Appropriate Property Association) and D4 (Appropriate Property Signification) differ greatly, depending on context. The number of children a person declares to an agency depends on that agency's definition of 'a child of a person' (and definitions may even differ between programs administered by the same agency, and over time). The same holds for marital status, and for gender. More complex examples are legion, such as a person's income, which can be measured differently, and can be accumulated and/or averaged over periods as diverse as daily and annually.

Quality assurance measures needs to be layered. Safeguards must be designed into authentication processes, and implemented. Controls must be designed, implemented and monitored, to ensure that the safeguards are operational and effective.

When concern arises that an Authentication process may have been malperformed or may have delivered a wrong result, it is necessary to conduct an audit. This depends on reviewability, replicability, auditability, accountability, and action. For any of these measures to be feasible, Data needs to be available that document the basis on which each decision was made.

Table 1: Quality Factors

Data Quality Factors Assessable when created and later	**Information Quality Factors** Assessable only at the time of use
D1 Syntactical Validity Conformance of the Data-Item-Value with the Domain on which the Data-Item is defined	**I1 Theoretical Relevance** Demonstrable capability of the Data-Item to, in principle, make a difference to the inferencing process in which the Data-Item is to be used
D2 Appropriate Phenomenon Association A high level of confidence that the Data-Item-Value is associated with the particular Real-World Thing or Event it is intended to represent	**I2 Practical Relevance** A demonstrable capability of the Data-Item-Value to, in practice, make a difference to the inferencing process in which the Data-Item-Value is to be used
D3 Appropriate Property Association A high level of confidence that the Data-Item-Value is associated with the particular Property of the Real-World Thing or Event that it is intended to represent	**I3 Currency** The absence of a material lag between a Real-World Event and the recording of the corresponding Data-Item-Values
D4 Appropriate Property Signification A high level of confidence that the Data-Item-Value represents the state of the particular Property of the Real-World Thing or Event it is intended to represent	**I4 Completeness** The availability of sufficient contextual information that the data is not liable to be misinterpreted
D5 Accuracy A high level of correspondence of Data-Item-Value with the particular Real-World Thing or Event that it is intended to represent	**I5 Controls** The application of business processes that ensure that the Data Quality and Information Quality factors are satisfied
D6 Precision The level of detail at which the data is captured, reflecting the Domain on which the Data-Item is defined	**I6 Auditability** The availability of Metadata that evidences the Data Quality and Information Quality factors
D7 Temporal Applicability The absence of ambiguity about the date and time, or period, when the Data-Item-Value represents a particular Real-World Thing or Event	

Adapted from Clarke (2016), Table 1

This section has articulated the basic theory of Authentication in contexts relevant to identity management activities in IS. It identifies a range of needs. Areas in which IS practice and theory evidence shortfalls include the widespread error of conflating Identity and Entity, failure to be clear about what Assertions need what strength of

Authentication, failure to evaluate threats, and ineffectiveness of relevant safeguards, resulting in inability to rationally select a good-enough approach to Assertion Authentication.

4 Implications

The analysis presented above has important implications for IS practitioners, and for practice-oriented IS research. Some of these relate to the quality of IS design, while others reflect the importance of the human-values aspects of IS activities.

(1) The Effectiveness of Identity Management

Attention has been drawn to the significant differences between Entities that reflect Physical Things and Identities that reflect Virtual Things. The ability of an IS to support organisational activities is undermined if the model on which it is built conflates an Entifier such as a device-id with an Identifier of one of many processes running within that device. In such circumstances, users of a cybersecurity-monitoring system, for example, would be hampered in their efforts to detect runaway, rogue and compromised processes. Similarly, confusion could arise between a non-corporeal principal (such as a corporate trustee) and the individual person or software-process acting as the agent for that principal.

In the case of humans, the failure to distinguish Entities from Identities means there is an implicit assumption that a person whose Assertion of Identity is authenticated is necessarily a single, particular instance of *homo sapiens*. This flies in the face of many real-world practices. Employees routinely share passwords. The Authenticators used by older family members continue to be provided to younger members, so that payments can be made. Commercial terms may well provide organisations with legal assurance that they can repudiate responsibility for transactions conducted in such ways (if they can gather evidence). On the other hand, all of the organisation's work on risk assessment and risk management, including distinguishing between abuse of commercial terms by the principal and abuse by another party through unauthorised masquerade, lie outside the model, and hence are unsupportable by the IS.

Another technical problem masked by conventional, inadequate identity management models is the risk of biometrics being compromised, such that convincing biometrics-based masquerade is able to be committed. The Properties of Physical Things that are used for biometrics (fingerprints, iris-patterns, password-capture dynamics, gait, DNA, etc.), are not capable of being tightly protected. They can be captured and replicated, then simulated sufficiently well that Entity Authentication can be duped. Each advance in liveness-testing stimulates countermeasures.

The value of biometrics-based Entification may fall and/or governments may move to limit its use to tightly-controlled, priority circumstances. This would be tantamount to imposing a licensing scheme and heavily-sanctioned legal prohibitions on retention and transmission of biometric data. PIN-pads were designed to prevent capture, retention, replay and transmission of PINs. The same design approach can be applied to biometrics, by implementing a secure stored-biometric measure in a personal card, and installing a secure capture and processing module in the authentication device (Clarke 2003a). This has recently become more common in the form of separation of Authentication of an individual's Entity Assertion to their personal device (e.g. mobile phone, tablet) from Authentication to a remote service of the device's Entity Assertion and/or of each process's Identity Assertion.

(2) The Effectiveness of Other Business Processes

The widespread availability of high-capacity information infrastructure since the 1990s has had impacts on many aspects of organisational and individual activity. One key aspect is greatly increased institutional distance. For example, until the turn of the century, consumer credit business processes embodied a blend of Authentication of both category (2) and category (3) Assertions, because they were 'high-touch' in nature. Since then, most business enterprises have abandoned such labour-intensive approaches, and are now remote from their clients, making their decisions on the basis of a Digital Persona rather than the person (Clarke 1994a, 2014). Moreover, the recent fashions of big data, data analytics and AI/ML, by increasing the volume and diversity of data being used, and decreasing the transparency of the decision process, have greatly increased the scope for erroneous inferences. Authentication of category (3) Assertions are curtailed or dropped, and the much weaker form of Authentication of category (2) Assertions relied upon instead, because they are easily automated and inexpensive and quick.

These factors have given rise to greatly increased scope for faulty business decisions. These are not limited to the example used in the previous paragraph, consumer credit, but pervade many other application areas as well. Some of the harm directly affects the organisation sponsoring the system, e.g. through faulty evaluations of loan-worthiness. In many cases, however, the harm is suffered by users and usees. The infliction of harm may not come to the organisation's attention for some time, resulting in reputational risk. Imprecisions in the models underlying identity management schemes exacerbate these risks, and hence far greater care is needed in IS design than in the past. There are few signs, however, that appropriate changes are being made to safeguards, controls and mechanisms for redress.

(3) The Economics of IS Design

Ineffective identity management can have efficiency and financial impacts. Reduced reputation harms market-share and sales volumes, and hence increases the gross profit margin needed to cover the overheads. In industry sectors in which consumer protection and other regulatory mechanisms exist, the scope exists for customer complaints numbers to rocket, and with that complaints-handling costs. Restitution and redress to individual complainants can be greatly exceeded by even the legal costs of a class action, and swamped by a class action damages settlement.

The previous sub-section also noted the concerns of individuals about Entification processes and biometrics, about a consolidated Digital Persona, and about the risks of data-leakage and and manipulation that both give rise to. Identification processes are of particular concern where organisations have the capacity to inter-link multiple of a person's many Identities. This results in tensions between the organisation and individual users, both employees of the sponsoring organisation and external users. Those tensions play out in avoidance, obfuscation, falsification, and lowered ethicality of behaviour and loyalty among individuals with whom the organisation interacts, and in many cases on which it depends.

Identity Authentication, and particularly Entity Authentication, are expensive, both in terms of financial costs and negative impacts on users and usees. This raises the question as to whether the Authentication of other forms of Assertion may be able to deliver sufficient assurance to an organisation, and to be performed materially less expensively. Property Authentication can be achieved in many contexts without having to perform (Id)Entification and (Id)Entity Authentication processes. In addition, the prior paper which presents a generic theory of authentication identifies several other Assertion-categories that can be effective in satisfying organisations' needs, and can be at the same time more efficient. These are Fact Assertions, Content Integrity Assertions, Liquid-Asset Value Assertions and Non-Liquid-Asset Value Assertions (Clarke 2023).

Remarkably few sources have been located that give systematic consideration to the Authentication of Assertions other than of (Id)Entity. Exceptions include Clarke (2001), which argued that "parties [need to] know what is being authenticated" (p.148), and gave examples of Value and Attribute Assertions; Rauniar et al. (2002), which distinguished user authentication, smartcard authentication and card-reader authentication; and Clarke (2003b), which listed "Assertions important to eBusiness" as extending to organisational and artefact Entities and Identities, Attributes, Agency (referred to in this paper as a Principal-Agent Assertion), Location and Value. The absence of serious treatment in the literature is remarkable given the relative ease and inexpensiveness of Authentication of some of the other categories of Assertion, at least in a proportion of the circumstances in which activities are conducted.

(4) Stakeholder Interests

The primary focus in the first three sub-sections above has been the interests of the organisational sponsor of the particular IS. This final sub-section broadens the view to encompass stakeholders generally.

Many circumstances arise in which Authentication of any category of Assertion, and Authentication of (Id)Entity Assertions in particular, involve clashes of values between the system sponsor and individual users and usees. In some of those circumstances, the tension is intrinsic and largely unavoidable. For example, in both the lending and the insurance sectors, the contracting organisation is unlikely to be able to protect their financial interest unless key Assertions by the other party can be reliably authenticated. Similarly, government agencies that make transfer payments to the needy have an obligation to authenticate the claims made by each applicant. There are many circumstances, however, in which an appreciation of the full range of Authentication possibilities may enable the discovery of scope for the organisation to adopt less intrusive process designs. Individuals live their lives in enormously varied circumstances. Organisations that understand particular customer segments may be able to offer alternative Assertion-Authentication channels for, say, the seriously sight- or mobility-impaired, or for victims of domestic violence who are currently taking great care not to disclose their whereabouts.

More generally, many people are concerned about the conflation of their separate Identities. Some have reasons that derive from a desire for physical safety, others because of an enclosed disposition, some because of embarrassing personal histories, and of course some for reasons that may deleteriously affect the interests of an organisation they deal with. All such categories of people are likely to be concerned about the conflation of roles that they perform on behalf of an employer, with their roles on behalf of associations, clubs, their families, and their friends. Some people are even more concerned about the conflation of their Identities with multiple consumer marketing corporations, and even more so as public-private partnerships proliferate, government agency databases are compromised, and a movement gathers steam that began as a gleam in the eye of a Google CEO and Chair: the high-tech, corporatised-government State (Schmidt & Cohen 2013). This risk is inherent in Entifiers, but also increasingly common with Identifiers, where governments and consumer marketing corporations alike invest heavily in the consolidation of personal data into a singular Digital Persona. Many individuals are very concerned about the enablement of surveillance and manipulation, the creation of 'honey-pots' that attract third parties, the inevitable abuse of insider privileges, and leakage of sensitive personal information.

Arguments can be advanced for organisations to take individuals' interests into account for ethical, consumer rights or social responsibility reasons. Leaving those aside, however, organisational self-interest may well be best served by recognising the extent to which individual user behaviour, especially among employees and contractors, and usee behaviour, may not be what the organisation prefers. Specifically, individuals' behaviour may include objections, non-adoption, noncompliance, avoidance, obfuscation, falsification, quiet sabotage, and whistleblowing. These drive up an organisation's costs, and drive down its internal morale and its external reputation. Opportunities exist to apply insights from the model and analysis presented in this paper to envision and implement satisfactory forms of Authentication that are less burdensome and intrusive for individuals and less expensive and otherwise harmful for organisations.

The focus of this paper has been, throughout, on IS practice and practice-relevant IS research. Mention also needs to be made, however, of the broader issues that arise from the application of the pragmatic metatheoretic model to (id)entity. The axiological aspects of the model highlight the inadequate attention paid by both IS practice and research to values, and particularly the interests of users and usees. Further work is needed to draw out the implications of this work for professionally responsible IS design.

5 Conclusions

This paper has built on a previously-published pragmatic metatheoretic model, that is intended to reflect the Real World and the Abstract Worlds as they are understood, manipulated and applied in IS practice and practice-oriented IS research. It has drawn further on a previously-published extension of that model into the identity management space, and a generic theory of Authentication of Assertion categories relevant to IS.

The first contribution of this paper is a body of theory that identifies categories of Assertion that involve (Id)Entity, outlines key requirements of processes for the Authentication of those Assertion categories, describes the forms that may be taken by Evidence that can support those processes, and provides a framework for the evaluation of Data Quality and Information Quality of that Evidence.

A second area of contribution is the discussion of the implications of this body of theory for IS practice, and for the organisations that depend on the products of IS practitioners. Proposals are made for improvements in effectiveness and efficiency within the frame of reference used by the organisations that utilise IS. Further proposals are made that reflect the somewhat different worldviews of those organisations' employees, customers and suppliers, and of usees, who are affected by but do not directly participate in the system.

The analysis presented in this paper also identifies a number of weak spots in IS and practice, and points towards ways to address them. The most significant weakness, visited at multiple points in the paper, is the conflation of the concepts of Identity and Entity, and how that plays out in faulty business models and ineffective, inefficient and unpopular business processes. Another area in which considerable scope exists for insightful work is the ways in which organisations, as Virtual Things, are represented within IS models, and how the reliability of Assertions relating to them can be evaluated. For example, see Eriksson & Ågerfalk (2022).

Beyond these implications for IS practice, new directions for practice-oriented IS research are opened up. More illustrations and applications of the model will deliver deeper insights that offer value in particular contexts. Some industry sectors deal in natural objects and passive artefacts, both physical and virtual, whose Properties may demand refinements and extensions of a model and theory that are intentionally somewhat generic.

Active artefacts, again both physical and virtual, are increasingly being conceived and injected into IS. There is current controversy concerning the extent to which active artefacts can reliably be delegated the power to infer, decide and act in isolation, or need to be oriented towards decision support roles, working closely with humans. The elements of the above analysis of (Id)Entification, and of the Authentication of (Id)Entity Assertions, provide what may prove to be valuable perspectives on that problem-domain.

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References

Abbas R. & Michael K. (2022) 'Socio-Technical Theory: A review' In S. Papagiannidis (Ed), 'TheoryHub Book', TheoryHub, 2022, at https://open.ncl.ac.uk/theories/9/socio-technical-theory/

Altinkemer K. & Wang T. (2011) 'Cost and benefit analysis of authentication systems' Decision Support Systems 51 (2011) 394-404

Avison D. & Fitzgerald G. (2006) 'Information Systems Development - Methodologies, Techniques & Tools' McGraw Hill, 4th ed., 2006

Basul A. & Muylle S. (2001) 'Achieving Authentication in Electronic Markets: A Principal-Agent Perspective' Proc. 8th Research Symposium on Emerging Electronic Markets, Maastricht, The Netherlands, September 2001, at https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=538ce0bbebb44ce0159 95e3e5122092a3fa93171

Baumer E.P.S. (2015) 'Usees' Proc. 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI'15), April 2015, at http://ericbaumer.com/2015/01/07/usees/

Berleur J. & Drumm J. (Eds.) (1991) 'Information Technology Assessment' Proc. 4th IFIP-TC9 International Conference on Human Choice and Computers, Dublin, July 8-12, 1990, Elsevier Science Publishers (North-Holland), 1991

Brands S.A. (2000) 'Rethinking Public Key Infrastructures and Digital Certificates: Building in Privacy' MIT Press, 2000

Breward M., Hassanein K. & Head M. (2017) 'Understanding Consumers' Attitudes Toward Controversial Information Technologies: A Contextualization Approach' Information Systems Research 28,4 (2017) 760-774

Brown A.D. (Ed.) (2020) 'The Oxford handbook of identities in organisations' Oxford University Press, 2020

Carpenter D.R., McLeod A.J. & Clark J.G. (2008) 'Using Biometric Authentication to Improve Fire Ground Accountability: An Assessment of Firefighter Privacy Concerns' Proc. AMCIS 2008, at 11

Chaum D. (1985) 'Security Without Identification: Transaction Systems To Make Big Brother Obsolete' Communications of the ACM 28, 10 (October 1985) 1030-1044, at https://dl.acm.org/doi/pdf/10.1145/4372.4373

Clarke R. (1992) 'Extra-Organisational Systems: A Challenge to the Software Engineering Paradigm' Proc. IFIP World Congress, Madrid, September 1992, PrePrint at http://www.rogerclarke.com/SOS/PaperExtraOrgSys.html

Clarke R. (1994a) 'The Digital Persona and its Application to Data Surveillance' The Information Society 10,2 (June 1994) 77-92, PrePrint at http://www.rogerclarke.com/DV/DigPersona.html

Clarke R. (1994b) 'Human Identification in Information Systems: Management Challenges and Public Policy Issues' Information Technology & People 7,4 (December 1994) 6-37, PrePrint at ://www.rogerclarke.com/DV/HumanID.html

Clarke R. (1999) 'Identified, Anonymous and Pseudonymous Transactions: The Spectrum of Choice' Proc. Conf. User Identification & Privacy Protection Conference, Stockholm, June 1999, PrePrint at http://www.rogerclarke.com/DV/UIPP99.html

Clarke R. (2001a) 'The Fundamental Inadequacies of Conventional Public Key Infrastructure' Proc. Conf. ECIS'2001, Bled, Slovenia, 27-29 June 2001, PrePrint at http://www.rogerclarke.com/II/ECIS2001.html

Clarke R. (2001b) 'Authentication: A Sufficiently Rich Model to Enable e-Business' Xamax Consultancy Pty Ltd, 19 October 2001, at http://www.rogerclarke.com/EC/AuthModel.html011019.html

Clarke R. (2002a) 'Personal Notes on Computers, Freedom & Privacy 2002' CFP'22, San Francisco, Xamax Consultancy Pty Ltd, 16-19 April 2002, at http://rogerclarke.com/DV/NotesCFP02.html

Clarke R. (2002b) 'Why Do We Need PKI? Authentication Re-visited' Xamax Consultancy Pty Ltd, Presentation at the 1st Annual PKI Research Workshop, at NIST, Gaithersburg MD, April 24-25, 2002, at http://www.rogerclarke.com/EC/PKIRW02.html

Clarke R. (2003a) 'The Scope for Privacy-Sensitive Biometric Architecture' Xamax Consultancy Pty Ltd, February 2003, at http://www.rogerclarke.com/DV/BioArch.html

Clarke R. (2003b) 'Authentication Re-visited: How Public Key Infrastructure Could Yet Prosper' Proc. 16th Bled eCommerce Conf., June 2003, PrePrint at http://www.rogerclarke.com/EC/Bled03.html

Clarke R. (2004) 'Identity Management: The Technologies Their Business Value Their Problems Their Prospects' Xamax Consultancxy Pty Ltd, March 2004, 66 pp., at http://www.xamax.com.au/EC/IdMngt-Public.pdf

Clarke R. (2008) 'Dissidentity: The Political Dimension of Identity and Privacy' Identity in the Information Society 1,1 (December, 2008) 221-228, PrePrint at http://www.rogerclarke.com/DV/Dissidentity.html

Clarke R. (2009) 'A Sufficiently Rich Model of (Id)entity, Authentication and Authorisation' Proc. IDIS 2009 - The 2nd Multidisciplinary Workshop on Identity in the Information Society, LSE, London, 5 June 2009, at http://www.rogerclarke.com/ID/IdModel-090605.html

Clarke R. (2014) 'Promise Unfulfilled: The Digital Persona Concept, Two Decades Later' Information Technology & People 27, 2 (Jun 2014) 182-207, PrePrint at http://www.rogerclarke.com/ID/DP12.html

Clarke R. (2016) 'Big Data, Big Risks' Information Systems Journal 26, 1 (January 2016) 77-90, PrePrint at http://www.rogerclarke.com/EC/BDBR.html

Clarke R. (2021) 'A Platform for a Pragmatic Metatheoretic Model for Information Systems Practice and Research' Proc. Austral. Conf. Infor. Syst. (ACIS), December 2021, PrePrint at http://rogerclarke.com/ID/PMM.html

Clarke R. (2022) 'A Reconsideration of the Foundations of Identity Management' Proc. 35th Bled eConference, June 2022, pp.1-30, PrePrint at http://rogerclarke.com/ID/IDM-Bled.html

Clarke R. (2023) "A Generic Theory of Authentication to Support IS Practice and Research' Xamax Consultancy Pty Ltd, January 2023, at http://rogerclarke.com/ID/PGTA.html

Clarke R. & Davidson R.M. (2020) 'Through Whose Eyes? The Critical Concept of Researcher Perspective' J. Assoc. Infor. Syst. 21, 2 (March-April 2020) 483-501, PrePrint at http://rogerclarke.com/SOS/RP.html

Coneybeare F.C. (1892) 'Professor Clifford on the Soul in Nature' The Monist 2,2 (January 1892) 209-224, at https://www.jstor.org/stable/27896942

Eaton B., Hallingby H.K., Nesse P.-J. & Hanseth O. (2014) 'Achieving Payoffs from an Industry Cloud Ecosystem at BankID' MIS Quarterly Executive 13,4 at 6

Elgarah W. & Falaleeva N. (2005) 'Adoption of Biometric Technology: Information Privacy in TAM' Proc. AMCIS 2005, at 222

Eriksson O. & Ågerfalk P.J. (2022) 'Speaking things into existence: Ontological foundations of identity representation and management' Information Systems Journal 32,1 (2022) 33-60, at https://onlinelibrary.wiley.com/doi/full/10.1111/isj.12330

Fairchild A.M., O'Reilly P., Finnegan P. & Ribbers P.M. (2007) 'Multi-Criteria Markets: An Exploratory Study of Market Process Design' Electronic Markets 17,4, (Nov 2007) 286-297, at http://www.electronicmarkets.org/fileadmin/user_upload/doc/Issues/Volume_17/Issue_04/V17I4_Multi-Criteria_Markets__An_Exploratory_Study_of_Market_Process_Design.pdf

Fischer-Huebner S. & Lindskog H. (2001) 'Teaching Privacy-Enhancing Technologies' Proc. IFIP WG 11.8 2nd World Conf. on Information Security Education, Perth, Australia

Gottwald S. (2001) 'A Treatise on Many-Valued Logics', January 2001, at https://www.researchgate.net/profile/Siegfried-Gottwald/publication/259645593_A_Treatise_on_Many-Valued_Logics/links/00b7d5324ce793473c000000/A-Treatise-on-Many-Valued-Logics.pdf

Haider A. (2008) 'Believable Unbelievable Internet Based Information' Proc. ACIS 2008, at 93

Halperin R. & Backhouse J. (2008) 'A roadmap for research on Identity in the information society' Identity in the information society journal 1,1 (2008) 71-87, at https://link.springer.com/article/10.1007/s12394-008-0004-0

Hewitt B. (2009) 'Using a Hybrid Technology Acceptance Model to Explore How Security Measures Affect the Adoption of Electronic Health Record Systems' Proc. AMCIS 2009, at 328

IETF (2022) 'RFCs' Internet Engineering Task Force (IETF), December 2022, at https://www.ietf.org/standards/rfcs/

Kambil A. & van Heck E. (1998) 'Reengineering the Dutch Flower Auctions' Information Systems Research 9,1 (March 1998) 1-19

Magnusson A. (2022) 'The Definitive Guide to Authentication' Strong DM, September 2022, at https://www.strongdm.com/authentication

Michael K. & Michael M.G. (2009) 'Innovative Automatic Identification and Location-based Services: From Bar Codes to Chip Implants' Information Science Reference, 2009

Mumford E. (2006) 'The story of socio-technical design: reflections on its successes, failures and potential' Info Systems J 16 (2006) 317-342, at https://executiveinsight.typepad.com/files/the-story-of-socio-technical-design.pdf

Nyst C., Makin P., Pannifer S. & Whitley E. (2016) 'Digital identity: Issue analysis: Executive summary' Consult Hyperion, 2016

OASIS (2005) 'SAML V2.0 Standard' OASIS, March 2005, at https://wiki.oasis-open.org/security/FrontPage

Rauniar R, Rauniar D., Shakya S. & Urcuyo C. (2002) 'A Mutual Authentication Scheme for Low Cost Smart Card Applications' Proc. AMCIS 2002, at 265

Ryan T.W. & Marett K. (2010) 'The Influence of Experiential and Dispositional Factors in Phishing: An Empirical Investigation of the Deceived' Journal of Management Information Systems 27,1 (Summer 2010) 273–303

Schmidt E. & Cohen J. (2013) 'The New Digital Age: Reshaping the Future of People, Nations and Business' Knopf, 2013

Stevens S.S. (1946) 'On the Theory of Scales of Measurement' Science 103, 2684 (7 June 1946), at https://psychology.okstate.edu/faculty/jgrice/psyc3120/Stevens_FourScales_1946.pdf

Way S.C. & Yuan Y. (2009) 'Criteria for Evaluating Authentication Systems' Proc. AMCIS 2009, at 338

Witman P. (2006) 'Anti-Phishing Strong Authentication Technology Options' Proc. AMCIS 2006, at 131

Zviran M. & Erlich Z. (2006) 'Identification and Authentication: Technology and Implementation Issues' Commun. Assoc. Infor. Syst. 17,4 (2006) 90-105

Supplementary Materials

Glossary, at http://rogerclarke.com/SOS/FDI.html#G
'The Authentication of Assertions Relating to (Id)Entity',
a comprehensive Working Paper from which the present paper is drawn, at
http://rogerclarke.com/ID/IEA.html

DECISION ANALYTICS - A POSITION PAPER

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The context we address is the 'digital or new economy' for which we propose that Decision Analytics will be one of the key drivers. The reasons are that we need to both meet the challenges from big data/fast data and to work out new possibilities to make experience and expert knowledge accessible and usable for local, ad hoc decision makers and for automated, intelligent systems. Digitalisation brings increasing competition, slimmer margins for productivity and profitability and more pronounced requirements for effective planning, problem solving and decision making. This requires a transfer of (sometimes tacit) knowledge from experts and experi-enced people to novice system operators—and to automated, intelligent systems—a transfer we call knowledge mobilisation. We will work out reasons for why Decision Analytics will be a key part of knowledge mobilisation and an essential contribution to the development of instruments we need for the progress of digitalisation.

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1 Introduction

INFORMS defines Operational Research and Management Science (OR/MS) as "the scientific process of transforming data into insights to making better decisions". OR/MS was the forerunner to analytics.

In a recent report called "Competing in 2020: Winners and Losers in the Digital Economy" [16] Harvard Business Review worked out the impact digitalisation will have in some key industrial sectors. Among the respondents 16% stated that their companies are digital (most products/operations depend on digital technology), 23% that they are non-digital (few if any products/operations depend on digital technology), and 61% that they are hybrid (some products/operations depend on digital technology).

The report found a significant performance gap between digital leaders ("digi-tals") and the rest ("non-digitals"): 84% of the digitals use big data and analytics, but only 34% of the non-digitals; 51% of the digitals use cognitive computing/AI, but only 7% of the non-digitals; the digitals have data science and data engineering on staff (62%), the non-digitals much fewer (20%); all professionals working for the digitals have the ability to work with and make sense of data and analytics (76%), not that common for the non-digitals (30%). The insight is that a strong analytics capability is key to digital business—companies that want to compete in the digital economy will have to invest in people, processes and technology that offer access to data and knowledge and skills in analytics.

One more detail—artificial and machine intelligence appear as key interests and concerns among the business leaders [16]; the formulation is that "future success will depend on the successful collaboration between human and machine intelligence".

Digitalisation is bringing big data (or "fast data" for streaming big data) which more recently has been claimed to make it impossible to use analytics as huge amounts of data make the algorithms impossible or impractical to use [4, 8]—or it will take too much time as fast decision making in almost real-time is a necessity in the digital economy ("the fast eat the slow" as the slogan goes). If there is time to make bad decisions (by guessing instead of using effective (but more demanding) instruments) there should also be time to make good decisions—we only need to know how and what instruments to use. The following tale offers some insight on analytics – it offers alternatives to approaches based on closed, secret and mysterious data sets.

Kahneman [18] relates the case of Orley Ashenfelter, a Princeton economist and wine lover, who wanted to find a way to predict the future value of fine Bor-deaux wines from information available in the year they are made. The experts taste the wine and use decades of experience and insight in the wine markets to decide future values. Ashenfelter, an economist, used multiple regression analysis and statistics tools as he had no possibility to actually taste exclusive Bordeaux wines. He collected statistics on London auction prices for select mature red Bordeaux wines 1990–1991. The quality of Bordeaux wines was found to be decided by (i) the age of the vintage, (ii) the average temperature over the growing season (April–September), (iii) the amount of rain in September and August (less rain gives better wine), and (iv) the amount of rain preceding the vintage (October–March). These four factors are all measurable, published and easily verifiable —tasting wines and making judgments has of course its benefits. Aschenfelter built a regression model with the four factors on vintages 1952–1980, which turned out to explain about 80% of the variation in the average price of Bordeaux wine vintages! We should notice that Aschenfelter is a professional—he avoided the fallacy of small samples and made sure that he had observations on large selections of wine over 10 years from six major century-old Bordeaux chateaux and limited his models to Bordeaux to reduce the number of external (but actually irrelevant) factors. Aschenfelter, in fact, follows what we describe as time-tested, good analytics practice: use facts and data that can be tested and verified, methods that can be validated for repeated use to work out insight that is useful, valid, and verifiable.

In Section 2 we will bring out some experience from the forest industry to show why it makes sense to take a couple of analytical steps beyond visualisation to gain insight; in Section 3 we show how Decision Analytics methods identify the core of a decision problem and clean out secondary problem elements that confuse the issues; in Section 4 we have summarized some points on what is required of Decision Analytics as a developed and effective approach for the decision context of the 'digital or new economy'; Section 5 collects a summary and some conclusions.

2 Lessons from the Forest Industry

The demand for fine paper products is slowly declining at 2-3% per year but has been rather stable for the last 10 years. Nevertheless, a paper mill we worked with showed significant variations in orders coming from the supply chain, variations that appear to be random and unexplainable. The managers had tried to use optimisation models, which did not work – they even suspected that the optimisation was part of the problem. One of the managers mentioned that he had heard about a "bullwhip effect" as a possible description of the supply chain problems, and that it involved some fairly tough mathematics.

Lee et al [19, 20] carried out some early, more systematic theoretical work and focused on distorted information as a driver of the bullwhip effect. They found that the bullwhip effect describes increasing variance in orders as they move up a supply chain (from customer trough retailer and wholesaler to producer), even when underlying customer demand shows only a small or even negligible variance. The reason seems to be that the retailer "improves" on the orders that customers place; there are many customers, and their demand estimates show variances that are judged not to be reliable – "they are not professionals on market dynamics". The retailers make their own demand estimates from "im-proved" customer estimates; the wholesaler gets orders from many retailers that show variations in estimated demand and "improves" on retailer orders when placing orders with the producer (the paper mill). Lee et al [19, 20] show that estimates over time of the actual demand get distorted as orders move up the supply chain.

The intuition is that this cannot be a big problem, but the paper mill managers listed several problems, that were later confirmed by the literature (cf. Lee et al. [19, 20], Carlsson-Fullér [2, 3]). The supply chain actor "improvements" build excessive inventory as the actors safeguard themselves against the variations. The safeguards will cause some part(s) of the supply chain to run out of products as actors overestimate their safety margins when deciding on orders; local shortages result in poor customer service and shortages result in lost revenue. Lost revenue translates to substandard productivity of capital allocated to operations.

On the corporate level the storyline is a bit different from the supply chain operations because of aggregated data: demand variations cause variations in the logistics chain and the planned use of transportation capacity; ad hoc changes will result in suboptimal transportation schemes and increase transportation costs; demand fluctuations caused by the bullwhip effect may unnecessarily change optimal production schedules, which shows up (much later) as increased production costs.

Lee et al [19, 20] found four reasonable operations that active supply chain actors could undertake to tackle variations. The first operation is to update demand forecasts when data shows that next period demands will be different. Forecasts are built with time series analysis of historical demand patterns from immediate customers. Then, only retailers build on actual customer demand patterns, the other actors adjust to (perhaps unmotivated) fluctuations in the orders of preceding actors. It appears that safety stocks, which are popular smoothing instruments, also will amplify the bullwhip effect [20] as they are optimal locally and subjectively for one actor but send the wrong signals up-stream.

The second operation is order batching: periodic ordering and push-ordering. The costs for frequent order processing may be high and attract customers to optimised periodic ordering schemes - which in most cases will destroy custom-er demand patterns. Standard MRP-systems use analytics models to decide optimal order size and frequency, and to activate periodical orders. Push-ordering occurs as upstream actors (working for producers, wholesalers, retailers) launch “special offers” to induce (non-optimal) out-of-period orders. This, again, contributes to variance in customer orders and destroys actual demand patterns, which contributes to the bullwhip effect.

The third operation builds up on price variations. The producers initiate and control price changes both in the long- and short term. Customers are encour-aged to buy in larger quantities by attractive offers on quantity discounts, in special price campaigns, through coupons or rebates. Then the buying patterns do not necessarily reflect consumption patterns - customers buy in quantities which do not reflect their needs. This will initiate and amplify the bullwhip effect.

Rationing and shortage gaming drives the fourth operation, which is initiated if/when demand exceeds supply. If the producers, even once, have met shortages with rationing of customer deliveries, customers start to exaggerate their real needs if there is fear that supply will not cover demand. This starts a bullwhip effect, which will grow if customers are allowed to cancel orders when their real demand is satisfied (and their gaming gets no downside cost).

These four causes/drivers of the bullwhip effect may be hard to monitor, and even harder to control in the industry. They may interact, and/or act in concert, and the resulting combined effects are not clearly understood, neither in theory nor in practice, which offer challenges for tackling them with decision analytics modelling.

In the real business case seasoned managers recognized the drivers of the bull-whip effect from their own experience and worked out some practical (producer) solutions: (i) share information with all supply chain down-stream actors; (ii) build channel alignment of pricing, transportation, inventory planning and ownership (if legal within antitrust legislation); and (iii) reduce order processing costs and shorten lead times to improve on operational efficiency. These (practical) steps make sense but there are two challenges - to adapt them to EU regulations controlling cartel-building and to develop decision analytics instruments to find optimal solutions.

In section 3 we will show how Decision Analytics methods identify the core of a decision problem and find solutions.

3 Analytics Modelling Guides Problem Solving

We will stay with the supply chain context and focus on the retailer-wholesaler stage as a retailer reacts to the actual demand from customers. We will add to the context description: consider a multiple period supply process where demand is non-stationary over time and demand forecasts are updated from observed demand.

Assume that the retailer gets orders representing a much higher demand in one period, interprets it as a signal of increasing demand in the future, adjusts demand forecasts for future periods, and places a larger order with the wholesaler. The demand is non-stationary, and an optimal ordering policy should also be non-stationary; non-stationary ordering increases the variance of the orders which starts the bullwhip effect. Another factor is the lead-time between the ordering point and the point of delivery; if this is long, uncertainty increases and gets the retailer to add some "safety margin" to the order, which increases the variance and adds to the bullwhip effect.

For analytics modelling we will simplify the context even further by focusing on a single product, (the models can be extended to multiple items and to batches of products), and inventory for multiple periods.

The process has the following structure: at the beginning of period t, the retailer decides to order a quantity z_t. This is called the decision point for period t. Next, goods ordered ν periods ago arrive. Retailer demand is fulfilled, and the available inventory is used to meet customer demand. Excess demand is backlogged until the next decision point. Lee at al [20] (cf. also [2, 3]) assume that the retailer faces serially correlated demands which follow the stochastic process,

$$D_t = d + \varrho D_{t-1} + u_t$$

where D_t is the demand in period t, ϱ is a constant satisfying $-1 < \varrho < 1$, and u_t is a random variable, normally distributed with zero mean and variance σ^2. Here σ^2 is assumed to be significantly smaller than d, a "usual" level of demand presumed to exist at any t, so that the probability of a negative demand is very small. The use of d is technical to avoid negative demand, which will destroy the stochastic process and make the analytics model useless.

The order quantity, which is found with a cost minimization model, is an optimal ordering policy and sheds some new light on the bullwhip effect. The effect gets started by rational decision making, which decides a precise order amount and time for delivery; there is not much hope to avoid the bullwhip effect by changing the ordering policy, as it is difficult to motivate people to act in an irrational way.

As an optimal, precise ordering policy drives the bullwhip effect we decided to modify the policy with imprecise order amounts that can be made more specific as the time of delivery gets closer. The order amounts can be intervals, which will be made more precise over time (communicating over some joint digital platform).

We worked out such a policy where intervals replaced the precise order amounts; for this we need to add a few more instruments to analytics modelling, fuzzy numbers. A fuzzy number A is a fuzzy set [5] of the real line $\mathbb{R}$ with a normal, (fuzzy) convex and continuous membership function of bounded support.

In [1] we proved a theorem that fuzzy subsets entail smaller variance (Var): let A, B $\in \mathscr{F}$, a family of fuzzy sets, with $A \subset B$. Then $Var(A) \leq Var(B)$. Then, if we develop better and better estimates of future sales in period t, D_t, we can reduce the variance of z_t by replacing the rule for optimal order amount with an adjusted rule. Fuzzy subsets entail smaller variance and $Var(z_{it}) < Var(z_{*t})$, i.e., the variance of z_{it} will get smaller as $D_t(i)$ gets closer to the point of order delivery, and the bullwhip effect can be eliminated. This was now carried out for demand signal processing; fuzzy (imprecise) numbers can be applied also to price variations and - with some more modelling efforts - to cases with rationing games and order batching.

The analogy with Kahneman and Ashenfelter [18] is that we found some simple, fact-based mechanism that works with data that can be tested and verified, and that we found to drive the bullwhip effect. We also noted that the four practical operations – demand forecast updates, order batching, price variations and shortage gaming – in effect mostly add complexity to the storyline without offering effective means to reduce or eliminate the bullwhip effect from supply chain operations. This illustrates Kahneman's point that "experts try to be clever … to work with (too) complex combinations of features".

4 An Agenda for Decision Analytics

Ciancimino et al [15] identifies distorted demand information – as we found out in sections 2-3 – as a key driver; in addition to this they also single out disintegrated material flow and lack of replenishment rule alignment. This resulted in a shift of focus to bullwhip avoidance [15] and implementation of supply chain collaboration practices. These include alignment of planning, forecasting and replenishment systems among partners, which is made possible with digital exchange of information. This new idea is described as a Synchronised Supply Chain (SSC) [15]; it could of course not apply to industries with strong (EU) regulations that guide and secure open competition in all parts of the supply chain. On the other hand, the practical measures we collected from the paper mill supply chain – (i) share information downstream, (ii) channel alignment of pricing, transportation, inventory planning and ownership (if legal at least formally) and (iii) technical steps to improve operational efficiency (order processing costs, lead times) – are in line with the SSC archetype.

On the other hand, the imprecise order amounts that become more specific as the time of order delivery gets closer are not directly reducing competition in the supply chain and should not conflict with EU regulations. The sequence of order specifications can be done with secure digital platforms that SC partners share.

Transfer of accumulated expertise on how to manage large, complex, and dynamic processes from senior to novice engineers is a classical problem in industry. The transfer needs to be done as experienced engineers retire or decide to leave the company or are let go to save on salary costs. Digitalisation brought a new requirement—the accumulated expertise should somehow be transferred to automated intelligent systems. Experience that we gained from industrial cases [7, 9, 17] shows that expert insight is not easily transferred to novice replacements (or automated systems) with much less or no experience of the processes.

We called this process knowledge mobilisation [6, 22] and worked out a first attempt with analytics modelling [7]. We noted that analytics has not gained much support in the last couple of decades (we have found several "common wisdom" (CW) claims as explanations, but which appear not to have support in research results). The first CW-claim states that mobilised knowledge will be too limited, that simplifications clean out most of the insights on offer from a real-life context. The second CW-claim finds that experienced engineers do not work with mathematical programming models. The third CW-claim notes that mathematical programming models gives an impression of precise insight and knowledge; models come from simplifying assumptions that clean out ambiguities and imprecision. The fourth CW-claim states that there are better ways to mobilize tacit knowledge with experienced engineers than using analytics. There are, however, valid counter arguments to the claims in actual cases [21, 22]. If simplifications are made properly, they will single out core functions in interacting processes and reduce complexity.

The paper machine case [21] offered some insight on how to work out challenges that digitalisation has introduced. Our contention was that digitalisation should build on joint human/system reasoning that combines experience, insight, intuition, social interaction, etc. with support produced by automatic, intelligent systems, which in the paper machine case were combinations of mathematical optmisation tools and fuzzy ontology [21]. We assumed and believed that this would work and managed to develop some test cases [22]. A partial answer builds on digital coaching [10, 12, 13] that offers instruments for knowledge transfer from experienced users to novice users and from knowledgeable users to automated systems. It appears that decision analytics could/should be the optimisaion part of the digital coaching.

There is a context understanding for the 2020's and an emerging research position for Decision Analytics that we can summarize in a few statements (cf. also [14]); these descriptions will no doubt change and be updated as our understanding of digitalisation and digital economy increases and improves, but the starting point builds on the proposals {4.1-4.4}:

{4.1} In a context of digital disruption and quickly growing competition in the digital economy we have in-creasing dynamic and real-time processes, which require rapid and timely problem solving and decision making in an environment of large and growing sets of giga-data that contribute to increasing and difficult to tack-le complexity. *Decision Analytics develops and offers instruments for insightful and concise representation of problems in the digital economy.*

{4.2} Management theory and research, combined with long-time experience, guide problem-solving and decision making in the digital economy. *Digital Analytics develops and/or finds alternative and simpler forms for problem solving and decision making that also offer more insight.*

{4.3} Complex and competitive environments (like the supply chains of major industries) invite rapid problem solving with locally available data and supported with ad hoc insight through digital platforms and applications. *Digital Analytics will search for and/or work out methods that adapt to both (optimal) local and ad hoc problem-solving as well as to the general and generic principles for intelligent, automated systems.*

{4.4} Knowledge mobilisation offers and distributes insight and knowledge in complex and competitive environments in the digital economy. *Digital Analytics forms the core and common language for knowledge mobilisation over digital platforms.*

5 Summary and Some Conclusions

We propose that Decision Analytics will be one of the key drivers for what is called the 'digital or new economy' (cf. also [11]). Digitalisation brings increasing competition, slimmer margins for productivity and profitability and more pronounced requirements for effective planning, problem solving and decision making. We worked out reasons for why Decision Analytics will be essential for meeting the challenges from big data/fast data and for working out new possibilities for effective problem-solving and decision making based on experience and expert knowledge. Artificial and machine intelligence appear as key interests and concerns among the business leaders; the formulation is that "future success will depend on the successful collaboration between human and machine intelligence". We introduced "knowledge mobilisation" as instrumental for the human-machine collaboration; Decision Analytics is proposed as a key component in this collaboration.

We introduced a study we carried out with a forest products corporation. The demand for the fine paper products was basically rather stable but a paper mill showed significant variations in orders coming from the supply chain, variations that appear to be random and unexplainable. The managers had tried to use optimisation models, which did not work – they even suspected that the optimisation was part of the problem. One of the managers mentioned that he had heard about "the bullwhip effect" but added that "nobody has been able to work out the bullwhip effect for fine paper supply chains" a nice challenge for analytics researchers.

The work with the paper mill focused on finding some simple, fact-based mechanism that works with data that can be tested and verified to drive the bullwhip effect. The principle found was to build up orders as intervals (actually, as fuzzy numbers) that give flexibility to adapt to changes in downstream demand and will be made more precise as a delivery time gets closer. We also found that four practical operations – demand forecast updates, order batching, price variations and shortage gaming – mostly add complexity to the storyline without offering effective means to reduce or eliminate the bullwhip effect.

Further research resulted in a shift of focus to bullwhip avoidance and implementation of supply chain collaboration practices. The new ideas are described as "synchronisation of supply chain operations", which has attracted new re-search.

The paper mill offered some insight on how to work out challenges that digitalisation has introduced. Our contention was that digitalisation should build on joint human/system reasoning that combines experience, insight, intuition, social interaction, etc. with support produced by automatic, intelligent systems, which in the paper mill case were combinations of mathematical optimisation and fuzzy ontology. A partial answer to joint human/system reasoning builds on digital coaching that offers instruments for knowledge transfer from experienced users to novice users and from knowledgeable users to automated systems. Decision Analytics could/should be the optimisation part of digital coaching.

Finally, the context understanding and an emerging research position for Deci-sion Analytics formed an agenda proposal in four statements (cf. {4.1-4.4}).

References

C. Carlsson R. Fullér, Problem solving with multiple interdependent criteria, in: J. Kac-przyk, H. Nurmi, M. Fedrizzi (Eds.), Consensus under Fuzziness, Kluwer Academic Publishers, Boston, (1997), pp. 231–246.

C. Carlsson, R. Fullér, A fuzzy approach to the bullwhip effect, Cybernetics and Systems '2000, Proc. of the 15th European Meeting on Cybernetics and Systems Research, Vienna, April 25 –28, 2000, Austrian Society for Cybernetic Studies, (2000), pp. 228–233.

C. Carlsson, R. Fullér, Reducing the bullwhip effect by means of intelligent, soft computing methods, in: Proc. of the 34th Hawaii Internat. Conf. on System Sciences (HICSS-34), Island of Maui, Hawaii, USA, January 3– 6, (2001).

C. Carlsson, Soft computing in analytics: handling imprecision and uncertainty in strategic decisions, Fuzzy Econ. Rev. XVII (2) (2012) 3–21.

C. Carlsson, J. Mezei, M. Brunelli, Decision making with a fuzzy ontology, Soft Computing 16 (7) (2012) 1143–1152.

C. Carlsson, J. Mezei, M. Brunelli, Fuzzy ontology used for knowledge mobilisation, Int. J. Intell. Syst. 28 (1) (2013) 52–71.

C. Carlsson, M. Brunelli, J. Mezei, A soft computing approach to mastering paper machines, in: Proceedings of HICSS-46, HICSS. 2013.61, IEEE (2013), pp. 1394–1401.

C. Carlsson, Imprecision and uncertainty in management—the possibilities of fuzzy sets and soft computing, in: NOEMA XV, Romanian Academy of Science, (2016), pp. 89–114.

C. Carlsson, M. Heikkilä, J. Mezei, Fuzzy entropy used for predictive analytics, in: C. Kahraman, U. Kaymak, A. Yazici (Eds.), Fuzzy Logic in its 50th Year. New Developments, Directions and Challenges, Studies in Fuzziness, Springer, 341, (2016), pp. 187–210.

C. Carlsson, Decision Analytics Mobilised with Digital Coaching, Intelligent Systems in Accounting, Finance and Management, ISAF1421, January/March, (2018), pp 3-17 DOI: 10.1002/isaf.1421

C. Carlsson, Decision Analytics – Key to Digitalization, Information Sciences, Vol 460-461, September (2018), pp 424-438

C. Carlsson, Combining ANFIS and Digital Coaching for Good Decisions in Industrial Processes, IFSA/NAFIPS'2019 (Lafayette, Louisiana, USA, June 18–21, 2019) Proceedings, Springer Verlag (2019), pp 190-200

C. Carlsson, Digital Coaching to Make Fuzzy Real Options Methods Viable for In-vestment Decisions, FUZZ-IEEE 2019 Proceedings, New Orleans (2019), pp 406-411, 978-1-5386-1728-1/19 ©2019 IEEE

D. Cecez-Kecemanovic, Doing critical information systems research – arguments for a critical research methodology, Eur. J. Inf. Syst. 20 (2011) 440–455.

E. Ciancimino, S. Cannella, M. Bruccoleri and J.M. Framinan, On the Bullwhip Avoid-ance Phase: The Synchronised Supply Chain, EJOR, Vol 221, (2012), pp 49-63

Competing in 2020: winners and losers in the digital economy (2017), A Harvard Business Review Analytic Services Report, April 25, (2017).

J. Hirvonen, T. Tommila, A. Pakonen, C. Carlsson, M. Fedrizzi, R. Fullér, Fuzzy keyword ontology for annotating and searching event reports, Proceedings of International Conference on Knowledge Engineering and Ontology Development (KEOD 2010), Valencia, Spain, (2010).

D. Kahneman, Thinking Fast and Slow, Farrar, Straus and Giroux, New York, (2011)

H.L. Lee, V. Padmanabhan and S. Whang, Information distortion in a supply chain: The bullwhip effect, Management Science, 43(1997) 546-558.

H.L. Lee, V. Padmanabhan and S. Whang, The Bullwhip Effect in Supply Chains, Sloan Management Review, Spring (1997) 93-102

J. Mezei, M. Brunelli, C. Carlsson, A fuzzy approach to using expert knowledge for tuning paper machines, JORS 68 (6) (2017) 605–616.

J.A. Morente-Molinera, R. Wikström, C. Carlsson, E. Viedma-Herrera, A linguistic mobile decision support system based on fuzzy ontology to facilitate knowledge mobilization, Decis. Support Syst. 81 (2016) 66–75.

RESEARCH IN PROGRESS

THE ROLE OF IT IDENTITY IN THE FORMATION AND MITIGATION OF TECHNOSTRESS

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The pervasive and ubiquitous nature of technology has grown exponentially in the last decades. Technostress has been a common consequence of such intensive use, causing serious damage to IT users and organizations. How technostress is formed via primary appraisal toward IT and how it can be mitigated has been overlooked by prior research. This research addresses these gaps by mobilizing an IT identity perspective. IT identity informs about individuals' attitudes towards IT and would explain the formation of negative feelings associated with the use of IT as well as how technostress mitigation occurs in a personal IT use setting.

Keywords:
IT identity,
IT features,
technostress,
primary appraisal,
mitigation

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1 Introduction

The pervasive and ubiquitous nature of digital technologies has permeated every aspect of organizational and nonorganizational settings, creating important implications and challenges for Information Systems (IS) scholars and giving rise to the so-called *dark side of Information Technology (IT) use* (Tarafdar et al., 2013). This research stream argues that some of the features that make IT powerful (e.g., reliability, usefulness, portability, user-friendliness, and fast processing) can also threaten individual well-being due to IT-induced stress, technology dependency, or IT misuse (Tarafdar et al., 2010). Within this line of research, the phenomenon of technostress has received great attention (Ragu-Nathan et al., 2018). Technostress has been defined as the stress experienced by individuals due to the constant need to adapt to new and evolving IT functionalities (Califf et al., 2020). It has been traditionally conceptualized as a negative aspect resulting from the use of IT, associated with negative consequences such as low job satisfaction, productivity, and high turnover rates (Ayyagari et al., 2011). Due to this negative denotation, how to mitigate technostress has also emerged as an important but overlooked topic (Galluch et al., 2015). Prior research has focused on technostress mitigation from an organizational perspective, disregarding how technostress mitigation takes place in a personal use setting (Salo et al., 2022).

This research takes an IT identity perspective to answer the following research question: what is the role of IT identity in the formation and mitigation of technostress in a personal IT use environment? This research contributes to two underexplored areas. First, the role of IT identity in the formation of technostress via primary appraisal toward IT, and second, how IT identity affects technostress mitigation in a personal IT use environment. *IT identity* refers to the extent to which an individual perceives the use of an IT as part of who he/she is and answers the question "Who am I in relation to this technology?" (Carter & Grover, 2015). It is therefore tied to the individual level of analysis. Today's landscape is characterized by an increasing interlacing of IT and social routines as well as higher expectations from perpetual contact with IT in more complex social structures. IT identity informs about individuals' attitudes toward IT and would explain the formation of negative feelings associated with the use of IT. We posit that IT identity plays a key role in understanding the formation and mitigation of technostress because IT identity might lead to a successful self-verification of individuals' role identities and reduce feelings of technostress (Carter & Grover, 2015).

2 Motivation & Gap

First, although central to the understanding of the phenomenon of technostress, prior IS literature still did not fully explore the formation and shaping of individuals' primary appraisal toward IT (Tarafdar et al., 2019). An individual can evaluate IT as a challenge and a motivating factor or as a threatening and disturbing factor. A very limited number of studies have explored how individuals appraise the introduction of technologies and their impact on the formation and mitigation of technostress (Salo et al., 2022). Second, we push the boundaries of the 'user' concept that has been dominating the research stream of technostress. Although very insightful, the user concept does not cover the surroundings of the interaction between the sides of the technostress process (i.e., the person and the technological environment). As Lamb and Kling (2003) argue, users should be considered social actors. In fact, individuals are not merely and uniquely 'users' of IT, they are rather 'social actors' embedded in complex social settings; as '*their social roles and relationships are increasingly inseparable from their interactions with IT*' (Carter & Grover, 2015, p.931). We believe that the socially thin conceptualizations of individuals as merely users constitute a barrier to our understanding of such complex phenomena. Our study adopts this theoretical positioning by developing a model that captures, on the one hand, the technical and environmental settings that create technostress, and the intertwinement of social roles and IT usage in the other hand. Finally, our study mobilizes the IT identity lens to look at the formation and mitigation of technostress. IT identity helps captures the complexity of the intertwinement of IT and social structures. In fact, IT identity represents '*the set of meanings individuals attach to the self in relation to IT—as a product of individuals' personal histories of interacting with IT, as well as a force that shapes their thinking and guides their IT use behaviors*'. Thus, IT and social contexts in which individuals are embedded, are established in relation to each other and mutually and continually develop. The previous echoes with two core elements of technostress conceptualization. First, IT identity embodies the relationship between technology and social contexts as it considers IT as a social object, while technostress is theorized as a process that involves a transaction between the individual and the environment. Second, IT identity interferes with the shaping of attitudes toward IT and the use of IT while "primary appraisal" focuses on the individual's assessment of the extent of environmental demand and influences the relationship between technology environmental conditions and techno-stressors. In consequence, considering IT as a social object that individuals categorize themselves in relationship to would inform about the formation and mitigation of technostress.

3 Theoretical Background

3.1 Technostress: A Fragmented and Evolving Literature

The questions of how and why the use of IT generates various demands on the individual are at the heart of an emerging area of scholarly investigation in the IS domain, namely technostress (Ayyagari et al., 2011; Ragu-Nathan et al., 2008). The concept of technostress, derived from the stress concept in the psychological stress literature, refers to the dynamic process in which individuals perceive that the demands of using an IT exceed one's resources and are hard to meet (Ayyagari et al., 2011; D'Arcy et al., 2014; Galluch et al., 2015). The process includes (1) the presence of 'technology environment conditions', which are appraised as (2) demands or 'techno stressors' that are taxing the individual and require (3) coping responses resulting in (4) outcomes for the individual on the psychological, physical and behavioral levels.

Studies on technostress have substantially focused on its creators, the techno-stressors, and its outcomes. Little is known about the appraisal aspect, which unfolds how individuals appraise the technological environment conditions and interpret them as a threat and disturbing or as a challenge and opportunity (Califf et al., 2020). Indeed, our knowledge about technostress is built on 'fragmented investigation' and disparate focus on specific aspects (Tarafdar et al., 2019). For example, according to Tarafdar et al. (2019)'s literature review, the antecedents of technostress have received a considerable proportion of interest (see Ayygari et al., 2011). Technostress outcomes have also been, according to the same source, under great focus. Overall, previous research falls short to discuss how individuals appraise techno-stressors neither why they perceive digital technologies as disturbing and potentially harmful.

Primary Appraisal

One of the most overlooked dimensions of this process is the primary appraisal. Primary appraisal establishes and influences the relationship between technology environmental conditions and techno-stressors and informs about how negative feelings towards IT are formed (Tarafdar et al., 2019). Primary appraisal is the user's assessment of the expected consequences of an IT event (Beaudry & Pinsonneault, 2005). Rooted in cognitive theories, it argues that individuals, when disrupted, proceed to an evaluation of the nature of the situation: does this constitute an opportunity or a threat? Individuals also judge the personal relevance of the disrupting event and its potential consequences (Lazarus, 1966; Lazarus & Folkman, 1984). If demands are perceived as adequate to the resources, individuals could develop a positive attitude towards the event and feel it as an opportunity. If perceived as exceeding one's abilities, the individual will experience feelings of stress.

To answer this question, different theoretical frameworks have been mobilized. The Person-Environment (P-E) fit of stress (Cooper et al., 2001; Edwards 1991) has been adopted to argue the absence of equilibrium between the IT demands and the capacity of individuals to meet them (Ayyagari et al., 2011). Other studies used the prism of individual and organizational characteristics to explore which ones would favor perceiving technology environment conditions as threat-techno-stressors. On the individual level, examples range from obsessive-compulsive personalities or neurotic dispositions (Bolger & Zuckerman, 1995; Chang, 1998) to low self-efficacy (Schaubroeck & Merritt, 1997). On the organizational level, examples range from the surveillance culture (Zuboff, 1988, 2015) to high organizational expectations (Barber & Santuzzi, 2015). Two recent studies (Califf, 2022; Salo et al., 2022) adopt an affordances lens to theorize what happens in the black box of the appraisal process.

Recurrent Techno-stressors

Techno-stressors refer to "*IS stress creators appraised by the individual as threatening*" (Tarafdar et al., 2015, p. 5). Prior research has identified several techno-stressors such as invasion, privacy concerns, complexity, overload, uncertainty, insecurity, or dependency (Califf et al., 2020; Ragu-Nathan et al., 2008; Tarafdar et al., 2007). We consider the most recurrent techno-stressors found in a personal use context:

invasion, privacy concerns, complexity, and dependency (Salo et al., 2022). Dependency involves an overreliance on IT to perform daily activities (Shu et al., 2011). Privacy concerns involve feelings of compromised individual privacy (Ayyagari et al., 2011). Complexity refers to the difficulty in using IT (Fischer & Riedl, 2017; Tarafdar et al., 2007). Invasion refers to situations in which users can be reached and available at any time (Fischer & Riedl, 2017; Tarafdar et al., 2010).

Technostress Mitigation

A few studies have addressed the question of how to mitigate technostress. Mainly from an organizational perspective, these studies explored the factors that help knowledge workers and IT professionals lower the negative feelings associated with using IT. Among these factors, researchers validated organizational programs, training, job control, and rewards (Arnetz, 1996; Hung et al., 2011; Tams et al., 2020), in addition to specific organizational support such as technical support, literacy facilitation, support with work–home boundaries, co-worker support, and user involvement (Benlian, 2020; Fuglseth & Sørebø, 2014; Maier et al., 2019; Ragu-Nathan et al., 2008; Tarafdar et al., 2015; Yan et al., 2013). On a more individual level, aspects pertaining to IT self-efficacy, IT experience and competencies have been associated with lower technostress levels (Shu et al., 2011; Tams et al., 2018) and better performance (Tarafdar et al., 2015). Studies on mitigating technostress have also explored the impact of individual actions such as positive re-interpretation, distancing or escaping from IT work on reducing technostress (Galluch et al., 2015; Pirkkalainen et al., 2019). Recent work by Salo et al. (2022) explored the formation of technostress using IT affordance as a theoretical lens (Majchrzak & Markus, 2014) and how individuals mitigate technostress feelings through a self-regulation perspective (Bandura, 1991; Baumeister et al., 1994).

3.2 IT Identity

IT identity has been articulated by prior research to better understand one's behavior with respect to IT in embedded social contexts. The conceptualization of IT identity builds on the assumption that identities represent the set of meanings and expectations that individuals internalize for their own behaviors (Carter & Grover, 2015). Identities are tied to social categories on both the collective and individual levels. While the former focuses on how identity emerges from membership in social groups or categories (Tajfal & Turner, 2004), the latter covers several forms of identity such as role identity (e.g., family role, work role) (McCall & Simmons, 1978), person identity (i.e., values and norms that individuals define themselves with) (Burke & Stets, 2009) and material identity. IT identity, as presented by Carter and Grover (2015), falls under the material identity form where individuals tie their identity to material objects such as places or personal possessions (such as IT) (Clayton, 2003). Given that IT identity applies to the individual, this variable is tied to the individual level of analysis. Prior research on identity indicates that IT identity should be a multidimensional construct (Clayton, 2003). IT identity is reflected in individuals' perceptions of relatedness, dependence, and emotional energy with respect to the IT (Carter & Grover, 2015). *Relatedness* refers to the extent to which the boundary between the self and IT becomes blurred and individuals show feelings of connectedness with the IT. *Dependence* captures the extent to which individuals are reliant on IT to achieve important instrumental goals. *Emotional energy* captures feelings of enthusiasm and energy when interacting with an IT.

4 Preliminary Research Design and Research Model

On the one hand, our sample includes undergraduate students from a Business School in France. Students are an appropriate target because they are digital natives who widely use IT for personal purposes in a voluntary way (Craig et al., 2019). This decision is also consistent with prior research on technostress (Galluch et al., 2015) and IT identity (Carter et al., 2020). On the other hand, we will focus on a specific unit of technology given that, according to prior work, users may develop many IT identities, each one tied to a specific IT (Carter & Grover, 2015; Stets & Burke, 2005). Given that technologies with broader use are more likely to enact IT identity (Carter & Grover, 2015), we will use a social networking site (SNS) (e.g., Facebook, Instagram). In addition, Carter and Grover (2015) stated that technologies such as Facebook or Instagram with material properties such as sharing status updates and photos, instant messaging notifications, and dynamic information feeds, which are at the same time portable and networked, are particularly amenable to IT identity formation.

We plan to perform a mixed-methods design. Mixed-methods design is an appropriate method because of its ability to "*address confirmatory and explanatory research questions*" (Venkatesh et al., 2016, p. 437). As our focus is on understanding the role of IT identity in the formation and mitigation of technostress, we first plan to conduct a qualitative study to help us develop the research model and understand how the different variables are related to each other. We plan to conduct focus group to understand how SNS features are appraised by students, how primary appraisal affects recurrent techno-stressors, and how students' IT identity affects primary appraisal and technostress mitigation. Once the hypotheses and research model are developed based on the first study, a quantitative approach will be followed for the empirical testing. Figure 1 shows the preliminary model we might test. We plan to develop a survey instrument adopting existing Likert scale measures of IT features, IT identity, and recurrent techno-stressors to ensure content validity. We will survey students from the same institution with a screening question to only include those students using the chosen SNS. IT features will be specified as a second-order composite construct and will include four dimensions: functionality, bandwidth, mobility, and malleability (Carter & Grover, 2015; Esmaeilzadeh, 2021). IT identity will be considered a second-order composite construct with three reflective dimensions whose items will be adopted from Carter et al. (2020). Measures of the techno-stressors will be adapted from prior work on technostress (e.g., Ragu-Nathan et al., 2008; Tarafdar et al., 2007; Tarafdar et al., 2017).

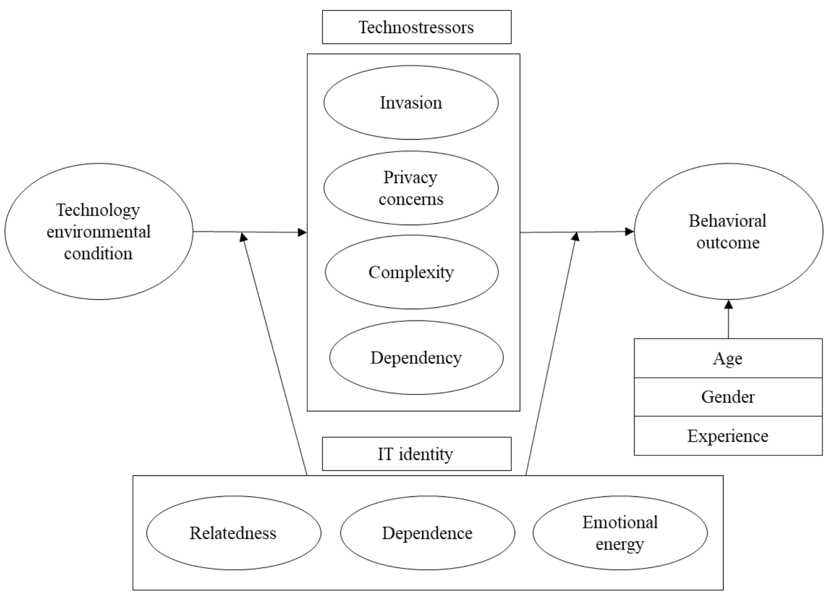

Figure 1: Research model

5 Conclusion and Expected Contributions

In order to expand the understanding of technostress, examining the formation of negative feelings towards IT and how users mitigate their effects represents a focal point. As part of that endeavor, this study looks at the formation and mitigation of technostress through the lens of IT identity. While prior IS research has acknowledged that understanding the role of IT use is critical to understanding how technostress forms over time via primary appraisal and how its mitigation takes place, our literature review reveals that little is known about the role of IT identity in such phenomena.

The potential contributions of this research are the following. First, we contribute and extend prior work on technostress formation and mitigation by investigating how primary appraisal for threat techno-stressors happens when IT identity is considered while examining whether IT identity is a way to mitigate technostress. Second, IT identity has been understudied in prior IS research. Although there are studies that explain who people are in relation to IT, they do not treat IT as an integral part of one's self (Esmaeilzadeh, 2021). This study will examine IT identity associated with a SNS and its role in the formation and mitigation of technostress. We will be able to elucidate whether IT identity reinforces or weakens the relationship between technology environmental conditions, techno-stressors, and user behavior. Therefore, this work will contribute to theory building on IT identity by also providing empirical evidence for the multidimensional nature of the construct.

References

Arnetz, B. B. (1996). Techno-Stress: A perspective psychophysiological study of the impact of a controlled stress-reduction program in advanced telecommunications systems design work. *Journal of Occupational and Environmental Medicine*, 38(1), 53-65.

Ayyagari, R., Grover, V., & Purvis, R. (2011). Technostress: Technological antecedents and implications. *MIS Quarterly*, 35(4), 831-858.

Bandura, A. (1991). Social cognitive theory of self-regulation. *Organizational behavior and human decision processes*, 50(2), 248-287.

Barber, L. K., & Santuzzi, A. M. (2015). Please respond ASAP: Workplace telepressure and employee recovery. *Journal of Occupational Health Psychology, 20*(2), 172–189.

Baumeister, R. F., Heatherton, T. F., & Tice, D. M. 1994. Losing Control: How and Why People Fail at Self-Regulation, San Diego, CA: Academic Press.

Beaudry, A., & Pinsonneault, A. (2005). Understanding User Responses to Information Technology: A Coping Model of User Adaptation. *MIS Quarterly*, 29(3), 493–524.

Belk, R. W. (1988). Possessions and the Extended Self. *Journal of Consumer Research*, 15(2), 139-168.

Benlian, A. (2020). A Daily Field Investigation of Technology-Driven Spillovers from Work to Home. *MIS Quarterly*, 44(3).

Bolger, N., & Zuckerman, A. (1995). A framework for studying personality in the stress process. *Journal of Personality and Social Psychology, 69*(5), 890–902.

Burke, P. J., & Stets, J. E. 2009. Identity Theory, New York: Oxford University Press.

Califf, C. B. (2022). Stressing affordances: Towards an appraisal theory of technostress through a case study of hospital nurses' use of electronic medical record systems. *Information and Organization*, 32(4), 100431.

Califf, C., Sarker, S., & Sarker, S. (2020). The bright and dark sides of technostress: A mixed-methods study involving healthcare IT. *MIS Quarterly*, 44(2), 809-856.

Carter, M., & Grover, V. (2015). Me, Myself, and I(T): Conceptualizing Information Technology Identity and its Implications. *MIS Quarterly*, 39(4), 931-957.

Carter, M., Petter, S., Grover, V., & Thatcher, J. B. (2020). Information Technology Identity: A Key Determinant of IT Feature and Exploratory Usage. *MIS Quarterly*, 44(3).

Cavanaugh, M. A., Boswell, W. R., Roehling, M. V., & Boudreau, J. W. (2000). An Empirical Examination of Self-Reported Work Stress among U.S. Managers. *Journal of Applied Psychology*, 85(1), 65-74.

Chang, E. C. (1998). Dispositional optimism and primary and secondary appraisal of a stressor: Controlling for confounding influences and relations to coping and psychological and physical adjustment. *Journal of Personality and Social Psychology, 74*(4), 1109–1120.

Clayton, S. (2003). Environmental Identity: A Conceptual and an Operational Definition, in Identity and the Natural Environment, S. Clayton and S. Opotow (eds.), Cambridge, MA: MIT Press, pp. 45-67.

Cooper, C. L., Dewe, P. J., & O'Driscoll, M. P. (2001). Organizational Stress: A Review and Critique of Theory, Research, and Applications, Thousand Oaks, CA: SAGE Publications.

D'Arcy, J., Herath, T., & Shoss, M. (2014). Understanding Employee Responses to Stressful Information Security Requirements: A Coping Perspective. *Journal of Management Information Systems*, 31(2), 285-318.

Edwards, J. R. (1991). Person-Job Fit: A Conceptual Integration, Literature Review, and Methodological Critique. *International Review of Industrial and Organizational Psychology*, 6, 283-357.

Esmaeilzadeh, P. (2021). How does IT identity affect individuals' use behaviors associated with personal health devices (PHDs)? An empirical study. *Information & Management*, 58(1), 103313.

Fuglseth, A. M., & Sørebø, Ø. (2014). The effects of technostress within the context of employee use of ICT. *Computers in Human Behavior*, 40, 161-170.

Galluch, P., Grover, V., & Thatcher, J. (2015). Interrupting the Workplace: Examining Stressors in an Information Technology Context. *Journal of the Association for Information Systems,* 16(1), 1-47.

Hung, W. H., Chang, L. M., & Lin, C. H. (2011). Managing the Risk of Overusing Mobile Phones in the Working Environment: A Study of Ubiquitous Technostress. In Proceedings of the Pacific Asia Conference on Information Systems, Brisbane.

Kahn, R., & Byosiere, P. (1992). Stress in organizations in M. D. Dunnette, and L. M. Hough (eds.) Handbook of industrial and organizational psychology (2nd ed.), vol. 3, Palo Alto: Consulting Psychologists Press, 571–650.

Lamb, R., & Kling, R. (2003). Reconceptualizing Users as Social Actors in Information Systems Research. *MIS Quarterly*, 27(2), 197-235.

Lazarus, R. S. (1966). Psychological stress and the coping process, New York, NY, USA: McGraw-Hill.

Lazarus, R. S., & Folkman, S. (1984). Stress, appraisal, and coping, New York, NY, USA: Springer publishing company.

Maier, C., Laumer, S., Wirth, J., & Weitzel, T. (2019). Technostress and the hierarchical levels of personality: a two-wave study with multiple data samples. *European Journal of Information Systems*, 28(5), 496-522.

Majchrzak, A., & Markus, M. L. (2014). Technology Affordances and Constraints in Management Information Systems (MIS), in Encyclopedia of Management Theory, E. H. Kessler (ed.), Thousand Oaks, CA: SAGE Publications.

McCall, G. J. (2003). The Me and the Not-Me: Positive and Negative Poles of Identity, in Advances in Identity Theory and Research, P. J. Burke, T. Owens, R. T. Serpe, and P. A. Thoits (eds.), New York: Springer, pp. 11-26.

McCall, G. J., & Simmons, J. L. (1978). Identities and Interactions, New York: Free Press.

Pirkkalainen, H., Salo, M., Tarafdar, M., & Makkonen, M. (2019). Deliberate or instinctive? Proactive and reactive coping for technostress. *Journal of Management Information Systems*, 36(4), 1179-1212.

Ragu-Nathan, T., Tarafdar, M., Ragu-Nathan, B., & Tu, Q. (2008). The consequences of technostress for end users in organizations: Conceptual development and empirical validation. *Information Systems Research*, 19(4), 417-433.

Salo, M., Pirkkalainen, H., Chua, C. E. H., & Koskelainen, T. (2022). Formation and Mitigation of Technostress in the Personal Use of IT. *MIS Quarterly*, 46(2), 1073-1108.

Schaubroeck, J., & Merritt, D. (1997). Divergent effects of job control on coping with work stressors: The key role of self-efficacy. *Academy of Management Journal*, 40(3), 738-754.

Shu, Q., Tu, Q., & Wang, K. (2011). The Impact of Computer Self-Efficacy and Technology Dependence on Computer- Related Technostress: A Social Cognitive Theory Perspective. *International Journal of Human–Computer Interaction*, 27(10), 923-939.

Stets, J. E., & Burke, P. J. (2005). A Sociological Approach to Self and Identity. In Handbook of Self and Identity, M. R. Leary and J. P. Tangney (eds.), New York: The Guilford Press, pp. 128-152.

Tajfal, H., & Turner, J. C. (2004). The Social Identity Theory of Intergroup Behavior. In Political Psychology: Key Readings, J. T. Jost and J. Sidanius (eds.), New York: Psychology Press, pp. 276-293.

Tams, S., Ahuja, M., Thatcher, J., & Grover, V. (2020). Worker stress in the age of mobile technology: The combined effects of perceived interruption overload and worker control. *Journal of Strategic Information Systems*, 29(1), Article 101595.

Tams, S., Thatcher, J. B., & Grover, V. (2018). Concentration, competence, confidence, and capture: An experimental study of age, interruption-based technostress, and task performance. *Journal of the Association for Information Systems*, 19(9), 2.

Tarafdar, M., Cooper, C., & Stich, J. (2019). The technostress trifecta-techno eustress, techno distress and design: Theoretical directions and an agenda for research. *Information Systems Journal*, 29(1), 6-42.

Tarafdar, M., Gupta, A., & Turel, O. (2013). The Dark Side of Information Technology Use. *Information Systems Journal*, 23(3), 269-275.

Tarafdar, M., Pullins, E. B., & Ragu-Nathan, T. S. (2015). Technostress: negative effect on performance and possible mitigations. *Information Systems Journal*, 25(2), 103-132.

Tarafdar, M., Tu, Q., & Ragu-Nathan, T. (2010). Impact of technostress on end-user satisfaction and performance. *Journal of Management of Information Systems*, 27(3), 303-334.

Tarafdar, M., Tu, Q., Ragu-Nathan, B. S., & Ragu-Nathan, T. S. (2007). The impact of technostress on role stress and productivity. *Journal of Management Information Systems*, 24(1), 301-328.

Venkatesh, V., Brown, S. A., & Sullivan, Y. (2016). Guidelines for conducting mixed-methods research: An extension and illustration. Venkatesh. *Journal of the Association for Information Systems*, 17(7), 435-495.

Yan, Z., Guo, X., Lee, M. K., & Vogel, D. R. (2013). A conceptual model of technology features and technostress in telemedicine communication. *Information Technology & People*, 26(3), 283-297.

Zuboff, S. (1988). In the Age of the Smart Machine: The future of work and power, New York, NY: Basic Books.

Zuboff, S. (2015). Big other: surveillance capitalism and the prospects of an information civilization. *Journal of Information Technology*, 30(1), 75-89

RESEARCH IN PROGRESS

CONCEPTUALIZING THE IMPACT OF DIGITAL BUSINESS MODELS ON PRIVACY CONCERNS

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Digital technologies have enabled novel forms and reconfigurations of value creation, delivery, and capture. These new reconfigurations challenge the conventional notion of value creation with digital business models. On that premise, the widening of privacy concerns, alert us that organizations of the elite digital, like Netflix, Amazon, and Spotify, design technology to feed on personal data, based on algorithmic profiling capabilities. Then, privacy itself becomes their digital business model. In this paper we conceptualize the impact of digital business models on privacy concerns, by presenting a focused literature review that presents 4 waves of research on understanding privacy from the context of digital business models. With our initial findings, we recommend that future technological development should pay central attention to privacy-preserving digital business models, by making it possible that data privacy is envisioned with the right safeguards, targeting 'invisibility' of the user.

Keywords:
digital business models, privacy concerns, value creation, invisibility, right safeguards

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1 Introduction

The exponential advancement and widespread utilization of digital technologies has spawned profound innovations, which have disrupted traditional businesses and reconfigured a number of industries (Nambisan et al., 2020). Digitization, which is defined as the conversion of analog data to digital (Yoo et al., 2010), of products and services, is the cornerstone of innovations, which transcend geographical and industrial boundaries enabling novel business models (Constantinides et al. 2018; Nambisan et al., 2020). A business model represents a key source of performance and competitive advantage of organizations (Teece, 2010), hence becoming an imperative for digital transformation. It refers to the "architecture of value creation, delivery and capture mechanism" (Teece, 2010, p.172), in a multi-actor network. The core of business models is on value creation and capture, not only for the organization itself, but also for other actors in the ecosystem (Amit and Zott, 2020).

For organizations, the advent of information technology (IT) in the 1990s became a ground to breed a new generation of entrepreneurs that redefined the rules of doing business, primarily on the basis of competition, facilitated by IT (Gordon, 2000). On that end, the dot com bust in the 2000s, mandated a few entrepreneurs to reinvent the use of IT by crafting a new economic order (Zuboff, 2015). Pioneers like Netflix, Amazon, and Spotify, started to become the best attendants of feeding on personal data (Loebbecke and Picot, 2015), with a constant online surveillance, often without the knowledge of a person (Zuboff, 2019). The legal enforcement, however, with the ratification of the General Data Protection Regulation (GDPR) as the most powerful regulation ever created, presented a shift in the mind-set of how data protection is handled by such organizations. In this paper, we look at digital business models vis-á-vis privacy concerns, with the aim to provide an initial conceptual model on the interplay of digital business models and privacy concerns, over time.

The rest of the paper is organized as follows. We first present our conceptualizations on digital business models and privacy. We then present a focused literature review followed by an initial conceptualization to view privacy as a direct consequence of reconfigurations of business and the growth of digital business models. We then highlight potential contributions of our initial conceptualization, followed by future work.

2 Digital Business Models and Privacy Concerns

Digital technologies have enabled novel forms and reconfigurations of value creation, delivery, and capture. These new reconfigurations challenge the conventional notion of value creation, postulating that value is co-created by "aggregating recombinant technology components by interacting with diverse resources and often across firm boundaries" (Hukal and Henfridsson, 2017 p. 488). As a result, the notion of digital business model has gained widespread popularity both in scholarly work, but also in practice. Digital business models refer to business models enabled by the utilization of digital technologies (Amit and Zott, 2020). Bärenfänger and Otto (2015, p. 18) define digital business models "as a business model whose underlying business logic deliberately acknowledges the characteristics of digitization and takes advantage of them; both in interaction with customers and business partners, and in its internal operations".

In consideration of the foregoing, it is no surprise that we have now reached a point when digital business models have influenced the generation of an organizational mind-set that even knows our deepest secrets (Acquisti et al., 2022; Zuboff, 2019). The value of personal information has made it possible for goods to increase prices tenfold on personalized services. Even the simplest case of M&M's legendary milk chocolate candy pack is no stranger to that. M&M owns a platform that allows you to personalize a chocolate pack, where you share personal information, e.g. dates and photographs, taking the opportunity of such data to turn it into a commodity (Crain, 2016). That also allows such platforms not only to influence our future consumer behavior, it also allows for an astronomical price tag, all made possible by the new wave of digital business models configured for personalization.

Then, it is not new to us that IT has become a constant in reconfiguring traditional roles of people in the digital realm, including their traditional view on privacy concerns (Zhang et al., 2022). Organizations driven by information capitalism (Zuboff, 2019), especially the elite digital, show an unstoppable appetite for data that forms 95% of the global economy (Srnicek, 2017). From a macro perspective, the digitization of an organization presented an opportunistic reality (Thrift, 2011) where concepts like "everyware" (Greenfield, 2006) came to life. From a micro perspective, however, secrecy in such organizations came at the expense of privacy (Solove, 2011). Zubbof's "big other" became a precondition to argue that we are in the hands of a new form of capitalism that she termed surveillance capitalism (Zuboff, 2015), where personal boundaries on our own privacy are put to test (Zhang et al., 2022).

Contrary to this view, we know that digitization is key to produce a number of digital business models that deserted the spatial and temporal limits, often empowering people. Just to name a few, from the speed of information, to the significance of online payments for simple transactions, technological capabilities can steer progress in the right direction. However, the digital era is a new reality for people that has brought us more tension than consensus, putting people's own privacy-protective behaviors to test (Quach et al., 2022; Zhang et al., 2022). We live with pressure trying to balance our and others' physical presence with the digital presence (Acquisti et al., 2022). Alongside the backdrop of this pressure, digital business models are leading us to conceptualize our personal digital self as a type of self that transcends the borders and acknowledges our physical self, often recognizing privacy as a loss in that transcension (Zuboff, 2019).

2.1 Focused Literature Review: Digital Business Models and Personal Boundaries on Privacy

In a focused literature review, we identify 22 research articles (listed in Appendix) published at the European Journal of Information Systems (EJIS) in the course of 3 decades. The focus on EJIS stems from their distinctive European perspective on theory and practice for a global audience. Coupled with European Union laws and regulations on data privacy, such as GDPR, it makes for a unique candidate to study the conceptualization of digital business models vis-á-vis privacy concerns, over time. The article analyses yielded 4 waves of research on understanding privacy from the context of digital business models. Important to highlight, is the fact that all articles recognize that privacy is a human right, but the difference across the waves is noticed on the fact that early studies have the tendency to conceptualize on privacy concerns from the user perspective, compared to current studies that place a lot of responsibility on the design of IT itself. Wave 1, presented the early take on the use of digital business models, such as in the form of e-commerce and social media from a network perspective, where privacy conceptions were formed around the "*user privacy concern*" (e.g. Junglas et al., 2008), where personal privacy and the identifiable person were key, along with the data rights, but centered on the actual "user x".

Wave 2 presented the wake of new digital business models that further fueled the presence and use of e-commerce and social media for more personalized services, including services for personal digital healthcare, which influenced a complex analysis on privacy as e.g. a right and commodity (Smith et al., 2011). This made it critical to view "*user disclosure and personalization*" as a real physical person and that data and information disclosure became pivotal to our understanding of privacy concerns (Posey et al., 2010; Warkentin et al., 2011). Wave 3, showed that new techniques on big data analyses with machine learning algorithms, made it more concerning that "*personal data and privacy loss*" is a real threat (Parks et al., 2017). Then, wave 4 and the current wave, focuses on important aspects, such as traceability and integrity (Raddatz et al., 2021; Parks et al., 2022), where a clear motivator for such studies depends on the movements of human rights perspective, where "*personal privacy rights*" are linked back to laws and regulations. In fact, the focus on privacy as a fundamental human right (UN Declaration of Human Rights, Article 12), is key to guide recent studies on design of technology for privacy protection and privacy-preservation mechanisms. Figure 1 illustrates these waves with an example where user x is identified as Sarah Smith, which leads to show how the other waves address privacy concerns, over time.

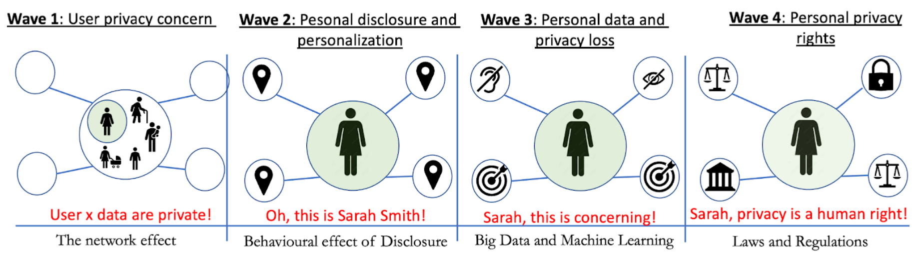

Figure 1: From User Privacy to Privacy as a Right

In reference to these waves, our analysis identified several types of digital business models studied in these waves, e.g. platform business models of e-commerce or data-driven business models; etc. In describing Figure 1, we conceptualize them as digital business models. Such digital business models rely on digital technologies, which contribute to the generation and proliferation of data, which has recently exceeded in growth and profit (Wiener et al., 2020).

As such, digital business model- dependent organizations have harnessed the potential of digital technologies to create novel reconfigurations of value creation and capture, either through novel offerings, reconfiguration of activities, transactions, structure and/or governance mechanisms (Amit and Zott, 2020), all dependent on personal data feeding. To that end, successful organizations as Netflix, Amazon, and Spotify, have configured their business models and innovations around data. Netflix for example, has shifted its focus from a retailer of DVDs mail delivery to innovating its business model around data to improve customer experience through personalization and customization (Mier and Kohli, 2021). The common link across these organizations is that their business models are configured and innovated as data dependent digital platforms. The latter leads us to reflect back on how privacy concerns have shifted from conceptualizing about the unknown "user x" to the actual "physical person".

3 Initial Findings and Future Research Direction

Despite the fact that we have ample opportunities with the introduction and exponential growth of digital business models, and that new IT developments present ideas, tools, and models with privacy-preserving mechanisms, we identify that challenges with data privacy still remain detrimental. Novel configurations of digital business models where privacy becomes the core value creation mechanism, leads us to term them as privacy-based business models. In this relationship, privacy itself becomes the business model. We recommend future technological design to focus on privacy-preserving digital business models, which should make it possible that data privacy is envisioned with the right safeguards, targeting 'invisibility'. Otherwise, Mann's and Matzner's (2019) call that we risk producing technology that does not account for privacy and data protection rights, goes against GDPR's call on the 'right' not to be ruled by automated decisions. Our future work depends on bringing the question of ethics into view, on how technology is shaped to feed on personal data, where user awareness and digital literacy remain challenging. The vast majority of today's digital users have limited awareness about algorithmic profiling capabilities and how detrimental its effects are on their privacy. At the same time, these users have become pivotal in supporting data-driven business models to thrive, letting such models to feed on their valuable personal data.

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References

Acquisti, A., Brandimarte, L., Hancock, J. (2022). How privacy's past may shape its future. Science, 375(6578), 270-272.

Amit, R., Zott, C. (2020). Business Model Innovation strategy: Transformational Concepts and Tools for Entrepreneurial Leaders. John Wiley & Sons: Hoboken, NJ, USA.

Bärenfänger, R., Otto, B. (2015). Proposing a capability perspective on digital business models. In 2015 IEEE 17th Conference on Business Informatics, 1, 17-25.

Crain, M. (2016). The limits of transparency: Data brokers and commodification, New Media and Society, 20(1), 88-104.

Gordon, R. J. (2000). "Does the "New Economy" Measure Up to the Great Inventions of the Past?" Journal of Economic Perspectives, 14(4), 49-74.

Greenfield, A. (2006) Everyware: The Dawning Age of Ubiquitous Computing, New Riders, Boston, USA.

Hukal, P., Henfridsson, O. (2017). Digital Innovation—A definition and integrated perspective. In The Routledge Companion to Management Information Systems, 1st ed.; Routledge: London, UK, 2017; pp. 360–369.

Junglas, I.A., Johnson, N.A., Spitzmüller, Ch. (2008). Personality traits and concern for privacy: an empirical study in the context of location-based services. European Journal of Information Systems, 17, 387-402.

Loebbecke, C., Picot, A. (2015). Reflections on societal and business model transformation arising from digitization and big data analytics: A research agenda. The Journal of Strategic Information Systems, 24(3), 149-157.

Mann, M., Matzner, T. (2019). Challenging algorithmic profiling: The limits of data protection and anti-discrimination in responding to emergent discrimination. Big Data & Society, 1-11.

Mier, J. & Kohli, A.K. (2021). Netflix: reinvention across multiple time periods, reflections and directions for future research. AMS Review, 11, pp.1-12.

Parks, R., Xu, H., Chu, Ch-H., Lowry, P.B. (2017). Examining the intended and unintended consequences of organisational privacy safeguards. European Journal of Information Systems, 26, 37-65.

Parks, R. F., Wigard, R. T., Lowry, P.B. (2022). Balancing information privacy and operational utility in healthcare: proposing a privacy impact assessment (PIA) framework. European Journal of Information Systems, 1-18.

Posey, C., Lowry, P.B., Roberts, T.L., Selwyn Ellis, T. (2010). Proposing the online community self-disclosure model: the case of working professionals in France and the U.K. who use online communities. European Journal of Information Systems, 19, 181-195.

Quach, S., Thaichon, P., Martin, K.D., Weaven, S., Palmatier, R.W. (2022). Digital technologies: tensions in privacy and data. Journal of the Academy of the Marketing Sciences, 50, 1299-1323.

Raddatz, N., Coyne, J., Menard, Ph., Crossler, R.E. (2021). Becoming a blockchain user: understanding consumers' benefits realization to use blockchain based- applications. European Journal of Information Systems, 1-28.

Smith, J.H., Dinev, T., Xu,H. (2011). Information Privacy Research: An Interdisciplinary Review. MIS Quarterly, 35(4), 989-1015.

Srnicek, N. (2017). The challenges of platform capitalism: Understanding the logic of a new business model, Juncture, 23(4), 254-257.

Teece, D.J. (2010). Business models, business strategy and innovation. Long Range Planning, 43, 172–194.

Wiener, M., Saunders, C., Marabelli, M. (2020). Big-data business models: A critical literature review and multiperspective research framework. Journal of Information Technology, 35(1), 66-91.

Zhang, N., Wang, Ch., Karahanna, E., Xu, Y. (2022). Peer Privacy Concerns: Conceptualization and Measurement. MIS Quarterly, 46(1), 491-530.

Zuboff, Sh. (2015). Big other: surveillance capitalism and the prospects of an information civilization. Journal of Information Technology, 30, 75-89.

Zuboff, Sh. (2019). The age of surveillance capitalism: The fight for a human future at the new frontier of power, Profile Books, UK.

Appendix

No	Citation	Key Focus of the Study	Context of Information Systems	Context of Data/Information	Theoretical Foundation
1	Parks et al. (2022)	Information privacy threats and maintaining utility in a healthcare privacy compliance context with value-focused thinking (VFT) approach.	eHealth	Patient Information	Means-end chain theory Value-Focused thinking approach
2	Raddatz et al. (2021)	Blockchain as data store to promote data privacy, transaction integrity. Factors that influence consumers' perceptions of blockchain-based databases' benefits	Blockchain databases	Transactional data, personal data	Blockchain research Health belief model Perceived benefits of blockchain-based databases
3	Lin, Carter & Liu (2021)	Contact tracing technology, citizen information privacy concerns.	Smartphones, contact tracing-apps	Information privacy ("the ability of individuals to control the terms under which their personal information is acquired and used" p.389)	Information Privacy Technology Adoption
4	Dincelli & Chengalur-Smith	Gamified SETA artefact using the formats of text and visual to identify security threats.	Social networking sites (SNS) Social engineering Gamification	Data privacy	Online self-disclosure (OSD) Attitudes and intentions towards OSD behavior

No	Citation	Key Focus of the Study	Context of Informatio n Systems	Context of Data/Infor-mation	Theoretical Foundation
		Provides an understanding of the linkage between technology artefacts and human experiences.	SETA		SETA and gamification
5	Trang et al. (2020)	Contact-tracing apps during the pandemic. Mass acceptance.	Contact-tracing apps Mobile technology	Contact data	Benefits of tracing apps Appeals for prosocial behavior Constant usage and usability requirements Sensitive data and privacy concerns App acceptance, user-centered design
6	Rowe, Nqwenya ma & Richet (2020)	The failure in the design and adoption of Stop-COVID app in France. Conditions of such failure.	Tracing, smartphone app	Collection of data	E-GOV Apps for crisis management Alienation in critical theory
7	Ozdemir, Smith & Benamati (2017)	Information privacy in the context of peer relationships on commercial social media sites. A model that considers relationships between the constructs of privacy experiences.	Social media	Personal information	Privacy research Privacy-related constructs Information disclosure
8	Lowry, Dinev &	Important concerns in the	IS Research	Big data	IT artefacts to IS artefacts

No	Citation	Key Focus of the Study	Context of Information Systems	Context of Data/Information	Theoretical Foundation
	Willison (2017)	hope of improving the effectiveness of security and privacy research. Outlines three promising opportunities for IS research that is compelling to security and privacy researchers.			Security and privacy research Opportunities – online platforms, IoT, big data
9	Parks et al. (2017)	Investigate the consequences of privacy safeguard enactment in medical practices, including whether it influences their ability to meet privacy requirements and whether workflows are impeded	Health informatics	Information privacy	Health informatics Privacy safeguards in healthcare The intended versus unintended consequences of enacting privacy safeguards in organizations.
10	Foth (2016)	Analyzed the influences of the attitudes, subjective norms and perceived behavioral control on employees' intentions to comply with data protection regulations.	Health care systems	Data protection	Information security
11	Bansal, Zahedi & Gefen (2015)	Important website features: privacy policy statements + privacy	Internet, websites	Collection of data	Privacy Concern, Trust, and Privacy Assurance

No	Citation	Key Focus of the Study	Context of Informatio n Systems	Context of Data/Infor-mation	Theoretical Foundation
		assurance cues are what online providers use to increase individuals' trust and willingness to disclose private information online. Comprehensive examination of the process by which privacy assurance mechanisms influence trust and the moderating role of privacy concern in this process			
12	Chen & Sharma (2015)	Facebook users' learning-based attitude formation and the relationship between member attitude and self-disclosure.	Social media	Data in social network	Self-disclosure Social networking sites Attitude literature
13	Roßnagel et al. (2014)	Determinants for success and failure of identity management systems. Analyze the preferences and willingness to pay of prospective users.	Identity management systems	User data	Success factors of we identity management solutions

No	Citation	Key Focus of the Study	Context of Information Systems	Context of Data/Information	Theoretical Foundation
14	Oetzel & Speikermann (2014)	Methodology that systematically considers privacy issues by using a step-by-step privacy impact assessment.	IT applications	Data protection	Existing privacy compliance procedures and privacy-by-design Risk assessment methodologies that tackle security and privacy issues PIA
15	Miltgen & Peyrat-Guillard (2014)	Examines how European citizens decide to disclose and protect their personal data and thereby reveals cultural and generational divides.	NA.	Information privacy	Information privacy Situationally Antecedents and consequences The importance of trust Privacy-related issues
16	Dinev (2014)	Privacy in the information age, future opportunities for research.	IT, e-commerce, social networks	Personal data	Privacy definition and conceptualization Anthropological and cultural angle of privacy Regulation Privacy and convenience. Privacy paradox
17	Dinev et al. (2013)	Develops and tests a framework of information privacy and its correlates, the latter often being confused with or built into definitions of information privacy per se.	NA.	Information privacy	The concept of privacy – literature review

No	Citation	Key Focus of the Study	Context of Information Systems	Context of Data/Infor-mation	Theoretical Foundation
18	Li & Unger (2012)	Perceived personalization quality can outweigh the impact of privacy concerns. Service providers can improve the perceived quality of personalization services being offered in order to offset customer privacy concerns.	Personalization applications	NA.	Personalization Customers' privacy concerns Privacy protection
19	Warkentin, et a.. (2011)	Investigates the antecedents of information privacy policy compliance efficacy by individuals.	Healthcare systems?	Personal data, sensitive data?	Social learning theory Compliance
20	Posey et al. (2010)	An online community self-disclosure model, tested in a cross cultural setting using data provided by French and British working profes sionals	Online communities, social networking	NA.	Social exchange theory Social penetration theory Cross-cultural theory related to individualism-collectivism
21	Junglas et al. (2008)	Fill the gap of "research has shown that the CFP can have a negative influence on the adoption of information technology; but	World wide web	NA.	Concern for privacy (CFP) The co-evolving nature of privacy and technology PMT and threat appraisals Personality traits and threat appraisals

No	Citation	Key Focus of the Study	Context of Information Systems	Context of Data/Information	Theoretical Foundation
		little is known about factors likely to influence such concern."			
22	Dinev et al. (2006)	Examines cross-cultural differences beliefs related to e-commerce use for Italy and the United States.	NA.	Personal information Information privacy concerns	Internet and e-commerce diffusion in Italy Hofstede's cultural theory Fukuyama's theory of trust and social capital

RESEARCH IN PROGRESS

INTEGRATION OF THE SUSTAINABLE DEVELOPMENT GOALS IN PROJECT-BASED IT EDUCATION

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Higher education institutions play a significant role in reaching the Sustainable Development Goals (SDGs). There is however a gap between the abstract nature of SDGs and the need to integrate these in the day-to-day educational environment. This paper presents an ongoing study that reports preliminary findings regarding the integration of insights from Value Sensitive Design into frequently employed artifacts within a project-based IT educational context, with the aim of translating abstract Sustainable Development Goals into teaching practice.

Keywords: sustainable development goals, SDGs, values, sustainability, ethics, information technology, IT, ICT, higher education

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1 Introduction

The adoption of the 2030 Agenda for Sustainable Development by United Nations Member States in 2015 set forth a comprehensive framework for achieving global sustainable development through 17 interrelated Sustainable Development Goals (SDGs). These goals target social, economic, and ecological sustainability and seek to promote universal values, such as health, equality, and social justice (UN, 2015; UN, 2017). In this paper we use the term value in the sense of 'what is important to living things, with a focus on ethics and morality', expanding the Friedman and Hendry (2019) definition referring to humans, in order to prevent an anthropocentric focus as indicated by Borthwick et al. (2022).

Higher education institutions have a significant role in contributing to these global efforts (Žalėnienė & Pereira, 2021). Literature on sustainable education highlights the importance of integrating sustainability across the entire curriculum to develop truly competent students on the SDGs (Robinson et al., 2022; Wu & Shen, 2016). However, operationalizing this integration presents a challenge. While research and international policy documents focus on sustainable competences (Dias, 2022; Peet et al., 2004; Wiek et al., 2015; Sinakou et al., 2019; UNESCO, 2017; UNECE, 2011; Bianchi et al., 2022), they do not address the integration of the SDGs in the methods, models and theories of a specific domain. In light of the abstract nature of the SDGs and their contextual dependency within specific domains (Leal et al., 2019), there is a need for an approach that can translate these abstract goals into practical applications within a particular educational setting. In this ongoing study we explore such a translation in the context of project-based IT education, a form of education that mirrors working practice and is increasingly employed in higher education (Chen & Yang, 2019). The research question we address is: *How can the SDGs be integrated in project-based IT education*?

In this study we focus on the design phase of IT projects since it entails the primary decisions on embedding values in IT products, as well as determining product functionality and non-functional characteristics (Becker et al., 2015; Friedman & Hendry, 2019; Lago et al., 2015; Shapira et al., 2017). Consistent with Umbrello et al. (2021), we utilize insights from the Value Sensitive Design (VSD) approach (Friedman et al., 2006) as a bridge between the values in the SDGs and IT projects. VSD is an approach to integrate values into technological design (Friedman et al., 2006). We use insights from VSD to incorporate values into the artifacts that students deliver in the design phase of their IT projects, such as a stakeholder analysis, persona descriptions or a prototype. Our aim is to adapt existing artifact formats to contain value dimensions by default, which we expect will lead to easier adoption among students, University staff and project clients than when we introduce completely new artifacts. We expect that these adapted artifacts will consequently lead to IT products that better incorporate SDG values. Two examples of this translation from SDG values to artifact formats are presented in the preliminary results section.

In the next section, we present the theoretical background on integrating sustainable development in the artifacts of project-based IT education. Section 3 discusses our research method. In section 4 we present preliminary results. We end with conclusions and further research in section 5.

2 Theoretical background

The Sustainable Development Goals (SDGs) embody specific values, as identified by Keitsch (2018), Muñoz et al. (2022), and Umbrello et al. (2021). The SDGs list ecological values, such as harmony with nature (SDG 12) and clean air (SDG 3), social values, including justice (SDG 16) and equality (SDG 5), as well as economic values, such as inclusive sustainable growth (SDG 8) and productivity (SDG 2) (UN, 2017).

Value Sensitive Design (VSD) is an approach to integrate values into technological design (Friedman et al., 2006). It is characterized by assessing the impact a new design may have on stakeholders' values. The values of different stakeholders may not always align and value tensions may be created. VSD aims to make values and value tensions explicit and carefully weigh them in making design choices. VSD offers a wide range of methods to do so, such as value dams and flows, value scenarios, and envisioning cards, and encourages to rework other existing methods and instruments to include a value perspective (Friedman & Hendry, 2019). VSD can be used to operationalize values mentioned in the SDGs using norms, leading to specific design criteria or requirements (Friedman & Hendry, 2019; Umbrella et al., 2021). The exact choice of which values and corresponding norms and design criteria are used depends on the interplay between the different stakeholders.

3 Research method

We adopt a design science approach in our study (Hevner & Chatterjee, 2010), since our object is to design a way to incorporate SDGs in project-based IT education. Structuring our study according to Peffers et al. (2007), we use the five steps of their design science research process: *problem identification and motivation, objectives of the solution (*as stated in the introduction)*, design and development, demonstration* and *evaluation.* The research is currently in the design and development phase. Insights from VSD are used to design adaptations of existing formats commonly used in project-based IT education.

As a first step in the design and development phase we made the SDG values explicit and translated them to the IT field. This was done by finding academic articles on the relationship between the SDGs and IT and publications such as Tjoa & Tjoa (2016) of mostly UN organizations aligned with a certain SDG. E.g. the UN agricultural organization FAO publicizes about SDG 2 on hunger and IT. Analyzing these publications we created a list of positive and negative influences of IT on each of the SDGs which contain a myriad of values. IT can e.g. lead to different types of inequalities: caused by lack of access for poor people (SDG 1), for people with disabilities or caused by discrimination due to the use of racially or gender skewed data sets (SDG 10). This list is not meant to be exhaustive, but it aims to help the thought process of translating SDGs to the IT context. Having such an overview is however not enough if values are not part of the artifacts the students produce. Therefore for each of the artifacts commonly used in the IT design phase, we analyzed the gap between the artifact in use and insights from VSD on how to incorporate values and consequently adapted the artifacts to include a value dimension. For example, personas typically do not contain values and tend not to include non-typical personas, therefore we added these aspects to the persona format. Student and lecturers can use the overview of (SDG) values in IT produced in the first step as an inspiration to draw values from. To make it easier for students to produce the adapted artifacts we made formats which include worked examples of the artifact and 'how to' steps. These formats were tested with ten IT lecturers who applied the formats to a real case in a workshop setting and adapted based on the lecturers' feedback. We additionally provided supporting material such as videos and an easy-to-fill-out lay-out on an online collaborative platform, learning materials, assignments and assessment criteria, and embedded the SDGs in the learning objectives. We are currently in the process of testing the formats with students in different years of their IT studies. The students use the formats in their projects, and we gather feedback from both lecturers and students.

4 Preliminary results

Until now we produced 11 formats to be used by students in the design phase, including formats for personas, formats for customer journeys and additional prompt questions. For example we extended the commonly used stakeholder analysis. In the regular IT design process, especially in an agile setting, the focus is on end-users. This creates IT that does not by default take into account the interests and values of a broad range of stakeholders and might create harm or fail to obtain benefits. The SDGs require including a broad group of stakeholders. VSD methods on stakeholder involvement offer insights, such as inclusion of indirect stakeholders (f.i. non-users, future generations or other cultures) and their values. The extended format aims to help students get a broader picture of stakeholders and their values so these can be taken into account as input for the design. Another example is the extension of the process of defining the problem. The typical questions used by students in defining the problem are limited in scope and tend to not contain questions that are vital for sustainable development such as looking into the relevance of the problem for future generations and relationships among various problems. VSD provides, with e.g. the envisioning cards method (Friedman et al., 2011), a whole range of added questions that can open up the students' horizon.

While testing the formats with the lecturers during the workshop they indicated that using them has definitely helped in making the abstract SDGs tangible for them. They indicated that it was easier for them to use IT specific values such as accessibility or privacy than the related more abstract SDGs *reduce inequality* or *ensure fundamental freedoms,* especially when integrated into artifact formats they were already used to. However, lecturers less familiar with the original artifacts, indicated that they felt overwhelmed by the added complexity.

The first results on the quality of the artifacts students made using the formats show a remarkable difference between students being coached by lecturers already familiar with the adapted formats and those to whom these were entirely new. Only the students with more experienced lecturers in this area were able to produce artifacts that incorporate ethical/sustainable values in a sensible way. Students from classes with a less experienced lecturer tended not to use the provided new sustainable formats or to use them in such a way that they did not provide any valuable insights into values and value tensions. The use of the formats also created discussion between students and lecturers. Some students, especially those that were newly introduced to these sustainable demands in the later part of their study, were protesting against them, even calling them “woke”, with a negative connotation.

5 Conclusion and further research

The preliminary results of this ongoing research indicate the feasibility of making the SDGs tangible for students and lecturers by enhancing existing methods with a value perspective. These methods can help to bridge the gap found in literature and in practice between SDGs and IT development. Even so, the inclusion of the value perspective adds complexity that may be overwhelming. Considering the still new, contested and volatile nature of the subject, there is clearly a need for training of lecturers, embedded in an aligned sustainable learning environment along with an ongoing open discussion among the stakeholders on SDGs and values in a specific context.

Our next steps are to complete the design and development phase by validating the usability and effect of the formats we developed with both lecturers and students. We will do so by continuing to use the formats in actual student projects throughout all years of the IT course and validating their use in focus groups. We will also conduct a comparative evaluation of the artifacts produced in various settings. Based on the outcomes we will further extend the formats with an implementation approach and supporting teaching materials. We intend to demonstrate the resulting way of integrating SDGs in project-based IT education by implementing it in other parts of the IT institute which offer project-based education.

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References

Becker, C., Betz, S., Chitchyan, R., Duboc, L., Easterbrook, S., Penzenstadler, B., Seyff, N., Venters, C. (2015). Requirements: The Key to Sustainability. IEEE Software. 33. 1-1. 10.1109/MS.2015.158.

Bianchi, G., Pisiotis, U., Giraldez, M.. (2022). GreenComp – The European sustainability competence framework. 10.2760/13286.

Borthwick, M., Tomitsch, M., Gaughwin, M. (2022). From human-centred to life-centred design: Considering environmental and ethical concerns in the design of interactive products. Journal of Responsible Technology. 10. 100032. 10.1016/j.jrt.2022.100032.

Chen, C. H., & Yang, Y. C. (2019). Revisiting the effects of project-based learning on students' academic achievement: A meta-analysis investigating moderators. Educational Research Review, 26, 71-81.

Cross, N. (2011). Design Thinking: Understanding how designers think and work. Bloomsbury/Berg. ISBN 9781847886361

Dias, B.,Onevetch, R., Santos, J., Lopes, G.(2022). Competences for Sustainable Development Goals: The Challenge in Business Administration Education. Journal of Teacher Education for Sustainability, 24(1) 73-86.

Friedman, B., Hendry, D. G. (2019). Value Sensitive Design: Shaping Technology with Moral Imagination. The MIT Press

Friedman, B., Kahn, P., Borning, A., Zhang, P., Galletta, D. (2006). Value Sensitive Design and Information Systems. 10.1007/978-94-007-7844-3_4

Friedman, B., Nathan, L.P., Kane, S., Lin, J. (2011). Envisioning cards, Seattle , W.A.: University of Washington. http://www.envisioningcards.com

Hevner, A., Chatterjee, S. (2010). Design science research in information systems. Design research in information systems: theory and practice, 9-22.

Keitsch, M. (2018), Structuring ethical interpretations of the sustainable development goals-Concepts, implications and progress. Sustainability 2018, 10, 829.

Lago, P., Aklini Kocak, S., Crnkovic, I., & Penzensradler, B. (2015). Framing Sustainability as a Property of Software Quality. Communications of the ACM, 58(10), 70-78. https://doi.org/10.1145/2714560

Leal Filho W., Shiel C., Paço A., Mifsud M., Ávila L.V., Brandli L.L., Molthan-Hill P., Pace P., Azeiteiro, U.M., Vargas V.R., Caeiro S. (2019), Sustainable Development Goals and sustainability teachingat universities: Falling behind or getting ahead of the pack?, Journal of Cleaner Production, doi: https://doi.org/10.1016/j.jclepro.2019.05.309.

Muñoz-Arteaga, J., García, H.L., Collazos, C.A., Granollers, A. (2022). Impact of Human-Computer Interaction in the Global Sustainable Development Goals. In: Verdegay, J.L., Brito, J., Cruz, C. (eds) Computational Intelligence Methodologies Applied to Sustainable Development Goals. Studies in Computational Intelligence, vol 1036. Springer, Cham. https://doi.org/10.1007/978-3-030-97344-5_3

Peet, D.,J. Mulder, K., Bijma, A. (2004), Integrating SD into engineering courses at the Delft University of Technology, International Journal of Sustainability in Higher Education. 5. 278-288. 10.1108/14676370410546420.

Peffers, K., Tuunanen, T., Rothenberger, M. A., Chatterjee, S. (2007). A design science research methodology for information systems research. Journal of management information systems, 24(3), 45-77.

Pereira, J. C., de FSM Russo, R. (2018). Design thinking integrated in agile software development: A systematic literature review. Procedia computer science, 138, 775-782.

Robinson, J., Ariga, A., Cameron, S., & Wang, R. (2022). Reaching the Rest: Embedding Sustainability in Undergraduate Student Learning. Journal of Integrative Environmental Sciences, 19(1), 171-187.

Shapira, H., Ketchie, A., Nehe, M. (2017). The integration of Design Thinking and Strategic Sustainable Development. Journal of Cleaner Production, 140, 277-287.

Sinakou, E., Boeve-de Pauw, J., Van Petegem, P. (2019). Exploring the concept of sustainable development within education for sustainable development: implications for ESD research and practice. Environment, Development and Sustainability. 21. 1-10. 10.1007/s10668-017-0032-8.

Tjoa, A.M., Tjoa, S. (2016). The Role of ICT to Achieve the UN Sustainable Development Goals (SDG). In: Mata, F., Pont, A. (eds) ICT for Promoting Human Development and Protecting the Environment. WITFOR 2016. IFIP Advances in Information and Communication Technology, vol 481. Springer, Cham. https://doi.org/10.1007/978-3-319-44447-5_1

Umbrello, S., Capasso, M., Balistreri, M. et al. (2021). Value Sensitive Design to Achieve the UN SDGs with AI: A Case of Elderly Care Robots. Minds & Machines 31, 395–419. https://doi.org/10.1007/s11023-021-09561-y

UNECE. Learning for the future: Competences in Education for Sustainable Development; United Nations Economic Commission for Europe (UNECE): Geneva, Switzerland, 2012.

UNESCO. (2017). Education for Sustainable Development Goals: Learning Objectives. Paris: UNESCO. http://unesdoc.unesco.org/images/0024/002474/247444e.pdf

UN (2015). Transforming Our World: The 2030 Agenda for Sustainable Development. Resolution Adopted by the General Assembly on 25 September 2015, 42809, 1-13.

UN (2017) Work of the Statistical Commission pertaining to the 2030 Agenda for Sustainable Development. Resolution adopted by the General Assembly on 6 July 2017, (A/RES/71/313).

Wiek, A., Bernstein, M., Foley, R., Cohen, M., Forrest, N., Kuzdas, C., Kay, B., & Withycombe, Keeler, L. (2015). Operationalising competencies in higher education for sustainable development. In: Barth, M., Michelsen, G., Rieckmann, M., Thomas, I. (Eds.). Handbook of Higher Education for Sustainable Development. Routledge, London. pp. 241-260.

Wu, Y.-C.J. and Shen, J.-P. (2016). Higher education for sustainable development: a systematic review. International Journal of Sustainability in Higher Education. Vol. 17 No. 5, pp. 633-651. https://doi.org/10.1108/IJSHE-01-2015-0004

Žalėnienė, I., Pereira, P. (2021). Higher Education For Sustainability: A Global Perspective. Geography and Sustainability. 2. 10.1016/j.geosus.2021.05.001.

RESEARCH IN PROGRESS

AUTOML AS FACILITATOR OF AI ADOPTION IN SMEs: AN ANALYSIS OF AUTOML USE CASES

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While the uptake of AI and ML has been rising in recent years, SMEs still face various adoption challenges. In contrast to large enterprises, SMEs struggle to adopt AI as already the identification of suitable AI use cases requires substantial technical expertise. At the same time, productivity tools like AutoML promise easy access to AI capabilities to non-experts. This research-in-progress aims to investigate how AutoML tools can be utilised to facilitate the adoption of AI in SMEs. In a focus group with 11 representatives from SMEs, we identified and discussed potential AutoML use cases in detail. Results show that the identification of potential use cases rarely focused on existing and available data but rather repeated known use cases and success stories from large enterprises. We argue that a paradigm shift towards a data-centric approach would be beneficial to exhaust the capabilities of AutoML for SMEs.

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1 Introduction

Advancements in artificial intelligence (AI) such as large language models have recently gained attention and increased awareness among the broader public. However, the utilization of AI in organisations still faces various challenges, ranging from technological and organisational to social, legal, ethical, economical and data-related ones (Dwivedi et al., 2021). As such, many organisations still struggle to apply AI in their key operations and outside of proof of concept deployments (Dzhusupova et al., 2022). Especially small and medium-sized enterprises (SMEs) have a slow pace of adopting AI (Hansen & Bøgh, 2021). In contrast to large enterprises, SMEs lack the financial resources to invest in infrastructure, recruit AI talents in a competitive labour market or buy in external expertise (Bauer et al., 2020). The resulting lack of AI capabilities hinders the identification of potential AI use cases in SMEs (Bauer et al., 2020). Additionally, current approaches and tools that address challenges in AI adoption usually presume existing AI knowledge (Kirschbaum et al., 2022).

One approach that aims to provide easy access to AI based on machine learning (ML) to non-specialist users is AutoML (Zöller & Huber, 2021). Automated ML, short AutoML, subsumes the methods aiming to automate, at least to some extent, all stages of the design and development of ML-based systems (Hutter et al., 2019). AutoML simplifies the application of ML by reducing the number of steps of data preparation, model selection, model hyperparameters for the applicant and helps them with data visualisation, model comprehensibility and usage (Crisan & Fiore-Gartland, 2021). One of the main goals of AutoML is to democratise access to AI/ML Technology for people without in-depth knowledge of coding, statistics or ML (Zöller & Huber, 2021).

Already a myriad of AutoML frameworks and tools exist which enable users to build and explore AI. Depending on the level of expertise, users can utilise coding libraries such as auto-sklearn or autokeras that automate only specific parts in the ML development pipeline or commercial tools that can be utilised through graphical user interphases (GUI), e.g., Google AutoML or JadBio. While the development of AI systems by non-ML expert users through the use of AutoML is often seen as problematic (Crisan & Fiore-Gartland, 2021; Wang et al., 2019), AutoML does provide an opportunity for early exploration and easy trial runs by domain experts

(Xin et al., 2021). As such, AutoML provides professionals in different areas of expertise the opportunity to explore and identify possible AI use cases without the need for in-depth knowledge of AI/ML. However, research on the required knowledge of AutoML users or the appropriate integration of AutoML into the AI development process is very limited (Polzer & Thalmann, 2022).

As of now, little research has focused on how SMEs identify and select AI use cases. Additionally, there is little knowledge of how AutoML can be utilised by domain and business experts to recognise AI opportunities in different application fields. This study combines both research gaps and tries to answer the question *How can AutoML facilitate the adoption of AI in SMEs?* Thus, this research in progress (RiP) is a first explorative investigation on how AutoML can be introduced to SMEs to leverage their AI capabilities and how AutoML provides an easy-to-use exploration tool to identify possible AI use cases.

2 Methodology

A focus group with 11 representatives from 10 Austrian SMEs was held in February 2023. As seen in table 1, the participants came from different industry sectors and with different AI experience. The goal was to discuss SMEs' capabilities concerning AI and to discover potential AutoML use cases the SMEs representatives saw in their own organisations.

After a short introduction to AI and its challenges, two demonstrators of exemplary use cases conducted with different AutoML tools were shown to foster the participants' creativity. The participants were grouped into two sub-groups in the second part of the workshop. In these focus groups, each participant was asked to think of possible AI use cases to be implemented using AutoML in their organisation. The participants were provided with template cards to elaborate on the identified use cases with additional information on what data would be needed, what type of analysis would be needed and what benefits and challenges they could encounter during the implementation of such an AI use case. The participants had 20 minutes to individually think of possible AI use cases and to fill the template. Afterwards, each participant presented their use case using the template, and the group discussed requirements, feasibility, and possible challenges in the implementation. Finally, we discussed and jointly reflected by the entire group. The focus groups were audio recorded and transcribed for analysis. The filled-in template cards were also analysed. Afterwards, all identified use cases of both focus groups were analysed and three distinct groups of AI use cases emerged.

Table 1: Participants

#	Industry sector[1]	Company Size[2]	AI/ML experience
1	Human health	Medium Sized	Novice
2	Professional, scientific & technical activities	Medium Sized	Some experience
3	Professional, scientific & technical activities	Medium Sized	Expert
4	Information & communication	Micro	Expert
5	Other service activities	Small	Some experience
6	Manufacturing	Small	Expert
7	Other service activities	not SME	Expert
8	Other service activities	Micro	Some experience
9	Transportation and storage	Small	Novice
10	Manufacturing	Small	Some experience
11	Information & communication	Micro	Expert

3 Results

In total, 15 distinct potential AutoML use cases were identified, discussed, and clustered into three groups depending on their purpose. As most use cases would influence either the primary value-adding activities (e.g., operations), or supporting activities (e.g. HR management) of a firm's value chain (Porter, 1998) value chain was used as the basis of the for the grouping of the use cases. As such, the first cluster focuses on improving the core activities of existing business models. The second cluster focuses on support activities, often managerial activities that are not specifically related to the value proposition of the business model. The third cluster

[1] Based on United Nations (2023): International Standard Industrial Classification, URL: https://unstats.un.org/unsd/publication/seriesM/seriesm_4rev4e.pdf [last retrieved March 31st]
[2] Based on Europan Commision SME Defintion (2003): https://single-market-economy.ec.europa.eu/smes/sme-definition_en [last retrived May 19th, 2023]

consists of the application of AI leading to extensions of the existing business model or business model innovations (see figure 1).

In the **primary activity cluster** seven AI use cases to be implemented with AutoML have been identified. A common theme across these use cases was quality management. Thus, the use cases focused on improving maintenance or quality testing activities. For this cluster, the participants had a clear idea of what input data might be needed and how implementing the use cases could influence their business as well as which challenges they might encounter. One exemplary use case was the prediction of the deterioration of plates used to punch out different components in a production process. The participant knew the data and analysis needed to implement the use case in their company. Clear benefits, such as better decision support for maintenance activities, were also recognised. The most important challenge for this use case was the availability of data, a common challenge across many identified use cases.

The use cases of the **support activity cluster** did not have a direct connection to any particular product or service offered by the SMEs. Instead, the five use cases were centred around supporting activities, such as improving project cost predictions or procurement needs. These use cases had a more general nature and were not focused on the core or value-adding processes of the SME. In contrast to the primary activity cluster, it seemed more challenging to estimate the business value and specially to make a proper cost–benefit analysis. For instance, one discussed use case suggested the segmentation of potential customers for acquisition purposes. The main advantage in this category of use cases was seen in freeing of resources, e.g., from routine and time-intensive tasks, which can then be better utilised in other activities.

The **business model innovation cluster** explored more innovative ways to use AI that were not variations of already broadly known use cases, like predictive maintenance. The use cases of this cluster had different purposes and application fields, such as decontamination acceleration through the support of AutoML models in healthcare facilities, emotion detectors for consumption predictions, or veracity evaluation of news. Participants had varying ideas about what input data was necessary for these use cases, and some were uncertain or had limited knowledge of what suitable input data would be necessary. However, with the novelty of the approaches also, the challenges and uncertainties concerning the implementation of such use cases increased. As such, aspects of privacy concerns in connection to GDPR were mentioned, but also the complexity and variety of data or the challenges in validation and ensuring compliance were mentioned.

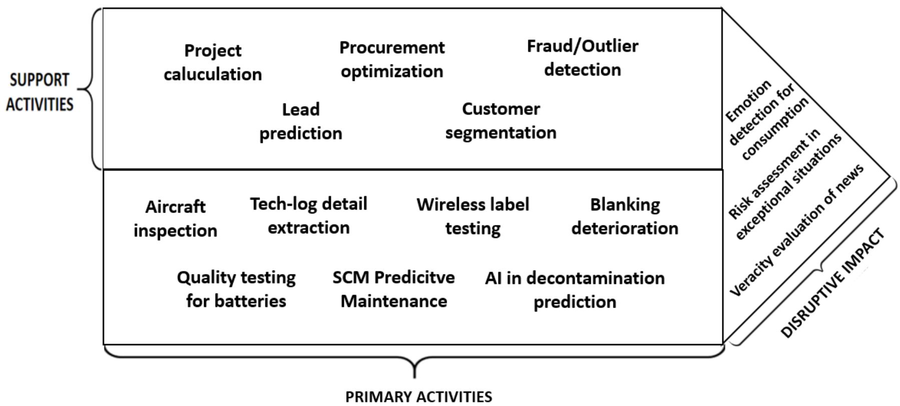

Figure 1: Identified use cases

4 Discussion and Outlook

Overall, our 11 participants acknowledged the capabilities of AutoML to start thinking about AI use cases in their SMEs. As the ideation and identification of AI use cases can either be purpose-driven or data-driven (Strum et al., 2021), AutoML, especially regarding data-driven identification, can provide beneficial support, as it provides easy to use access for exploring existing data sets (Wang et al., 2019). Therefore, we provided first evidence that AutoML can support the identification of AI use cases.

The analysis of the focus groups showcased that the identification of the use cases was based on already known success stories that can be observed in literature and are present in the public discourse, such as predictive maintenance or customer segmentation (Thalmann et al., 2018). In this regard, mostly a purpose-driven approach to finding AI use cases was utilised, which aimed at improving process steps, tasks, or decisions through AI. However, especially a data-driven explorative approach of use case identification can lead to new ideas and approaches on how to use AI.

In this regard, participants who already have good knowledge or experience with AI, proposed novel and disruptive AI use cases. The use cases of the business model innovation cluster were proposed by participants who at least had some experience in the field of AI/ML. As such, a minimum of training regarding AI applications upfront is required, which also influences the necessary level of knowledge required to utilise AutoML effectively (Polzer & Thalmann, 2022). Thus, the identification and further the implementation of AI use cases (especially with disruptive impact) still requires conscious effort in the development of organizational AI capabilities (Sjödin et al., 2021).

The black-box character of AI was discussed as a potential barrier, especially regarding its adoption in sensitive use cases. Participants demanded explainability features (see (Gashi et al., 2022) for an overview) and many times envisioned causal discovery (see (Vuković & Thalmann, 2022) for an overview). Similarly, also the feasibility of the proposed use cases in relation to ethical and privacy issues was discussed. Thus, especially in use cases relying on personal data, like in the emotion detection use case, considerable challenges concerning legal but also ethical perspectives were highlighted. Therefore, there is a need for providing user guidance on AutoML tools to ensure the development of fair, accountable, and transparent AI systems (Polzer & Thalmann, 2022).

This RiP paper has many limitations and serves as starting point for future research. First, we used AutoML demos to spark discussions among SME representatives and to identify use cases. So far, we do not have evidence that such use cases can be implemented in SMEs. For this purpose, we plan implementation case studies with SMEs organised as think-aloud studies. Second, the AutoML knowledge of some participants was limited, and our data suggest that more knowledge could facilitate the capabilities to "think out of the box". Also, in our case studies, we will investigate which knowledge is needed to use AutoML in a responsible way and how more knowledge affects the capability to identify new use cases. Third, so far, our sample relies on a small sample of SMEs just from Austria. For this purpose, we plan additional workshops in Austria, Germany, Portugal, and Spain to broaden our focus. This future work will especially focus on the limitations and challenges in implementing AutoML into SMEs.

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References

Bauer, M., van Dinther, C., & Kiefer, D. (2020). Machine Learning in SME: An Empirical Study on Enablers and Success Factors. In AMCIS 2020 Proceedings. https://aisel.aisnet.org/amcis2020/adv_info_systems_research/adv_info_systems_research/3

Crisan, A., & Fiore-Gartland, B. (2021). Fits and Starts: Enterprise Use of AutoML and the Role of Humans in the Loop. In Y. Kitamura (Ed.), ACM Digital Library, Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems (pp. 1–15). Association for Computing Machinery. https://doi.org/10.1145/3411764.3445775

Dwivedi, Y. K., Hughes, L., Ismagilova, E., Aarts, G., Coombs, C., Crick, T., Duan, Y., Dwivedi, R., Edwards, J., Eirug, A., Galanos, V., Ilavarasan, P. V., Janssen, M., Jones, P., Kar, A. K., Kizgin, H., Kronemann, B., Lal, B., Lucini, B., . . . Williams, M. D. (2021). Artificial Intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. International Journal of Information Management, 57, 101994. https://doi.org/10.1016/j.ijinfomgt.2019.08.002

Dzhusupova, R., Bosch, J., & Olsson, H. H. (2022). The Goldilocks Framework: Towards Selecting the Optimal Approach to Conducting AI Projects. In 2022 IEEE/ACM 1st International Conference on AI Engineering–Software Engineering for AI (CAIN)) (pp. 124–135).

Gashi, M., Vuković, M., Jekic, N., Thalmann, S., Holzinger, A., Jean-Quartier, C., & Jeanquartier, F. (2022). State-of-the-Art Explainability Methods with Focus on Visual Analytics Showcased by Glioma Classification. BioMedInformatics, 2(1), 139–158. https://doi.org/10.3390/biomedinformatics2010009

Hansen, E. B., & Bøgh, S. (2021). Artificial intelligence and internet of things in small and medium-sized enterprises: A survey. Journal of Manufacturing Systems, 58, 362–372. https://doi.org/10.1016/j.jmsy.2020.08.009

Hutter, F., Kotthoff, L., & Vanschoren, J. (2019). Automated Machine Learning. Springer International Publishing. https://library.oapen.org/handle/20.500.12657/23012 https://doi.org/10.1007/978-3-030-05318-5

Kirschbaum, J., Posselt, T., & Roth, A. (2022). Use-Case-Based Innovation For Artificial Intelligence–An Ontological Approach. In ECIS 2022 Research-in-Progress Papers. https://aisel.aisnet.org/ecis2022_rip/64/

Polzer, A. K., & Thalmann, S. (2022). The impact of AutoML on the AI development process. In Proceedings of the 2022 Pre-ICIS SIGDSA Symposium. https://aisel.aisnet.org/cgi/viewcontent.cgi?article=1012&context=sigdsa2022

Porter, M. E. (1998). Competitive Advantage: Creating and Sustaining Superior Performance (2. Auflage). Free Press. https://ebookcentral.proquest.com/lib/kxp/detail.action?docID=4934923

Sjödin, D., Parida, V., Palmié, M., & Wincent, J. (2021). How AI capabilities enable business model innovation: Scaling AI through co-evolutionary processes and feedback loops. Journal of Business Research, 134, 574–587. https://doi.org/10.1016/j.jbusres.2021.05.009

Strum, T., Fecho, M., & Buxmann, P. (2021). To Use or Not to Use Artificial Intelligence? A Framework for the Ideation and Evaluation of Problems to Be Solved with Artificial Intelligence. In Hawaii International Conference on System Sciences 2021. University of Hawai'i at Manoa Hamilton Library.

Thalmann, S., Mangler, J., Schreck, T., Huemer, C., Streit, M., Pauker, F., Weichhart, G., Schulte, S., Kittl, C., Pollak, C., Vukovic, M., Kappel, G., Gashi, M., Rinderle-Ma, S., Suschnigg, J., Jekic, N., & Lindstaedt, S. (2018, July 11–14). Data Analytics for Industrial Process Improvement A Vision Paper. In 2018 IEEE 20th Conference on Business Informatics (CBI) (pp. 92–96). IEEE. https://doi.org/10.1109/CBI.2018.10051

Vuković, M., & Thalmann, S. (2022). Causal Discovery in Manufacturing: A Structured Literature Review. Journal of Manufacturing and Materials Processing, 6(1), 10. https://doi.org/10.3390/jmmp6010010

Wang, D., Weisz, J. D., Muller, M., Ram, P., Geyer, W., Dugan, C., Tausczik, Y., Samulowitz, H., & Gray, A. (2019). Human-AI Collaboration in Data Science. Proceedings of the ACM on Human-Computer Interaction, 3(CSCW), 1–24. https://doi.org/10.1145/3359313

Xin, D., Wu, E. Y., Lee, D. J.-L., Salehi, N., & Parameswaran, A. (2021). Whither AutoML? Understanding the Role of Automation in Machine Learning Workflows. In Y. Kitamura, A. Quigley, K. Isbister, T. Igarashi, P. Bjørn, & S. Drucker (Eds.), Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems (pp. 1–16). ACM. https://doi.org/10.1145/3411764.3445306

Zöller, M.-A., & Huber, M. F. (2021). Benchmark and Survey of Automated Machine Learning Frameworks. Journal of Artificial Intelligence Research, 70, 409–472. https://doi.org/10.1613/jair.1.11854

RESEARCH IN PROGRESS

RAPID SCALING OF A DANISH PUBLIC HEALTH SYSTEM UNDER COVID-19

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In recent years cloud infrastructure services have acted as engines for scaling applications when user demand spikes. A discipline typically recognized as complex, expensive, error-prone, and time-consuming. In the field of healthcare services, data is considered sensitive under the European Union's data protection law and are therefore under strict jurisdiction disallowing the Danish public services to utilize cloud scalability.

During the COVID-19 lockdown a small group of expert practitioners was tasked with scaling public health services to accommodate an exponential number of excess users who needed to access test results and immunity passports. An effort further restrained by a severely limited timeframe of two weeks.

By utilizing the critical incident technique this paper is an effort empirically to capture the most significant decisions in the scaling process including organizational aspects, virtualization, content delivery network, lazy-loading, and firewall interface configuration.

Keywords:
scalability, health information systems, rapid scaling, sensitive data, Bled eConference

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1 Introduction

Scaling information systems is an important discipline for both academics and practitioners from various industries. The discipline can be defined as the process of expanding in scope or size (for example increasing the number of features or the number of end-users) (Sahay & Walsham, 2006). Scaling has been studied from various theoretical perspectives and with different aspects in focus, including the technical, organizational, and institutional aspects. It has been noted that the inability to scale is not caused by technological problems alone. Often, the difficulties are caused by organizational or managerial issues such as confusion of roles, people making bad decisions, and lack of attention to organizational and technical implementation (Abbott & Fisher, 2015).

With the COVID-19 pandemic, the rapid scaling of a public health information system suddenly became critical for the Danish public. Citizens were vaccinated and tested regularly since it became required to document one's status when traveling and physically attending restaurants, shops, and other public areas. Consequently, a digital corona passport was introduced and the national website for health information sundhed.dk was updated with additional features to provide digital vaccination or test certification. Within two weeks, a time constraint was imposed by the government and sundhed.dk had to scale a digital infrastructure from accommodating a rough estimate of a few hundred daily user logins to 5500 concurrent users with a recorded peak load of 1.4 million daily logins. Modern online cloud services such as Amazon Web Services usually accommodate unanticipated and immediate requirements for rapid scaling infrastructure. Still, due to regulations concerning sensitive health data – this was not an option.

This leads to a research question: What critical technical and organizational decisions enabled the rapid scaling of sundhed.dk within two critical weeks during the COVID-19 pandemic?

2 Related literature

In the literature, scalability covers a wide variety of subtopics. Within the organizational part of the information system literature, it is argued that scaling is not only a technical matter but also involves huge managerial efforts if a company wants to scale successfully. Abbott & Fisher (2015) argue that setting the right team with the right roles and clarified responsibilities is a critical prerequisite when scaling. Sahay & Walsham (2006) focus more on the socio-human aspects of scaling and allude to a variety of dilemmas associated with scaling. Some of them include standardized versus customized solutions, top-down versus bottom-up approaches, and appropriate versus complex technological solutions. Furthermore, they point our attention to considering scaling both concerning the increase in users of the systems and the number of members participating in the implementation team at different stages of the scaling and implementation process. In this regard, they distinguish between two approaches for scaling information systems, the cultivation approach, and the construction approach. The cultivation approach is a more incremental way of seeing scaling which favors a smooth, situated, and improvisational strategy changing smaller parts at a time while aligning those changes with the rest of the system. The cultivation approach stands against the construction approach which offers a more rational and planned approach to scaling emphasizes. It is argued that neither of the two should be prioritized over the other (Sahay & Walsham, 2006).

In classical computer science, scalability has mainly been concerned with algorithm optimization, multithreading, processor optimization, or other techniques that allow scalable performance and execution in a given context, such as a piece of hardware (Ahn et al., 2015; Rajan, 2010; Thierens, 1999; Vachharajani et al., 2005; Yeung, 1999). In other branches, scalability has been studied through the lens of software engineering and architecture, highlighting models, patterns, and processes to make a system scalable and evaluating the potential for scalability (Brataas & Hughes, 2004; Isoyama et al., 2012; Leesatapornwongsa et al., 2017; Mirakhorli et al., 2008; Pahl & Jamshidi, 2016; Rajan, 2010; Srinivas & Janakiram, 2005; Vaquero et al., 2011). The scale cube was introduced to structure at least some of the architectural scale options (Abbott & Fisher, 2015). The scale cube breaks down horizontal scaling into three dimensions. The three dimensions are defined as the x-axis, replication, y-axis, functional splitting, and z-axis, request splitting.

In recent years, a main subtopic of academic interest within scalability has revolved around component-based systems or microservices (D'Antonio et al., 2004; Hasselbring, 2016; Kächele & Hauck, 2013; Lehrig et al., 2015; Márquez et al., 2018) to leverage the elastic horizontal/vertical scaling potential of online modern PAAS or IAAS solutions in the cloud. However, in the field of healthcare services and other critical systems (Knight, 2002), data is considered sensitive and therefore under strict jurisdiction making it difficult to utilize cloud scalability (Heitmeyer, 2005; Walling, 2020).

3 Methodology

The purpose of this study is to examine the successful rapid scaling of sundhed.dk that took place over two weeks during the COVID-19 pandemic as a juxtaposition to other public IS projects (Lauesen, 2020). By examining success stories from the novel context of the COVID-19 pandemic we hope to uncover and retain unheard experiences (Boéri & Giustini, 2023) and tacit knowledge (Schluter et al., 2008) of event-based IS development and scaling processes that evolved throughout the events.

We focus on the period between the day when the Danish prime minister announces the partial re-opening of the Danish society until 14 days, later when the scaled health platform, sundhed.dk should be fully functional and ready to handle the heavily increased user load. This two-week period constitutes the context of our interviews.

Our selection of participants and interview design was inspired by the critical incident technique (CIT) (Flanagan, 1954), to gain entry to, and collect data about the events of the 14 days of rapid scaling (Cenfetelli & Schwarz, 2011) (Gogan et al., 2014). By framing our research interest in a CIT-inspired perspective we aim at identifying the important and relevant events of the rapid scaling process in the unexpected and unusual context of the COVID-19 pandemic.

Our study draws on the technique from a phenomenological perspective and interpretative paradigm (Chell, 1998) rather than the positivist perspective from which it was originally developed. We are interested in subjective nuances that can bolster our understanding of what happened during the scaling of sundhed.dk, hence.

The critical incident interviews were planned and conducted according to Chell's (1998) eight distinguishable aspects of the method (preliminary design work, gaining access, introduction CIT, focusing the theme, controlling the interview, concluding the interview, ethical issues, and analyzing the data. Access was obtained from one of the IT architects involved in the scaling process who pointed out additional respondents inspired by the snowball sampling method. The criteria that we gave to him was that he should choose those who were most intensively involved in the scaling process. We are aware of a potential selection bias regarding the number and criteria for selecting the respondents and we consider also including respondents with a more peripheral role in the scaling process such as managers, developers, and testers in the sample. After interviewing the four respondents, they were pointing out the same critical incidents and thereby we reached the level of saturation (Glaser & Strauss, 1967). The length of each interview was between forty-five minutes and two hours. All the interviews were conducted at the company which supported a natural and relaxed atmosphere for the respondents. A semi-structured interview guide was designed consisting of the following steps. First, the motivation, focus, and aim of the research were presented. The respondent was then asked to present himself including tasks and responsibilities related to the scaling process. To reconstruct the critical incidents in the scaling process a timeline was drawn to let the respondent point out the critical incidents graphically. The interview continued with a detailed focus on each of the identified incidents starting from the launch of the system and going backward from that. During the interview, the respondent was encouraged to describe both the organizational and technical aspects related to the specific incidents. During the interview, we gave attention to potential discrepancies in the respondents' descriptions of the incidents and asked follow-up questions to clarify misunderstandings, thereby increasing the validity of the data. At the end of the interview, the respondent was asked whether we could contact them in case we needed to get some of the discussed topics and incidents clarified. For analyzing the data, we used analytical triangulation where each interview was processed by all four authors. When analyzing the data, we started describing and analyzing each of the identified critical situations inspired by the typical application of the CIT. However, this process revealed several themes across the incidents which were much more interesting to analyze than the individual incidents. Hence, we moved away from an event-based analysis to a more thematic analysis.

4 Preliminary results

The following analysis will examine the prerequisites, diagnostics, and critical decisions made by the task force during the two weeks of intense work that transformed the critical infrastructure of sundhed.dk and enabled the platform to scale accordingly to user demand and regulatory requirements. The analysis will be divided into groups of scalability perspectives such as organizational aspects, virtualization, content delivery network, lazy-loading, and firewall interface configuration.

The initial challenge that was overcome was the formation of a task force itself. Before the rapid scaling requirements, sundhed.dk was limited to a quarterly deployment schedule and processes involving several confirmation steps, stakeholders and budgetary approval hereby presenting overhead for decision-making. Their solution was an appointment of the task force that conducted daily meetings with top-level management to present findings and approve solutions. The task force furthermore was organizationally relocated from development to operations to pre-emptively remedy challenges caused by the principles of separation of duties.

Several challenges were identified by the task force from a technical standpoint. To horizontally scale a platform, the platform should be able to perform and accommodate concurrent users by load-balancing requests between a dynamic set of virtual machines containing all required services. By fulfilling such requirements new hardware was introduced to scale horizontally – and proved to reduce overhead due to service communication located locally on virtual machines as opposed to network communication. Communication overhead between services interfacing was then identified as the result of an infrastructure relying on synchronous network calls and timeouts. Timeout limits were reduced which in turn reduced response time for non-responding services and a large-scale design pattern change in the shape of circuit-breaking was proposed but was not implemented due to the time limitations presented. Consequently, their incoming and outgoing bandwidth was expanded, hardware was added to their prior setup, firewall-interface policy was configured to accommodate more users and an asymmetrical volume was identified between low-volume ingoing requests and high-volume outgoing responses. When identified, the task force implemented a content delivery network that provided additional static insensitive content to clients such that bandwidth from within secured services provided the sensitive data.

5 Conclusion

This research-in-progress paper explored a single unique case. In this case, a select group of Health IT expert practitioners was faced with a scaling problem. The problem progressed under a set of unprecedented circumstances caused by sudden and extensive user request increase during COVID-19. Due to the sensitive nature of health data, it was not an option to scale horizontally and elastically by utilizing cloud services meaning that infrastructure, application, platform, and network had to be configured to allow the service to scale. It was found that the practitioners used a multiplicity of techniques to accommodate the increased number of requests such as reconfiguration of services to allow virtualization and horizontal scaling, lazy-loading, content delivery network of static content, and firewall interface configuration to name a few of which they successfully implemented within a short frame of time.

References

Ahn, J., Hong, S., Yoo, S., Mutlu, O., & Choi, K. (2015). A scalable processing-in-memory accelerator for parallel graph processing. Proceedings of the 42nd Annual International Symposium on Computer Architecture, 105–117. https://doi.org/10.1145/2749469.2750386

Boéri, J., & Giustini, D. (2023). Qualitative research in crisis: A narrative-practice methodology to delve into the discourse and action of the unheard in the COVID-19 pandemic. Qualitative Research.

Brataas, G., & Hughes, P. (2004). Exploring architectural scalability. Proceedings of the 4th International Workshop on Software and Performance, 125–129. https://doi.org/10.1145/974044.974064

Chell, E. (1998). Critical Incident Technique. In G. Symon & C. Cassell (Eds.), Qualitative Methods and Analysis in Organizational Research (pp. 51–72). SAGE Publications.

D'Antonio, S., Esposito, M., Romano, S. P., & Ventre, G. (2004). Assessing the scalability of component-based frameworks. ACM SIGMETRICS Performance Evaluation Review, 32(3), 34–43. https://doi.org/10.1145/1052305.1052311

Hasselbring, W. (2016). Microservices for Scalability. Proceedings of the 7th ACM/SPEC on International Conference on Performance Engineering, 133–134. https://doi.org/10.1145/2851553.2858659

Heitmeyer, C. (2005). Developing Safety-Critical Systems: The Role of Formal Methods and Tools. 10th Australian Workshop on Safety Related Programmable Systems.

Isoyama, K., Kobayashi, Y., Sato, T., Kida, K., Yoshida, M., & Tagato, H. (2012). A scalable complex event processing system and evaluations of its performance. Proceedings of the 6th ACM International Conference on Distributed Event-Based Systems, 123–126. https://doi.org/10.1145/2335484.2335498

Kächele, S., & Hauck, F. J. (2013). Component-based scalability for cloud applications. Proceedings of the 3rd International Workshop on Cloud Data and Platforms, 19–24. https://doi.org/10.1145/2460756.2460760

Knight, J. C. (2002). Safety critical systems. Proceedings of the 24th International Conference on Software Engineering - ICSE '02, 547. https://doi.org/10.1145/581339.581406

Leesatapornwongsa, T., Stuardo, C. A., Suminto, R. O., Ke, H., Lukman, J. F., & Gunawi, H. S. (2017). Scalability Bugs. Proceedings of the 16th Workshop on Hot Topics in Operating Systems, 24–29. https://doi.org/10.1145/3102980.3102985

Lehrig, S., Eikerling, H., & Becker, S. (2015). Scalability, Elasticity, and Efficiency in Cloud Computing. Proceedings of the 11th International ACM SIGSOFT Conference on Quality of Software Architectures, 83–92. https://doi.org/10.1145/2737182.2737185

Márquez, G., Villegas, M. M., & Astudillo, H. (2018). A pattern language for scalable microservices-based systems. Proceedings of the 12th European Conference on Software Architecture: Companion Proceedings, 1–7. https://doi.org/10.1145/3241403.3241429

Mirakhorli, M., Azim Sharifloo, A., & Shams, F. (2008). Architectural challenges of ultra large scale systems. Proceedings of the 2nd International Workshop on Ultra-Large-Scale Software-Intensive Systems, 45–48. https://doi.org/10.1145/1370700.1370713

Pahl, C., & Jamshidi, P. (2016). Microservices: A Systematic Mapping Study. Proceedings of the 6th International Conference on Cloud Computing and Services Science, 137–146. https://doi.org/10.5220/0005785501370146

Rajan, H. (2010). Building scalable software systems in the multicore era. Proceedings of the FSE/SDP Workshop on Future of Software Engineering Research, 293–298. https://doi.org/10.1145/1882362.1882423

Schluter, J., Seaton, P., & Chaboyer, W. (2008). Critical incident technique: a user's guide for nurse researchers. Journal of Advanced Nursing, 61(1), 107–114.

Srinivas, A. V., & Janakiram, D. (2005). A model for characterizing the scalability of distributed systems. ACM SIGOPS Operating Systems Review, 39(3), 64–71. https://doi.org/10.1145/1075395.1075401

Thierens, D. (1999). Scalability Problems of Simple Genetic Algorithms. Evolutionary Computation, 7(4), 331–352. https://doi.org/10.1162/evco.1999.7.4.331

Vachharajani, N., Iyer, M., Ashok, C., Vachharajani, M., August, D. I., & Connors, D. (2005). Chip multi-processor scalability for single-threaded applications. ACM SIGARCH Computer Architecture News, 33(4), 44–53. https://doi.org/10.1145/1105734.1105741

Vaquero, L. M., Rodero-Merino, L., & Buyya, R. (2011). Dynamically scaling applications in the cloud. ACM SIGCOMM Computer Communication Review, 41(1), 45–52. https://doi.org/10.1145/1925861.1925869

Walling, S. (2020). A Comprehensive Review on Cloud Computing and Cloud Security Issues. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 483–490. https://doi.org/10.32628/CSEIT206489

Yeung, D. (1999). The scalability of multigrain systems. Proceedings of the 13th International Conference on Supercomputing, 268–277. https://doi.org/10.1145/305138.305203

RESEARCH IN PROGRESS

STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREATS TO BLOCKCHAIN IN INDUSTRIES BEYOND CRYPTO

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Despite the hype of the blockchain technology, the implementation and execution of blockchain technologies in sectors beyond cryptocurrency is lagging and below par. Understanding the reasons behind this lag is important to enable addressing any voids and enable making maximum use of the technology. We shed light on this void by trying to identify the strengths, weaknesses, opportunities, and threats (SWOT) faced by the use of blockchain technologies in industries beyond crypto, and thereby, draw insights valuable to develop a blockchain platform for healthcare.

Keywords:
blockchain,
catena-X,
healthcare,
SWOT
Analysis,
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1 Introduction

Blockchain is a technology for data sharing and has the key characteristics of transparency, anonymization, and decentralization (Sarmah, 2018). Blockchain was introduced for recording cryptocurrency transactions and today, the millions of crypto transactions being completed presents a solid use-case for blockchain technology. This has led to the exploration of prospects of blockchain technology in other data-driven sectors such as finance (Kahyaoglu & Aksoy, 2021), healthcare (Epiphaniou, et. al., 2019), government (Guarda, et. al., 2021), manufacturing and distribution (Kasten, 2020), and more. However, the implementation and execution of blockchain technologies in other sectors beyond crypto is lagging and is below par in contrast to the hype (Luthra, et. al., 2022). Therefore, understanding the reasons behind this lag is important to enable addressing key voids and thus, making maximum use of the technology. With the aim of serving to this gap, answering the following research question is attempted through this research in progress paper: What are the strengths, weakness, opportunities, and threats, faced by the use of blockchain technology in industries beyond crypto? In particular, we focus on private blockchains.

While there are numerous ways that can be crafted to answer the aforesaid research question, we take a unique approach that would benefit our larger aim of designing, developing, and implementing a blockchain platform for healthcare. This project is currently ongoing, and an approach inspired by the Design Science Research Methodology (DSRM) (Hevner, et. al., 2010), (Hevner & Wickramasinghe, 2018) is followed. The focus of this paper is reporting on the outcomes of the "Problem Identification" phase our DSRM-inspired approach.

Since our focus is towards development and implementation of a blockchain platform, the unique approach we take to answer our research question is by reviewing a commercial data sharing platform that has been recently rolled out and makes use of blockchain technologies. The commercial platform we have chosen for review is Catena-X (Catena-X, 2022). Catena-X is a state-of-the-art collaborative and open data ecosystem utilizing blockchain, that is currently gaining traction in Europe, especially in the automotive sector. Catena-X stands as one of the earliest commercially available data ecosystems of its kind, and it is still in its early years of being rolled out. As such, Catena-X serves as an exemplary use case to understand the challenges especially pertaining to the implementation and execution of blockchain platforms in different industries. We thus, answer our research question by performing a scoping review about the literature on Catena-X.

2 Method Followed for the Scoping Review

We started by searching the keyword “Catena-X" OR "Catena X” in academic databases such as Scopus and IEEE Xplore. However, a minimal number of results were found. Therefore, we repeated the same keyword search in Google Scholar—a more inclusive database. The search was carried out between 4th and 6th of May 2022. This search resulted in 175 results. These included a mix of peer reviewed academic publications to grey literature such as industry reports and media articles. Since the search was done in Google Scholar, we had limitations in specifying where exactly the searched keywords would appear. For instance, in databases like Scopus, one can search for keywords specifically within the article Titles and Abstract. However, Google Scholar offered limited capability to allow such constriction. This meant that our results could include the keyword Catena-X anywhere in the text, for example even in the reference list or an Acknowledgement. Therefore, we performed an Abstract review to find out which articles were relevant. Our inclusion criteria were to include the items that discussed information systems in the Abstract. Items not related to information systems were excluded. This resulted in 16 articles being relevant, which had Catena-X mentioned within the text body of the article. These articles were taken forward for full text review. From the full text review, five more articles were found to be irrelevant, as some of the articles had the name Catena mentioned for things other than the Catena-X platform. Thus, our review ended up with the 11 Articles. The 11 articles are the following: (Berg, et. al, 2021), (Garrido, et. al., 2022), (Johann, et. al., 2020), (Langdon and Schweichhart, Data Spaces), (Müller, et. al., 2022), (Ramesohl, et. al., 2022), (Sautter, 2021), (Schulz, et. al., 2022), (Staab, et. al., 2022), (Usländer, et. al., 2021) and (Zhongming, et. al., 2021). A flowchart of our search is available in the Results section (Figure 1).

In the following step, we performed a SWOT analysis, i.e., find out the Strengths, Weaknesses, Opportunities, and Threats, related to Catena-X as reported in the available literature. The selected 11 articles were read in search of specific issues regarding Catena-X. The related text segments were tabulated, and themes were assigned to the main points raised. These themes eventually yielded a list of relevant issues.

Since the rigor of critique was lacking nevertheless as said before, most of the points we found in these articles could be listed as “Opportunities”. Few of the issues pointed at “Threats”. However, the depth and richness of what we expected as “Strengths” and “Weaknesses” were not explicitly talked about in these articles. Therefore, for the sake of completeness, we went a step further, and looked at some other material for what was missing. Since we set out starting at a lens of fast-track learning for “implementation,” we referred to commercial and educational providers that offered Blockchain-related services rather than reading academic research. Thus, we selected IBM (IBM, 2022)—a renowned Blockchain service provider, and 101blockchains (101blockchains, 2022)—an education provider offering courses and training on Blockchain. We referred to the material published by IBM and 101blockcains and selected what they identified as Strengths and Weaknesses, thereby filling gas in our analysis.

3 Results

Shown in Figure 1 is a flowchart of our literature search. The identified Strengths, Weaknesses, Opportunities, and Threats are listed in Table 1 as summary themes. Descriptions of these themes with elaborate meanings and text extracts are presented in Appendix A (provided as an external reference) along with the detailed full text analysis. We list out the Strengths as identified in the IBM article in (Benefits of Blockchain, 2022). The weaknesses are listed as identified in the 101blockchains article in (Disadvantages of Blockchain, 2022), and from the 11 works identified for the full text review. The Opportunities and Threats are listed from the findings of our literature review (i.e., the full text review of the 11 works). The findings are listed in Table 1. The frequency each theme was found in the literature is mentioned within parentheses in front of each theme in Table 1. A detailed analysis of the findings is provided in Appendix A (provided as an external reference).

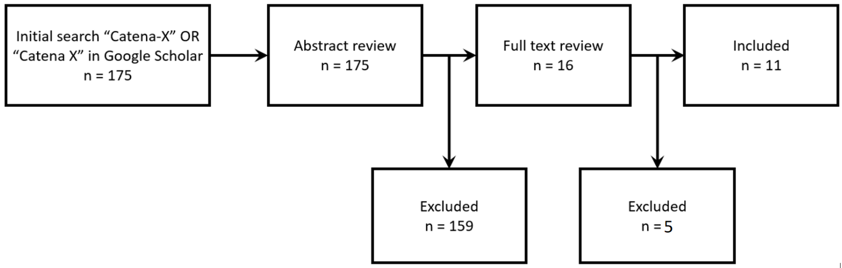

Figure 1: Flowchart depicting the literature search

Table 1: Summary of the SWOT Analysis

Strengths	Weaknesses	Opportunities	Threats
• Enhanced security (1) • Greater transparency (1) • Instant traceability (1) • Increased efficiency and speed (1) • Automation (1)	• Node dependent (1) • Scalability challenges (1) • Interoperability issues (1) • Energy consumption (1) • Immutability of data (1) • Not Completely Secure (1) • Responsibility on the users (1) • Cost and implementation struggle (1) • Lack of maturity (1) • Require antitrust laws (1) • Require special corporate models (1)	• Increased efficiency (3) • Environmental friendliness (3) • Enhanced collaboration (6) • Smart factories (2) • Team robotics (1) • Transparent value chain (1) • Optimized production (1) • Increased average productivity (1) • Increased marginal productivity (1) • Increased national product (1) • Increased trust (1) • Digital twins (1) • Increased transparency (1) • Increased security (1) • Increased autonomy (2) • Enhanced interoperability (1) • Enhanced sustainability (1) • Improved infrastructure (1) • Improved guidelines (1) • Improved scalability (1)	• Lack of collaborative thinking (1) • Lack of digital trust (1) • Lack of financial resources (1) • Lack of skills (1) • Lack of reliable technical foundations (1) • Lack of reliable legal foundations (1) • Lack of suitable business models (1) • Requirement of new infrastructure (1) • Requirement of new rules and guidelines (1) • Requirement of IP protection, trade secrets (1)

4 Discussion

This paper contributed by way of a SWOT analysis to the use of blockchain in different industries through reviewing some early works regarding Catena-X. Themes were assigned to the main issues identified and thereby lists were formed and presented. These themes eventually yielded a list of relevant issues. Although our review contains limited sources, the importance of the results that can be found even at this level, must not be undermined as it does identify and envisage issues at an early stage is extremely important. Therefore, we consider the points found through our review of early articles related to Catena-X as a great starting point for planning the design and development of blockchain platforms for different sectors.

4.1 A Pathway for Healthcare

Today, healthcare operations are generating volumes of critical and highly sensitive data including medical records in EMRs and genomic data. As such, it becomes vital for healthcare organizations and all healthcare stakeholders to consider responsible approaches to best manage these data and ensure appropriate levels of security and privacy to ensure the highest levels of trust between and within all parties involved in the healthcare sector. Becoming proactive in this pursuit is extremely important in this era of rapid digital transformation of healthcare. In this context, we see significant potential in private blockchains to increase data integrity in the healthcare sector. This paper has highlighted the key strengths, weaknesses, opportunities, and threats, of blockchain technologies being used in sectors outside crypto. The identified issues are certainly applicable to the healthcare sector as well.

5 Conclusions

The implementation and execution of blockchain technologies in sectors beyond cryptocurrency is lagging (Luthra, et. al., 2022). The reasons behind this lag must be understood to enable filling any voids to enable making maximum use of the technology. We set out in this paper to fill this void by identifying the strengths, weaknesses, opportunities, and threats (SWOT) faced by the use of blockchain technologies in industries beyond crypto.

We take a unique approach to perform the SWOT analysis to benefit our larger aim of designing, developing, and implementing a blockchain platform for healthcare. The project of designing this blockchain platform is currently ongoing, and a DSRM-inspired approach is followed. This SWOT analysis serves as an outcome of the “Problem Identification” phase our design approach. We also discussed a pathway suitable for the healthcare sector grounded on the findings of the SWOT analysis.

Our future work will involve carrying out the subsequent steps of DSRM to develop a private blockchain prototype for a hospital and then trial it. The findings of our SWOT analysis will guide our design. Our findings are also generalizable for other industries that may hold interest in developing blockchain platforms or data ecosystems that would serve the unique needs of their sectors. Later, we expect to get the opportunity to review some other commercial data ecosystems as well (e.g., SAP Datasphere) to confirm generality of our findings from Catena-X, or to learn differences. Furthermore, we will attempt to discuss the identified themes in more detail; elaborating on how they relate to healthcare and perhaps other sectors as well. Such attempts would assist in identifying ways to convert the identified weaknesses into strengths and threats into opportunities and thereby help the uptake of the blockchain technology in different sectors.

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References

Appendix A. Link: https://dit.swin.edu.au/clotsapp/Appendix_A.pdf

Benefits of Blockchain. (2022). IBM Website. Link: https://www.ibm.com/au-en/topics/benefits-of-blockchain, date of last visit: July 28, 2022.

Berg, H., Bendix, P., Jansen, M., Le Blévennec, K., Bottermann, P., Magnus-Melgar, M., ... & Wahlström, M. (2021). Unlocking the potential of Industry 4.0 to reduce the environmental impact of production. European Environment Agency, European Topic Centre on Waste and Materials in a Green Economy: Mol, Belgium.

Catena-X. (2022). Catena-X website. Link: https://catena-x.net/en/ visited last: November 9, 2022.

Disadvantages of Blockchain. (2022). 101blockchains Website. Link: https://101blockchains.com/disadvantages-of-blockchain/, date of last visit: July 28, 2022.

Epiphaniou, G., Daly, H., & Al-Khateeb, H. (2019). Blockchain and healthcare. In Blockchain and Clinical Trial (pp. 1-29). Springer, Cham.

Garrido, G. M., Sedlmeir, J., Uludağ, Ö., Alaoui, I. S., Luckow, A., & Matthes, F. (2022). Revealing the landscape of privacy-enhancing technologies in the context of data markets for the IoT: A systematic literature review. Journal of Network and Computer Applications, 103465.

Guarda, T., Augusto, M. F., Haz, L., & Díaz-Nafría, J. M. (2021). Blockchain and Government Transformation. In International Conference on Information Technology & Systems (pp. 88-95). Springer, Cham.

Hevner, A., & Chatterjee, S. (2010). Design science research in information systems. In Design research in information systems (pp. 9-22). Springer, Boston, MA.

Hevner, A. R., & Wickramasinghe, N. (2018). Design science research opportunities in health care. Theories to Inform Superior Health Informatics Research and Practice, 3-18.

IBM. (2022). IBM Website. Link: https://www.ibm.com/au-en/, date of last visit: July 28, 2022.

Johann, H., Klein, M., & Rieger, A. (2020). EUROPEAN COMMISSION HORIZON 2020 LC-MG-1-4-2018 Grant agreement ID: 814951.

Kahyaoglu, S. B., & Aksoy, T. (2021). Survey on Blockchain Based Accounting and Finance Algorithms Using Bibliometric Approach. In Accounting and Finance Innovations. IntechOpen.

Kasten, J. E. (2020). Engineering and manufacturing on the blockchain: A systematic review. IEEE Engineering Management Review, 48(1), 31-47.

Langdon, C. S., & Schweichhart, K. Data Spaces: First Applications in Mobility and Industry (Part IV Solutions & Applications).

Luthra, S., Janssen, M., Rana, N. P., Yadav, G., & Dwivedi, Y. K. (2022). Categorizing and relating implementation challenges for realizing blockchain applications in government. Information Technology & People, (ahead-of-print).

Müller, T., Gaertner, N., Verzano, N., & Matthes, F. (2022). Barriers to the Practical Adoption of Federated Machine Learning in Cross-company Collaborations. In ICAART (3) (pp. 581-588).

Ramesohl, S., Berg, H., & Wirtz, J. (2022). The circular economy and digitalisation-strategies for a digital-ecological industry transformation: a study commmissioned by Huawei Technologies Germany GmbH.

Sarmah, S. S. (2018). Understanding blockchain technology. Computer Science and Engineering, 8(2), 23-29.

Sautter, B. (2021). Shaping Digital Ecosystems for Sustainable Production: Assessing the Policy Impact of the 2030 Vision for Industrie 4.0. Sustainability, 13(22), 12596.

Schulz, W. H., Franck, O., Smolka, S., & Geilenberg, V. (2022). Applicable Knowledge for Sustainability. The Status of Artificial Intelligence in Industrial Production and the Impact of Future Sustainability. In The New Digital Era: Digitalisation, Emerging Risks and Opportunities (Vol. 109, pp. 117-124). Emerald Publishing Limited.

Staab, P., Pietrón, D., & Hofmann, F. (2022). Sustainable Digital Market Design: A Data-Based Approach to the Circular Economy.

Usländer, T., Schöppenthau, F., Schnebel, B., Heymann, S., Stojanovic, L., Watson, K., ... & Morinaga, S. (2021). Smart Factory Web—A Blueprint Architecture for Open Marketplaces for Industrial Production. Applied Sciences, 11(14), 6585.

Zhongming, Z., Linong, L., Xiaona, Y., Wangqiang, Z., & Wei, L. (2021). Automotive industry leaders partner to develop a shared approach to carbon emissions data.

101blockchains. (2022). 101blockchains Website. Link: https://101blockchains.com/, date of last visit: July 28, 2022.

RESEARCH IN PROGRESS

ORGANIZATIONS IN DIGITAL TRANSFORMATION (ODT): A LITERATURE REVIEW ON THE IMPLICATIONS FOR MALLEABLE ORGANIZATION AND HRM

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The digital age has brought significant changes in the way organizations operate and compete. As a result of rapid technology development, many organizations are undergoing a digital transformation to stay relevant and competitive in the marketplace. This literature review aims to find future research topics by providing an overview of the current state of research on organizations in digital transformation (ODT), especially on malleable organization design and HRM aspects. The article begins by defining digital transformation (DT), and then examines how organizations change during DT, before delving into the perspectives of malleable organization design and HRM. Finally, it concludes by identifying gaps in the literature and suggesting a research agenda for future. Overall, organizational factors that need more investigation are highlighted to tackle complexities of ODT for further research.

Keywords:
digital transformation, organizations, malleable organization, HRM, Bled eConference

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1 Introduction

In recent years, rapid and continuous advancements in technologies lead to systemic changes across governmental, economic, social and organizational domains (Ivaldi et al., 2022). Organizations have been facing increasing pressure to digitally transform to stay competitive and meet the ever-evolving needs of their stakeholders. The way organizations operate and interact with their customers, partners, and employees has therefore drastically changed. Within digital transformation (DT), emphasis is placed on human-centricity and sustainability, as finding balance between technology and humans is crucial, and promoting sustainable development goals such as socio-environmental sustainability and resilience is the priority (Ghobakhloo et al., 2022; Reiman et al., 2021; Zizic et al., 2022).

The goal of this work-in-progress paper is to develop a future research agenda on the topics of human-centricity and sustainability of organizations in DT by reviewing the literature.

2 Theoretical background

Although DT is a central topic in many recent studies, there is much conceptual confusion about what exactly it entails. Therefore, it is essential to clearly define DT before addressing the challenges in relation to human-centricity and sustainability it poses to organizations. The theoretical background of this article is based on two systematic literature reviews: the definition of DT developed by Gong and Ribiere (2021) as a starting point, followed by an overview of changes in organizations in digital transformation (ODT) described by (Hanelt et al., 2021).

DT requires new ways of working and thinking, such as new strategies, structures, processes, operations and organizational culture. Successful DT leads to strategical benefits for organizations, unlike digitalization and digitization which mainly impact operational work within the organization (Gong & Ribiere, 2021). DT can be defined as:

> "A fundamental change process, enabled by the innovative use of digital technologies accompanied by the strategic leverage of key resources and capabilities, aiming to radically improve an entity* and redefine its value proposition for its stakeholders. (*An entity could be: an organization, a business network, an industry, or society.)" (Gong & Ribiere, 2021, p.12)

DT leads to developments in two major areas for organizations (Hanelt et al., 2021): malleable organizational designs (internally) and digital business ecosystems (externally). A malleable organizational design is one that adapts easily and quickly to change through digital technologies and agile structures. A digital business ecosystem has rapidly changed value propositions which cause participants, positions, and roles of the organization to constantly evolve in a turbulent environment.

Because of the progression and complexity of DT established theoretical models do not fit anymore with the new empirical reality (Hanelt et al., 2021), a broader view on organizational changes and innovation associated with ODT is required. This study adds to developing that broader view by addressing the challenges that DT brings in relation to human-centricity in organizations and sustainability, by specifically focusing on human resource management (HRM) and a malleable organization for ODT.

3 Research method

A literature review is conducted using the PRISMA 2020 approach (Page et al., 2021) to undercover the topics of ODT. The PRISMA 27-item checklist was applied for a transparent and thorough manner. The literature search follows screening stages with defined criteria, which is visualized in a flow diagram. See Figure 1 with explanations of screening stages and criteria in the Appendix. The search strategy is an advanced search action in Web of Science database with a final inclusion of 40 articles for this article after screening. As the article presents work in progress, it only includes the current literature search on malleable orgnization and HRM for ODT.

4 Preliminary results

From selected literature, some preliminary results are found regarding malleable organization and HRM for ODT that help formulating a future research agenda.

A malleable organization for ODT

A stable digital malleable organization is expected to be established where stakeholders connect online and interact digitally in dynamics that create value for all (Zizic et al., 2022). Investigating a digital malleable organization is a necessary step in understanding how digital technologies can be leveraged to benefit society as a whole. A malleable orgnization requires a corresponding strategy, business model and organizational culture, and a proper alignment of them (González-Díaz et al., 2021). Our literature review on the malleable orgnization starts by examining the adoption of organizational agility as the latest approach for operating and managing ODT. Subsequently, the review explores sustainable business models, as well as people and culture within ODT.

A malleable orgnization requires a new approach for operation and management with *organizational agility* as the core strategy. (Reuschl et al., 2022) named it as *organizational elasticity*, which means organizations can take quick decisive actions for changes and be flexible to either return to old or adapt to new routines after a crisis. (Hanelt et al., 2021) called this *malleable organizational designs,* as previously explained. *Innovation* is essential for agility and it enables organizations to stay sustainable, resilient and to create long-term value when dealing with the digital change and disruption (Di Vaio et al., 2021). Simultaneously with innovation, understanding and applying *change management* is required for successful ODT (Florek-Paszkowska et al., 2021). Change management - the process of planning, implementing, and monitoring changes in organizations and ensure that they are successful and sustainable – is needed because innovation often requires changes to an organization's processes, systems, and culture. This involves regularly reassessing various aspects of the organization, reflecting on their efficacy, evaluating their impact, and taking appropriate action. In the process of innovating and applying change management, knowledge is a key which can be not only created but also shared via digital advancement, for example the use of big data to predict the market so that the organization can respond accordingly (Di Vaio et al., 2021), or constantly involving all relevant stakeholders at all stages for *knowledge co-creation* and *sharing* via a liquid network (Borchardt et al., 2022; Schiavone et al., 2022).

Besides organizational agility as a core strategy, both a sustainable business model and a supportive organizational culture are critical components that must be consistent and in sync with each other. In general, a dynamic, adaptive business model is suggested for a sustainable and resilient ODT (Florek-Paszkowska et al., 2021), that not only sustains current core business, but also invest in new emerging external opportunities (Li, 2020). Specifically (Gruenbichler et al., 2021) and (Andersen et al., 2022) revealed some case studies of dynamic and adaptive business models with empirical data in SMEs. (Gruenbichler et al., 2021) investigated business performance management (BPM) which serves as a measurement tool to achieve business objectives successfully while enhancing the competitiveness and sustainability of ODT. (Andersen et al., 2022) explored business model innovation (BMI), confirming that a agile and data driven nature is important for the whole business process including identifying opportunities and making decisions. Finally, it should be noted that individuals and the prevailing organizational culture are essential factors for fostering a prosperous malleable organization in DT. Innovation requires continuous re-skilling and up-skilling of both leaders and employees, and with strong commitment and engagement during disruptive DT, e.g. an agile culture (Florek-Paszkowska et al., 2021). The next sections delves further into the human-centric aspect of ODT.

Strategic HRM for ODT

Although DT is driven by rapid and continuous advancements in digital technologies, it depends largely on the human factor: a combination of and synergy between top-down initiatives and bottom-up acceptance and commitment determine its success (Gong & Ribiere, 2021). Therefore, multiple studies address the human-related challenges that organizations face as a result of DT. On the one hand, these challenges refer to the knowledge, skills and attitudes of employees, including lack of employees' awareness of newly available digital technologies, lack of adequate skills, and confidence caused by the disruptive DT changes. On the other hand, these challenges refer to the adaptation of HRM practices, such as talent acquisition, retainment and employees training (James et al., 2022). These challenges underline that a successful DT strategy should include a refined HRM strategy that anticipates and responds to human-related challenges during DT (Bamel et al., 2022; Vereycken et al., 2021). The included articles show that DT requires adaptation of HRM strategy and practices aimed at the following aspects.

Firstly, strategic talent management - a systematic process of recruiting, developing and maintaining the best talents for the organization - should be (re-)designed to fit the DT context (Kuchciak & Warwas, 2021). Key elements in this (re-)design are recruitment, re- and upskilling, and redeployment. Recruitment should emphasize acquiring new talents who bring essential DT skills that are not yet sufficiently present in the organization, as a new target group to trigger change in the organization. An example of this are "digital talents", who possess essential IT-related skills (Gilch & Sieweke, 2021). Regarding re- and upskilling, DT creates an urgent need for continuous development of employees, so that employees do not become obsolete, can co-exist, collaborate with, and benefit from new technologies, and can increase their confidence in working in digitalized workplace (Gjika & Pano, 2022; Kuchciak & Warwas, 2021; Vereycken et al., 2021). These skills include not only relevant technical skills but also non-technical, transformational skills, such as creativity, workplace learning, problem solving, conceptual thinking, entrepreneurship and resilience (Bamel et al., 2022; Kuchciak & Warwas, 2021). Re- and upskilling practices should be flexible and sustainable to respond to continuous technological developments (Piwowar-Sulej, 2021). Moreover, constant support is required during these practices, such as monitoring of employees' skills and development needs, offering training and mentoring, and organizing work in such ways that it stimulates learning, e.g. by creating diverse and multidisciplinary teams (Kuchciak & Warwas, 2021). Redeployment - assigning employees to new, fitting, tasks - is becoming increasingly important as work can change tremendously and employees may no longer have fitting roles or tasks. Relevant practices include helping employees to plan career development paths, inform them about promotion opportunities, address job offers to diverse employees, develop work-life balance programs, and introduce well-being audits (Kuchciak & Warwas, 2021).

Secondly, HRM strategies and practices should be adapted to increase employee involvement and empowerment though job design. As new technologies take over physical, sensorial and cognitive-based tasks, many professional tasks will shift from predominantly operations-related tasks to more complex tasks such as coordination and decision-making. This is only possible when employees are granted with more autonomy. It requires an organizational context that is characterized by a flat hierarchy, decentralized decision making, and employee empowerment (Vereycken et al., 2021). HR practices that promote employee involvement and empowerment are expected to increase employee acceptance of the changes that DT brings, stimulate employees' contribution to these changes (Vereycken et al., 2021), and facilitate employees' work-life balance and wellbeing because they experience a high degree of control over work, can adapt to changes, pick up technologies that make their work more effective and efficient, and experience fulfillment (Bamel et al., 2022).

Finally, the complexity of DT emphasizes that HR professionals need to rethink their own roles. HR professionals should increasingly act as consultative, strategic, business partners and change agents, who makes sense of trends in digital technologies and understand the consequences for the organization and its employees, understand new ways of working and how different parts of the organization will interact during and as a result of DT, and promote and support the needed organizational change (Dhanpat et al., 2020).

5 Conclusion and discussion

The interdependencies and co-constitutive relationship between organizing and technology, the tensions between ways of knowing and the value laden nature of decision making in ODT call for research that effectively engages insights from multiple disciplines that coalesce in the questions that rise from the phenomenon of DT.

Malleable organizational designs and digital business ecosystems are under development for ODT, however progression and complexity of DT still requires a broader view on organizational change and innovation of DT (Hanelt et al., 2021). More research is needed to examine the design and testing of malleable organization for ODT. Specifically, further exploration is required to determine how a malleable organization can effectively facilitate open innovation by connecting stakeholders to share and co-create knowledge, and react quickly to disruptive changes with optimal solutions. Moreover, future research could further examine how malleable organizations impact traditional business models, including what are the successful factors for ODT business models and how people and culture of ODT should respond accordingly. Furthermore, it is important to study the alignment between strategy, business model, and organizational culture, as current activities in digital transformation are being carried out at a rapid pace without taking this alignment into account (González-Díaz et al., 2021).

Although key HRM areas for adaptation are identified in the results section, in-depth insights into the content of relevant HRM strategies and practices in response to DT remains limited and fragmented (Bamel et al., 2022). How HRM strategy and practices should be refined requires more fine-grained research into the specific changes that DT brings, and how HRM should anticipate and respond to them. For instance, the implementation of advanced robotics in the manufacturing industry will require a different HR strategy than the need for data analytics to optimize processes in healthcare (Vereycken et al., 2021). Moreover, research should take different organizational contexts into consideration, as similar technology implementations may lead to different requirements for HRM strategies and practices depending on this context (Gjika & Pano, 2022). It is therefore important to conduct this fine-grained research in the near future to gain more insight into required differences as well as similarities in successful HRM strategies and practices.

References

Andersen, T. C. K., Aagaard, A., & Magnusson, M. (2022). Exploring business model innovation in SMEs in a digital context: Organizing search behaviours, experimentation and decision-making. Creativity and Innovation Management, 31(1), 19–34. https://doi.org/10.1111/CAIM.12474

Bamel, U., Kumar, S., Lim, W. M., Bamel, N., & Meyer, N. (2022). Managing the dark side of digitalization in the future of work: A fuzzy TISM approach. Journal of Innovation and Knowledge, 7(4). https://doi.org/10.1016/J.JIK.2022.100275

Borchardt, M., Pereira, G. M., Milan, G. S., Scavarda, A. R., Nogueira, E. O., & Poltosi, L. C. (2022). Industry 5.0 Beyond Technology: An Analysis Through the Lens of Business and Operations Management Literature. Organizacija, 55(4), 305–321. https://doi.org/10.2478/orga-2022-0020

Dhanpat, N., Buthelezi, Z. P., Joe, M. R., Maphela, T. V., & Shongwe, N. (2020). Industry 4.0: The role of human resource professionals. SA Journal of Human Resource Management, 18(0), 11. https://doi.org/10.4102/SAJHRM.V18I0.1302

Di Vaio, A., Palladino, R., Pezzi, A., & Kalisz, D. E. (2021). The role of digital innovation in knowledge management systems: A systematic literature review. Journal of Business Research, 123, 220–231. https://doi.org/10.1016/J.JBUSRES.2020.09.042

Florek-Paszkowska, A., Ujwary-Gil, A., & Godlewska-Dzioboń, B. (2021). Business innovation and critical success factors in the era of digital transformation and turbulent times. Journal of Entrepreneurship, Management and Innovation, 17(4), 7–28. https://doi.org/10.7341/20211741

Ghobakhloo, M., Iranmanesh, M., Mubarak, M. F., Mubarik, M., Rejeb, A., & Nilashi, M. (2022). Identifying industry 5.0 contributions to sustainable development: A strategy roadmap for delivering sustainability values. Sustainable Production and Consumption, 33, 716–737. https://doi.org/10.1016/J.SPC.2022.08.003

Gilch, P. M., & Sieweke, J. (2021). Recruiting digital talent: The strategic role of recruitment in organisations' digital transformation. German Journal of Human Resource Management, 35(1), 53–82. https://doi.org/10.1177/2397002220952734/FORMAT/EPUB

Gjika, I., & Pano, N. (2022). Human resource development AS a contributor to industry 4.0 implementation IN Albania . THE ELECTRONIC JOURNAL OF INFORMATION SYSTEMS IN DEVELOPING COUNTRIES. https://doi.org/10.1002/ISD2.12250

Gong, C., & Ribiere, V. (2021). Developing a unified definition of digital transformation. Technovation, 102. https://doi.org/10.1016/j.technovation.2020.102217

González-Díaz, R. R., Guanilo-Gómez, S. L., Acevedo-Duque, Á. E., Campos, J. S., & Cachicatari Vargas, E. (2021). Intrinsic alignment with strategy as a source of business sustainability in SMEs. Entrepreneurship and Sustainability Issues, 8(4), 377–388. https://doi.org/10.9770/JESI.2021.8.4(22)

Gruenbichler, R., Klucka, J., Haviernikova, K., & Strelcova, S. (2021). Business performance management in small and medium-sized enterprises in the slovak republic: An integrated three-phase-framework for implementation. Journal of Competitiveness, 13(1), 42–58. https://doi.org/10.7441/JOC.2021.01.03

Hanelt, A., Bohnsack, R., Marz, D., & Antunes Marante, C. (2021). A Systematic Review of the Literature on Digital Transformation: Insights and Implications for Strategy and Organizational Change. Journal of Management Studies, 58(5), 1159–1197. https://doi.org/10.1111/JOMS.12639

Ivaldi, S., Scaratti, G., & Fregnan, E. (2022). Dwelling within the fourth industrial revolution: organizational learning for new competences, processes and work cultures. Journal of Workplace Learning, 34(1), 1–26. https://doi.org/10.1108/JWL-07-2020-0127/FULL/PDF

James, A. T., Kumar, G., Tayal, P., Chauhan, A., Wadhawa, C., & Panchal, J. (2022). Analysis of human resource management challenges in implementation of industry 4.0 in Indian automobile industry. Technological Forecasting and Social Change, 176. https://doi.org/10.1016/J.TECHFORE.2022.121483

Kuchciak, I., & Warwas, I. (2021). Designing a Roadmap for Human Resource Management in the Banking 4.0. Journal of Risk and Financial Management 2021, Vol. 14, Page 615, 14(12), 615. https://doi.org/10.3390/JRFM14120615

Li, F. (2020). Leading Digital Transformation: Three Emerging Approaches for Managing the Transition. International Journal of Operations and Production Management . https://doi.org/10.1108/IJOPM-04-2020-0202

Page, M. J., Moher, D., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., Mcdonald, S., … Mckenzie, J. E. (2021). PRISMA 2020 explanation and elaboration: Updated guidance and exemplars for reporting systematic reviews. In The BMJ (Vol. 372). BMJ Publishing Group. https://doi.org/10.1136/bmj.n160

Piwowar-Sulej, K. (2021). Human resources development as an element of sustainable HRM – with the focus on production engineers. Journal of Cleaner Production, 278. https://doi.org/10.1016/J.JCLEPRO.2020.124008

Reiman, A., Kaivo-oja, J., Parviainen, E., Takala, E. P., & Lauraeus, T. (2021). Human factors and ergonomics in manufacturing in the industry 4.0 context – A scoping review. Technology in Society, 65. https://doi.org/10.1016/J.TECHSOC.2021.101572

Reuschl, A. J., Deist, M. K., & Maalaoui, A. (2022). Digital transformation during a pandemic: Stretching the organizational elasticity. Journal of Business Research, 144, 1320–1332. https://doi.org/10.1016/J.JBUSRES.2022.01.088

Schiavone, F., Leone, D., Caporuscio, A., & Lan, S. (2022). Digital servitization and new sustainable configurations of manufacturing systems. Technological Forecasting and Social Change, 176. https://doi.org/10.1016/J.TECHFORE.2021.121441

Vereycken, Y., Ramioul, M., Desiere, S., & Bal, M. (2021). Human resource practices accompanying industry 4.0 in European manufacturing industry. Journal of Manufacturing Technology Management, 32(5), 1016–1036. https://doi.org/10.1108/JMTM-08-2020-0331/FULL/XML

Zizic, M. C., Mladineo, M., Gjeldum, N., & Celent, L. (2022). From Industry 4.0 towards Industry 5.0: A Review and Analysis of Paradigm Shift for the People, Organization and Technology. In Energies (Vol. 15, Issue 14). MDPI. https://doi.org/10.3390/en15145221

Appendix

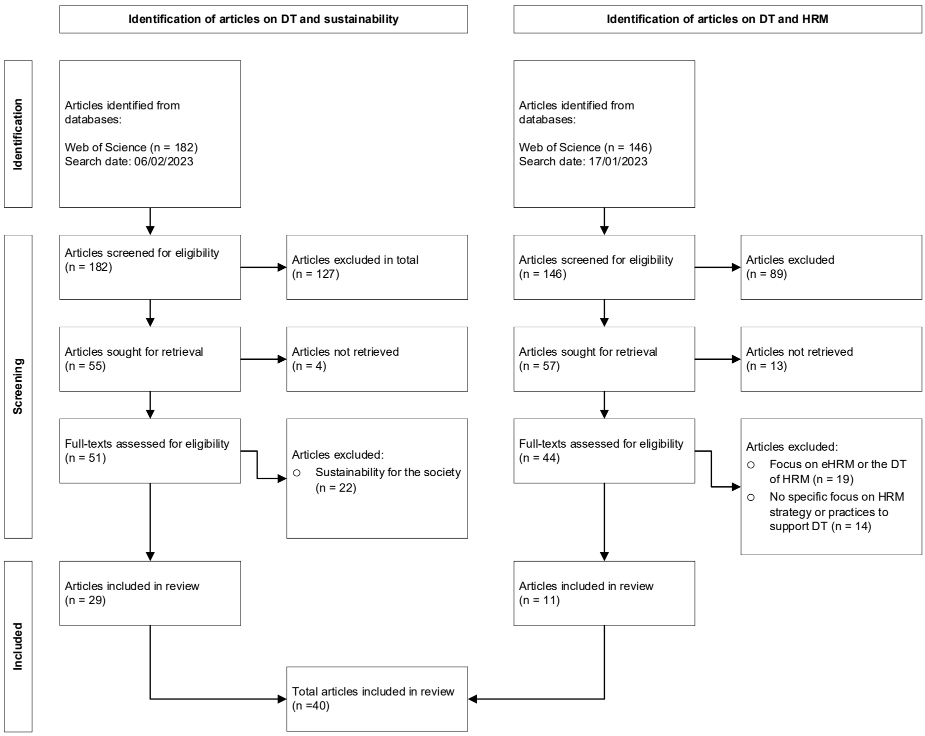

Figure 1: Adapted PRISMA 2020 flow diagram

For the search action in Web of Science multiple search terms were combined into two Boolean search operator, one for sustainability of ODT and one for HRM of ODT. This resulted in an identification of in total of 328 articles. After identification, articles were screened in two stages. In stage one, titles and abstracts of all articles were screened for the eligibility criteria mentioned below. This resulted in the exclusion of 233 articles, including articles that could not be retrieved. For each article, reasons for exclusion were provided. In stage two, the full-texts of the remaining 95 articles were checked. This resulted in a final inclusion of 40 articles from the Web of Science database.

Papers needed to meet the following eligibility criteria:

1. Be published in a peer-reviewed journal.
2. Be written in English.
3. DT and HRM: papers should focus on the (changing) role of HRM to support successful DT of organizations. Papers that focused on eHRM or on the DT of HRM itself (e.g. digital recruitment or HR analytics) are not yet included in this present article.
4. DT and sustainability: papers should not be specifically focused on one field, for example supply chain, and papers with empirical application only on specific countries are not included in this present article. In stage 2, only papers with a focus on sustainability regarding organization are included. Papers on sustainability as a societal development are excluded in this present article.

RESEARCH IN PROGRESS

IMPROVING SAFETY AT SEAS

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Digitalization in the maritime industry has been suggested as means to achieve safe, economically, and environmentally sound marine traffic. Despite the increasing adoption of digital services and technology in the maritime industry in Finland, the number of accidents has not reduced significantly. This research article aims to explore the potential for improving waterway safety in Finland. The study analyzes waterway accident data to identify the user group most in need of safety improvements and proposes targeted safety measures better tailored to recreational boaters. The study suggests enhancing the physical infrastructure and related digital services of sea areas to provide better coordinated traffic at sea and situational awareness among seafarers, including non-professional seafarers. Finally, a roadmap for implementing these safety measures will be developed. The research provides a comprehensive framework for improving waterway safety in Finland, reducing accidents, and fatalities.

Keywords: digitalization, waterway safety, recreational boaters, maritime, accident reduction

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1 Introduction

The pace of international development in traffic system automation has been rapid, driven by the goal of reducing human errors in traffic through increased automation and autonomy of vehicles and traffic control. Seafaring is no exception: more digital services have been approved by authorities and adopted by merchant and private mariners. Remotely operated and autonomous ships are being increasingly trialed and developed in the maritime industry (Aawa, 2016; Kepesedi, 2022). Equipping ships and fairways with positioning, navigation, sensoring, and communication technology has been suggested to achieve safe, economically, and environmentally sound marine traffic for all (socially sustainable seafaring) as communicated by the ministry in their societal objectives (Miettinen et al., 2021). However, despite these improvements we see limited progress in reducing the total number of accidents – the improvements are due to safer merchant traffic of big vessels - most accidents happened outside merchant traffic by recreational seafarers in 2017-2020 (Statistics Finland, 2022).

The aim of this research article is to explore the potential for improving the safety of waterway users in Finland by leveraging the opportunities provided by digitalization for vessels and waterways. Specifically, we aim to identify the user group that require the most attention in terms of improving their safety, assess the suitability of planned safety elements for addressing their needs, and develop a roadmap for implementing these elements to ensure the safety of all waterway users.

To determine the user group most in need of safety improvements, we conduct an analysis of waterway accident data. Based on this analysis, we propose targeted safety measures that are better tailored to recreational boaters. We suggest enhancing both the physical infrastructure and related digital services of territorial sea to provide better coordinated traffic at sea and situational awareness among seafarers - meaning all seafarers and even beyond official fairways. We believe that technology and its usage has reached a point where even non-professional seafarers can utilize digitally-enhanced fairway infrastructure for safer and more environmentally-friendly travel.

Overall, this research-based development intiative provides a framework for improving waterway safety, leveraging the opportunities provided by digitalization for vessels and waterways. By identifying recreational boaters as the user group most in need of safety improvements and tailoring safety measures to their specific needs, we aim to ensure the safety and reduce the number of accidents and fatalities in Finnish waters.

2 Analysis of accident data

In recent years, several new elements have been introduced to improve the safety of merchant traffic on well maintained fairways, resulting in a significant decrease in the number of accidents involving large ships. In fact, merchant shipping accounts for only 1-3% of the total accidents, and fatalities are very rare today.

However, despite this improvement, relaxed practices and an increasing number of vessels with high speed differences have led to more near-misses and limited progress in reducing the total number of accidents. More than 2000 accidents and approximately 50 annual fatal incidents happened outside merchant traffic in 2017-2020 (2022, Statistics Finland). Over 90% of these fatalities happen to recreational crafts and are a consequence of operating error while drunk leading to listing or cap sizing (ibid.).

But the picture changes when looking into the non-lethal accidents: they mostly happen under good daytime conditions during the weekends (ibid.). Of the accidents, motorboats form a clear majority (70%), but rigid inflatable boats (ribs) and sailboats are over-represented in accident statistics. The root causes for accidents are technical failures (68%) such as malfunctions of manoeuvring devices or engines, and human error/misconduct in 37% the accidents. Weather conditions are the reason for approximately 5% of the accidents.

As a consequence, we suggest that the most potential area for the development of safety at seas is to provide means for recreational watercrafters (motorboats, ribs and sailboats) to avoid, react and receive help for malfunctions, groundings, allusions, and collisions, and ultimately also receive search and rescue services (SAR) quickly enough on the accident site. This calls for a better joint situational awareness among all seafarers and safety organizations.

3 Digitalisation of vessels and traffic

At open seas, modern vessels have been semiautomatic for a long time, and this is now spreading towards regular traffic between harbours and to some extent, also recreational traffic. However, bigger vessels have to fulfil the requirements set by Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW, 1978). The trials with remote piloting and autonomous traffic (Aawa, 2016; Kepesedi, 2022) have shown the need for enhanced information to improve the perceptive, automated capabilities of the vessel and to provide potential for better situational awareness of the traffic situation for the mariners, e.g. on fairways or in the port area or on the fairways.

Categories of autonomous vessels are defined according to the operator's role on a ship (IMO, 2021). A Maritime Autonomous Surface Ship (MASS) is *"a ship which, to a varying degree, can operate independently of human interaction"*. IMO identified four *'degrees of autonomy'*, of which two are manned, i.e. seafarers are on board, and two are unmanned (ibid.): ***Manned vessels*** are assisted with *automated operation processes and decision support systems* (type 1), *even remotely controlling* the vessel (type 2), *but the crew can intervene and override the systems*. When there is ***no crew on board*** the vessel is either *remotely operated* (type 3) or *operating autonomously* (type 4) without crew intervention (table 1).

Table 1: Degrees of autonomy

Manned Vessels	*Type 1: Automated operation and DSS* Both in merchant and increasingly in recreational traffic	*Type 2: Remote control, but crew can intervene* Helping merchant traffic on restricted areas at harbours and piloting.
No crew on board	*Type 3: Remote operation:* Regular merchant traffic in restricted areas and waterways	*Type 4: Autonomous operation:* Trials in merchant traffic (test beds and test areas).

As vessels are turning more automated and autonomous, towards types 3 and 4, there is a greater need for careful analysis of faults to improve. This involves continuously monitoring and improving the reliability and performance of the systems and their components' quality (Chaal et al., 2022), to create Safety

Instrumented Systems (SIS) with relative levels of risk-reduction (Safety Integrity Levels, SIL) for continous safety improvement.

In navy and merchant shipping, these ideas of automation is slowly becoming a reality towards types 3 and 4 (e.g. Kepesedi, A., 2022). The first trials show, that the behaviour of such vessels is different from traditional ships: they are following pre-planned routes, with limited set of maneuvers (Safety and Regulations for European Unmanned Maritime Systems[1] and SOLAS, 1974). This is to optimize time and fuel consumption for profit, to meet environmental and emission requirments and, only secondly, to participate in the communication, interaction with other traffic, not to mention participating in rescue operations in traditional sense at waters.

For recreational vessels, the first autonomous category, i.e. providing navigational aids – to increasing extent also decision support systems – are becoming common integrated with ECDIS[2] for new vessels. Still, recreational vessels are mostly relying on the traditional watchkeeping and elementary safety measures at seas.

However, lately improved self-services are being introduced to track merchang vessels and show maritime alerts (e.g. https://aluskartta.com; https://extranet.vayla.fi/pooki_www/merivaroitukset/list_fi.html).

Summary of Research in Progress

This is the outset of our research and development project aimed at improving the safety in territorial seas. We will focus on an area where can be leveraged to address unique local conditions. In the future, Finnish waters will witness the presence of both autonomous vessels and more accident prone recreational boats, which poses additional challenges for seafarers in terms of situational awareness.

To address these challenges effectively, it is necessary to enhance data accessibility for all seafarers, enabling them to develop a better understanding of each other's intentions and safe navigation routes. Given the diverse capabilities of different user groups in terms of maneuvering and communication at sea, the standard fairway,

[1] https://eda.europa.eu/docs/documents/SARUMS-Flyer-2012.pdf

[2] Electronic Chart Display and Information System, definitions by International Hydrgraphic organization IHO S-57 (content and display) and IHO S-52 (transfer) and complying with IEC 61174 test procedures.

weather, and traffic information often fails to meet the specific needs of each group. Therefore, we propose utilizing common, multisided platforms and developing applications tailored to the requirements of different user groups, thus taking advantage of suitable applications (Heikkilä et al., 2023; Parker and Van Alstyne, 2004).

The responsibility of authorities is limited to traffic on official fairways, but there is a clear safety discrepancy when it comes to providing guidance and assistance for recreational traffic outside waterways. Therefore, it is crucial to carefully examine the technical means by which safe routes in the archipelago can be identified. This may involve tracing traffic patterns, digitalizing currently fragmented oral information on traffic conditions, safety alerts, and environmental hazards, and utilizing VHF-radio for interaction with authorities and fellow seafarers, both through broadcast and point-to-point communication.

Digitalization has made these advancements possible, and the most crucial standardization efforts for improving safety have shifted from IMO to IALA[3] and ITU[4]. This transition is driven by the increasing autonomy of merchant traffic and the telecommunications limitations faced by recreational vessels. These organizations are focused on designing more efficient digital communication systems (e.g. VDES R-mode[5]) and integrated navigational aids. With the assistance of machine learning and artificial intelligence models, it is anticipated that these functionalities (e.g., as described by Pedersen et al., 2020) will expand to type 1 applications and remotely assisted services (type 2), thereby benefiting recreational vessels as well.

However, it is evident that achieving this requires collaborative, co-created design efforts and the willingness of authorities to enhance, open, and maintain safety-critical data. Similarly, developing robust communication infrastructure at sea is of equal importance. None of these advancements can be effective if they are not integrated into the education of recreational seafarers, emphasizing enhanced digital

[3] International Association of Marine Aids to Navigation and Lighthouse Authorities, "gathers together Marine Aids to Navigation authorities, manufacturers, consultants, and, scientific and training institutes from all parts of the world and offers them the opportunity to exchange and compare their experiences and achievements." (IALA, 2023).
[4] The International Telecommunication Union
[5] https://www.iala-aism.org/product/g1158/

seafaring skills and fostering a safety culture. Research is necessary to make informed decisions, identify effective transformational measures, and ensure the successful implementation of safer seafaring practices.

References

Aawa (2016). Remote and autonomous ships – the next steps. Position paper, Rolls-Royce, London. 88 pages. Retrieved from: https://www.rolls-royce.com/~/media/Files/R/Rolls-Royce/documents/customers/marine/ship-intel/aawa-whitepaper-210616.pdf

ABS (2020). American Bureau of Shipping.

Chaal, M., Bahootoroody, A., Basnet, S., Banda, O. A. V., & Goerlandt, F. (2022). Towards system-theoretic risk assessment for future ships: A framework for selecting Risk Control Options. Ocean Engineering, 259, 111797.

Heikkilä, J., Heikkilä, M., & März, G. (2023). Platforms for Smart Fairways – Enhancing Services for Autonomous Maritime Traffic and Other Emerging Uses of Territorial Sea, in the Proceedings of the 56th HICSS, 2023-01-03. 1001- 1009. https://scholarspace.manoa.hawaii.edu/items/61d49342-893b-4e4a-ba40-bc10236e4a4c

IALA (2023). https://www.iala-aism.org/about-iala/

IMO (2021). Outcome of the regulatory scoping exercise for the use of maritime autonomous surface ships (MASS), IMO, 3.6.2021. available at https://wwwcdn.imo.org/localresources/en/MediaCentre/PressBriefings/Documents/MSC .1-Circ.1638 - Outcome Of The Regulatory Scoping ExerciseFor The Use Of Maritime Autonomous Surface Ships... (Secretariat).pdf

Kepesedi, A. (2022) Maritime Autonomous Surface Ships: A critical 'MASS' for legislative review, UNCTAD Transport and Trade Facilitation Newsletter, article no 97, 13 Dec 2022, Retrieved from:: https://unctad.org/news/transport-newsletter-article-no-97-fourth-quarter-2022

Miettinen K., Miettinen A., Hauta J., Töyrylä S. & Reinimäki S., (2021). Liikenteen automaation lainsäädäntö- ja avaintoimenpidesuunnitelma, (Action plan on legislation and key measures of transport automation). Liikenne- ja viestintäministeriö Helsinki 2021, 243 pages (in Finnish).

Parker G.G. and Van Alstyne M.W., (2005). Two-Sided Network Effects: A Theory of Information Product Design. Management Science 51(10),1494-1504. https://doi.org/10.1287/mnsc.1050.0400

Pedersen, T. A., Glomsrud, J. A., Ruud, E. L., Simonsen, A., Sandrib, J., & Eriksen, B. O. H. (2020). Towards simulation-based verification of autonomous navigation systems. Safety Science, 129, 104799. https://doi.org/10.1016/j.ssci.2020.104799

SOLAS, (1974). International Convention for the Safety of Life at Sea. https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS),-1974.aspx

Statistics Finland (2022). Vesiliikenneonnettomuustilasto - Statistik över sjöolyckor Ennakkotieto tammi- joulukuu 2021. (Statistics on accidents on seas and lakes, pre-information for Jan-Dec 2021). In Finnish and Swedish; available at https://www.traficom.fi/sites/default/files/media/file/VESILONN-2021-1-12-ennakko.pdf.

STCW Convention (1978). International Convention on Standards of Training, Certification and Watchkeeping for Seafarers. Available at https://www.imo.org/en/OurWork/HumanElement/Pages/STCW-Convention.aspx

RESEARCH IN PROGRESS

TOWARDS AN ADAPTIVE IMPLEMENTATION TOOL FOR DEVICES IN COMPLEX HOSPITAL DEPARTMENTS

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Implementation of technological digital devices in existing complex hospital environments remains a challenge. We constructed a framework for the implementation of technological devices in operating rooms. In this research, we address users' needs for an adaptive (digital) implementation tool or app. We use a requirements engineering method to identify stakeholders and to identify steps to define requirements for this digital tool. We will construct personas to identify requirements and based on these findings a market search will follow to decide, either to buy and configure an existing tool or to develop a new tool that facilitates the implementation of devices in complex hospital departments.

Keywords: implementation framework, technological devices, digitization, hospitals, operating room

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1 Introduction

Digitization of healthcare occurs in many hospitals and affects many stakeholders in hospitals. Many technological devices are used in hospitals to facilitate health care processes and these devices are connected with various information systems. For example, when vital signs are recorded these can be transferred to a patient electronic health care record (EHR) automatically; many other devices used in operating rooms are connected to EHR's, and thus increase digitization in operating rooms in hospitals. Not only because of this dependence on and connectivity to information systems, but also due to many other situational and contextual variables, implementation of new devices into an existing and complex environment such as an operating room in hospitals, is a challenge. Success rates of implementations of information systems and other technological devices vary and numerous implementations fail (Damschroder et al., 2022; Jacobs et al., 2015; Rafferty et al., 2013). Less successful implementations of systems and devices in healthcare are reported less often, and many learnings for successful implementations can be derived from less successful implementation projects (Ebad, 2020). Successful implementations require well-prepared implementation activities in preparation to the introduction of the device and to influence adoption for use of the new device (Fennelly et al., 2020). To facilitate the implementation of new technological devices in OR's, we conducted several studies to construct a framework for implementation of new technological devices (Sewberath Misser, 2023). Based on the findings and the evaluation of this research, potential users of this framework identified a need for a (digitized) tool or app that enables users to be equipped with situational relevant implementation activities In this study, we adress this need and we composed the following research question:

How can requirements be identified for a user friendly and adaptive digital tool or app for implementation activities for new devices and software in complex hospital environments such as operating rooms?

In the next section, we in short describe the framework for implementation for technological (digital) devices in operating rooms (Sewberath Misser, 2023). In section three, we describe an approach to develop an adaptive tool for the implementation of activities.

2 Background

2.1 Introducing technological and digital devices

Implementation of new technological devices in hospitals appears to be a challenge, as many stakeholders and departments are involved when introducing these new tools. Edmondson et al. refer to a successful implementation of a new tool when the tool is used in day-to-day activities of users (Edmondson et al., 2001). This implementation remains a challenge and will need to be addressed carefully. To address this challenge, we used characteristics from design science research (Peffers et al., 2007). In previous research, we identified in three phases to develop and evaluate an implementation framework, starting with identifying a problem definition. Based on these findings, we developed an artifact in the second phase of research. In the third and last phase of our research we evaluated this artifact. We constructed a problem definition by providing an overview of the research context and by identifying the problem. Schoville et al. state that there is no overarching implementation theory but only a number of models and processes to facilitate implementation (Schoville & Titler, 2015). For the implementation of electronic health care records (EHR) various studies have been conducted to identify factors or barriers for the implementation and adoption of EHR (Fennelly et al., 2020). Based on existing literature an implementation framework or process model for the implementation of new technological devices in an existing operating room environment appeared not available (Damschroder et al., 2009; Moullin et al., 2015; Nilsen, 2015). Based on these findings, an artefact to implement new technological devices in OR's was needed. With that knowledge, we conducted several studies to develop the artifact: a framework for implementation. In this framework we distinguished determinants for implementation, and we identified activities and instructions for implementations. To construct this framework for implementation we conducted an explorative study with scrub nurses and circulating nurses in Operating Rooms to identify relevant factors for implementation (Sewberath Misser, Jaspers, et al., 2018). In a systematic literature review we focused on relevant factors and activities for implementations based on existing studies and theories (Sewberath Misser, Zaane, et al., 2018). Based on the findings of these two studies, we composed a baseline framework for implementation, consisting of implementation factors, implementation activities and implementation instructions (Sewberath Misser et al., 2020). We conducted two studies to validate this framework. In the first validation study we organized three focus group sessions with implementation experts from varying backgrounds and hospital departments. These experts were surgeons, anesthesiologists, logistics employees, scrub nurses, OR-management, and a methodologist. Based on these findings suggestions for revisions were proposed and analyzed (Sewberath Misser, Jaspers, Van Zaane, et al., 2021). In the second validation study, our base line implementation framework was used to introduce an exoskeleton in the OR (Sewberath Misser, Jaspers, van Zaane, et al., 2021). An exoskeleton is a wearable, mechanical external structure that enhances or supports the power of someone when performing specific activities (De Looze et al., 2016). Based on the data of this case study and the outcomes of the validation study with experts, revisions for the baseline protocol were identified and processed. The final and revised framework for implementation consists of four implementation factors, with related activities and instructions. In the next subsections these factors are explained.

- *Set up a project plan.*

The first factor for implementation focuses on the composition of a project plan. Activities involve identifying topics, goals, performance indicators, risks and relevant implementation activities based on the complexity of the device.

- *Organizational preparation*

The second implementation factor involves preparation of the organization. Implementation activities include activities to assemble a multi-disciplinary implementation team and to prepare the existing stakeholders of the organization. Processes and activities that need adjustment due to the introduction of a new technological device are redesigned and shared with relevant users and departments. Simulations using the new device are prepared and executed and communication plans are identified and deployed.

- *Technical preparation*

The third factor for implementation involves the technological preparation of the environment and the configurational preparations of the device. These configurational preparations include positioning of the device as well as assembly and disassembly procedures. Technical preparation also entails composing and deploying data management plans, maintenance plans, and updating (safety) regulations.

- *Training and evaluation*

Training and evaluation activities include composing and deploying a training and evaluation plan. Training involves technical and non-technical skills and technical skills also include troubleshoots and interpretation of necessary data and alarms. This training and evaluation plan also covers assessment of skills, as well as evaluation of the device and evaluation of the implementation project. Our implementation framework is included in appendix 1.

3 Towards an adaptive tool for implementation activities

In the previous chapter, the implementation framework and its activities are described. The purpose of this research is to identify requirements to develop an adaptive tool or app for implementation activities, depending on the user requirements and the device. There are different ways to develop or to configure a tool, such as the waterfall method or more agile methods to develop software. A waterfall method of software development generally consists of sequential phases: requirement analysis, system design, implementation, system testing, system deployment and system maintenance (Zayat & Senvar, 2020). The advantages of this method are that this method is described as structured, simple to understand and to implement. However, this method is described as less flexible and difficult when changes in requirements need to be considered and processed (Kramer, 2018). Similarly, the Software Development Life Cycle (SDLC) consists of the following phases: surveying and assessing the feasibility of a software development project, analyze existing information systems, determine requirements for the system, selecting the best solution, determine hardware and software, designing the system, building the system, implementing the system, and maintain the new system (Adi Guna Permana, 2015; Zayat & Senvar, 2020). A more flexible method for developing a software tool is for example the agile development method SCRUM. In agile development methods a development team is selected with a common goal to develop a holistic product. Different team roles are identified. One team member (product owner) defines business goals and requirements for the tool and this team member initiates the development process by prioritizing activities. These activities are scheduled and executed in development cycles (sprints) (Adi Guna Permana, 2015; Zayat & Senvar, 2020).

To develop a tool for our framework for implementation, we need to consider these development frameworks. As the requirements for a tool are not clear yet, one of the steps in the development process is to identify requirements for the tool. Panday et al. introduced a requirements engineering process model, in which they consider four steps to identify and select requirements for a software tool (Pandey et al., 2010). In the first step, requirements elicitation and development, stakeholders are identified to provide requirements. In the second step, requirements are documented and in the third step requirements are verified and validated. In the last step, they describe how the agreed requirements can be tracked and controlled during the development process of a software tool (Pandey et al., 2010). When focusing on the identification of requirements, Mayas et al. introduces the use of personas to identify requirements for users (Mayas et al., 2016). They describe personas as archetypes: distinguishable characters based on behavior and dispositions of real people.

To identify requirements for an adaptive tool or app for implementation activities we will use personas, as we expect the tool to be used by different stakeholders in OR's. When executing the first step of the requirements engineering process we will identify personas based on potential users with stakeholders (Mayas et al., 2016; Pandey et al., 2010). We will then use these constructed and validated personas to define requirements for an adaptive tool or app for implementation activities. These requirements will be documented and after documentation these requirements will be verified and validated with stakeholders. Following the SDLC method, the best solution needs to be selected based on validated requirements. In this phase, it should become clear whether a new tool needs to be developed or whether an existing tool used for other purposes needs to be considered. If a suitable tool is not available on the market, tool development can be prepared. Agile methods of tool development are preferred, as with our current knowledge we consider the tool to be an incremental tool which would enable rapid development cycles. To develop this adaptive tool, we would like to include users and developers to increase development success and adoption (Abrahamsson et al., 2017).

4 Conclusion, limitations and further research

Implementation of technological digital devices in complex environments such as operating rooms remain a challenge. To address this challenge, we developed and evaluated a framework for implementation consisting of implementation factors, related implementation activities and implementation instructions. These factors are: setting up a project plan, organizational preparation, technical preparation and training and evaluation. This research adresses the need of potential users of this framework. These users identified a need for an adaptive tool or app enabling users to select and prioritize implementation activities. To respond to the research question we will use process steps of requirements engineering to identify requirements for this tool. Based on the findings up to now and our current knowledge, we need to select stakeholders and develop personas. Based on these personas we will identify requirements. A market search on available tools needs to be executed to decide whether to buy and adjust an existing vendor tool or to develop a new tool. In case of a development of a new tool, we prefer an agile method for development.

Limitations and further research

In this research in progress we initiate the process to follow up on users needs to develop or acquire a tool or app that facilitates implementation of new technological equipment. Up to now did a provisonal and limited search, on development methodologies for software to develop this tool. We use the body of knowledge of requirements engineering to identify requirements with use of personas. After these requirements have been specified, further research needs to be conducted on the preferred agile development method.

References

Abrahamsson, P., Salo, O., Ronkainen, J., & Warsta, J. (2017). Agile Software Development Methods: Review and Analysis. Chemistry (Weinheim an Der Bergstrasse, Germany), 19(21), 6641–6649. https://doi.org/10.1002/chem.201203966

Adi Guna Permana, P. (2015). Scrum Method Implementation in a Software Development Project Management. International Journal of Advanced Computer Science and Applications, 6(9), 198–204. https://doi.org/10.14569/IJACSA.2015.060927

Damschroder, L. J., Aron, D. C., Keith, R. E., Kirsh, S. R., Alexander, J. A., & Lowery, J. C. (2009). Fostering implementation of health services research findings into practice: A consolidated framework for advancing implementation science. Implementation Science, 4(1), 1–15. https://doi.org/10.1186/1748-5908-4-50

Damschroder, L. J., Reardon, C. M., Widerquist, M. A. O., & Lowery, J. (2022). The updated Consolidated Framework for Implementation Research based on user feedback. Implementation Science, 17(1), 1–16. https://doi.org/10.1186/s13012-022-01245-0

De Looze, M. P., Bosch, T., Krause, F., Stadler, K. S., & O'Sullivan, L. W. (2016). Exoskeletons for industrial application and their potential effects on physical work load. Ergonomics, 59(5), 671–681. https://doi.org/10.1080/00140139.2015.1081988

Ebad, S. A. (2020). Healthcare software design and implementation—A project failure case. Software - Practice and Experience, 50(7), 1258–1276. https://doi.org/10.1002/spe.2807

Edmondson, A. C., Bohmer, R. M., & Pisano, G. P. (2001). Disrupted Routines: Team Learning and New Technology Implementation in Hospitals. Administrative Science Quarterly, 46(4), 685. https://doi.org/10.2307/3094828

Fennelly, O., Cunningham, C., Grogan, L., Cronin, H., O'Shea, C., Roche, M., Lawlor, F., & O'Hare, N. (2020). Successfully implementing a national electronic health record: a rapid umbrella review. International Journal of Medical Informatics, 144(September), 104281. https://doi.org/10.1016/j.ijmedinf.2020.104281

Jacobs, S. R., Weiner, B. J., Reeve, B. B., Hofmann, D. A., Christian, M., & Weinberger, M. (2015). Determining the predictors of innovation implementation in healthcare: A quantitative analysis of implementation effectiveness. BMC Health Services Research, 15(1), 1–13. https://doi.org/10.1186/s12913-014-0657-3

Kramer, M. (2018). Best Practices in Systems Development Lifecycle: An Analyses Based on the Waterfall Model. Review of Business & Finance Studies, 9(1), 77–84.

Mayas, C., Hörold, S., & Krömker, H. (2016). Personas for Requirements Engineering. In Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics): Vol. 9312 LNCS (pp. 34–46). https://doi.org/10.1007/978-3-319-45916-5_3

Moullin, J. C., Sabater-Hernández, D., Fernandez-Llimos, F., & Benrimoj, S. I. (2015). A systematic review of implementation frameworks of innovations in healthcare and resulting generic implementation framework. Health Research Policy and Systems, 13(1), 1–11. https://doi.org/10.1186/s12961-015-0005-z

Nilsen, P. (2015). Making sense of implementation theories, models and frameworks. Implementation Science, 10(1), 1–13. https://doi.org/10.1186/s13012-015-0242-0

Pandey, D., Suman, U., & Ramani, A. K. (2010). An Effective Requirement Engineering Process Model for Software Development and Requirements Management. 2010 International Conference on Advances in Recent Technologies in Communication and Computing, 287–291. https://doi.org/10.1109/ARTCom.2010.24

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A design science research methodology for information systems research. Journal of Management Information Systems, 24(3), 45–77. https://doi.org/10.2753/MIS0742-1222240302

Rafferty, A. E., Jimmieson, N. L., & Armenakis, A. A. (2013). Change Readiness: A Multilevel Review. Journal of Management, 39(1), 110–135. https://doi.org/10.1177/0149206312457417

Schoville, R. R., & Titler, M. G. (2015). Guiding Healthcare Technology Implementation. CIN: Computers, Informatics, Nursing, 33(3), 99–107. https://doi.org/10.1097/CIN.0000000000000130

Sewberath Misser, N. (2023). Introducing technological innovations in Operation Rooms in hospitals : an implementation framework for technological devices LK - https://hu.on.worldcat.org/oclc/1368026515. Open Universiteit.

Sewberath Misser, N., Jaspers, J., van Zaane, B., Gooszen, H., & Versendaal, J. (2018). Transforming operating rooms: factors for successful implementations of new medical equipment. Digital Transformation – Meeting the Challenges, June, 279–289. https://doi.org/10.18690/978-961-286-170-4.18

Sewberath Misser, N., Jaspers, J., van Zaane, B., Gooszen, H., & Versendaal, J. (2021). Evaluating an Implementation Protocol for Digitization and Devices in Operating Rooms: a Case Study. 34th Bled EConference Digital Support from Crisis to Progressive Change: Conference Proceedings, 351–364. https://doi.org/10.18690/978-961-286-485-9.26

Sewberath Misser, N., Jaspers, J., Van Zaane, B., Gooszen, H., & Versendaal, J. (2021). Evaluation of an implementation protocol for digitization and devices in Operating Rooms. AMCIS 2021 Proceedings, 0–10. https://aisel.aisnet.org/amcis2021/healthcare_it/sig_health/2

Sewberath Misser, N., Jaspers, J., Zaane, B. Van, Gooszen, H., & Versendaal, J. (2020). A protocol for the implementation of new technology in a highly complex hospital environment: the operating room. International Journal of Networking and Virtual Organisations, 22(2), 199. https://doi.org/10.1504/IJNVO.2020.105543

Sewberath Misser, N., Zaane, B. Van, Jaspers, J. E. N., Gooszen, H., & Versendaal, J. (2018). Implementing Medical Technological Equipment in the OR : Factors for Successful Implementations. Journal of Healthcare Engineering, 2018. https://doi.org/https://doi.org/10.1155/2018/8502187

Zayat, W., & Senvar, O. (2020). Framework Study for Agile Software Development Via Scrum and Kanban. International Journal of Innovation and Technology Management, 17(04). https://doi.org/10.1142/S0219877020300025

Appendix 1: implementation framework for technological devices in operating rooms

A revised framework for implementation for technological devices was constructed and is presented in the next table (Sewberath Misser, 2023). We intend to use the contents of this framework as first data set for an adaptive digital tool or app to help users to implement new digital and technological devices.

Table 1: Revised implementation framework (Sewberath Misser, 2023)

Id	Implementation Activities	Instructions for implementation
1	**Set up a project plan**	
1.1	Identify strategic and tactical topics	Operationalize overall strategic and tactical goals for the implementation stage.
1.2	Identify performance	Identify performance indicators to define the performance of the implementation stage and define how these variables are measured and analyzed. Performance metrics for success could be efficiency, finance, and ergonomics.
1.3	Identify stakeholders	Identify (groups of) stakeholders, which are responsible, accountable, consulted and informed such as sponsors, key-representatives, staff, teams. Identify a project manager for implementation
1.4	Identify risks related to implementation	Perform a risk assessment to identify risks and identify unintended outcomes as new technology may have unforeseen consequences.
1.5	Identify activities for implementation	Identify relevant activities for implementation, based on listed activities. Generate a planning or timeline for execution of these activities.
2	**Organizational preparation**	
2.1	Assemble a multidisciplinary implementation team	Assemble a team which includes various members of involved departments and stakeholders such as scrub nurses, circulating nurses, anesthesiologists, perioperative technicians, surgeons, administrators, IT specialists, and schedulers. Consider assigning an extra team member during implementation to

Id	Implementation Activities	Instructions for implementation
		increase familiarity with procedures, e.g. setup procedures.
2.2	Foster team familiarity	Team familiarity and stability impacts teamwork, communication, and satisfaction during implementation. Assign a dedicated implementation team. Involve and inform this team well.
2.3	Identify affected activities and/or processes	Introducing new (medical) equipment influences existing activities and work processes. Identify these and analyze how these processes are affected and which identified stakeholders are involved.
2.4	Update checklists and/or protocols	Checklists improve safety and reliability prior to, and during surgical procedures. Update operating procedures or protocols. If necessary, update existing check lists.
2.5	Perform simulations	Simulate with stakeholders (and departments) how processes and work activities are executed prior to introducing (medical) equipment. Practice with a new tool or new (prototype) equipment on trial basis.
2.6	Identify and deploy activities to increase employees' engagement	Participation of employees when introducing new (medical) equipment increases employees' engagement in the OR. Deploy activities to engage employees in the OR, e.g., involvement of work councils, create a communications council.
2.7	Identify and deploy activities to increase employees' adoption	Embedding information systems or new (medical) equipment in day-to-day activities as an accepted routine is a challenge. Identify and deploy activities to increase adoption with stakeholders such as demonstrating relative advantages, possibilities to observe and experiment, demonstrate benefits, use training and assign key users or champions.
2.8	Communicate with stakeholders	Communication with stakeholders increases engagement and involvement of stakeholders. Set up a communications plan, consisting of

Id	Implementation Activities	Instructions for implementation
		communication activities over time. Involved stakeholders should be aware what their role is relating to the new (medical) equipment. For example, nursing personnel should be familiar with the instrumentation needs and they should be proficient in properly connecting, calibrating, set up and use (medical) equipment. Communication activities can be: (pre-operative) group briefings, interviewing stakeholders, using videos and newsletters, developing patient centered information.
3	**Technological preparation**	
3.1	Prepare equipment	Prepare technical facilities related to the use of the information system or device in the OR e.g., power and plugs (if needed)
3.2	Consider ergonomic aspects	Introducing a new tool or system may affect ergonomic aspects of staff in the OR. Consider these aspects in an early stage of the project, prior to implementations. Simulations may lead to ergonomic changes and positioning of tools in the OR.
3.3	Prepare interfaces with other information systems	Introducing new equipment requires integration in and with other devices in the OR. Consider the connectivity to the clinical networks to ensure safety and reliability.
3.4	Integrate device within existing environment	The introduction of new equipment affects current workflows and processes. These workflows need to updated, and existing standard operating procedures need to be updated accordingly.
3.5	Manage generated data	When introducing equipment data can be generated and/or stored, e.g. when introducing a new information system. Consider data processing and security aspects and develop or update procedures.
3.6	Set up maintenance plan	New equipment in use should be maintained periodically and in case of problems, support

Id	Implementation Activities	Instructions for implementation
		should be available. To address and facilitate this, a maintenance plan should be set up. Provide instructions how to maintain (clean) tools/equipment such as screens in the OR and confirm who is responsible for this activity.
3.7	Update safety (regulations)	The introduction of new equipment may affect work activities of personnel. Assess the safety procedures and if needed, update these procedures accordingly.
4	**Training and evaluation**	
4.1	Train involved staff	(Recurrent) training is crucial for correct and safe use of the system or tool and affects adoption and success of an implementation. Training focuses on technical skills and non-technical skills. Technical skills may include cognitive, integrative, and automatic skills such as congress visits, demonstrations, research results, online courses, knowledge training, expert opinions, and simulation trainings. Specific trainings on changing ICT and updated workflows and activities should be included as well. Non-technical skills may include decision making, communication and leadership skills.
4.2	Interpret screens and troubleshooting	In case of electronic equipment, notifications may occur visibly on screens, lights, or audible (alarms). Involved personnel should be able to interpret these notifications and should be able to troubleshoot in case of occurring problems.
4.3	Assess Skills	To assess the readiness for use, a skills assessment plan needs be developed and executed, tailored to the stakeholders. This plan may include supervision by co-workers. An assessment plan can be determined and executed by a manufacturer, the hospital or a department. (If applicable) assess whether skills need to be recorded and tracked.
4.4	Evaluate experiences	Evaluate experiences and gather feedback regarding the use of the new device, provide

Id	Implementation Activities	Instructions for implementation
		input to optimize the device, the use of the device or the workflow.
4.5	Evaluate implementation process	Evaluate the implementation process and relate results to the performance indicators mentioned in the implementation plan.

RESEARCH IN PROGRESS

Component Models for IoT Search Engine

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The more distributed system expands, the higher need for search engines of its elements we have. The Internet of Things (IoT) systems become very complex, and the number of devices is growing exponentially. The demand for the search engine of things now reached the demand for the search engine of web pages as it was in the 1990s. We propose to use component-based architecture for the search engine of things (IoTSE). As IoT systems are heterogeneous, and the interoperability of various component models is problematic, we must focus on selected component models only. This paper surveys existing component models and discuss their feasibility to be used in IoT search engine.

Keywords: search engine, internet of things, component model, component-based software engineering

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1 Introduction

The Internet of Things (IoT) is an example of a complex computational system. It evolved from the idea in the 1990s to the infrastructure of everyday life nowadays. The number of IoT devices is growing exponentially, so the demand for the search engine of "things" is as big as for the search engine of webpages 3 decades ago (Gubbi et al. 2013; Fathy, Y., Barnaghi, P., Tafazolli, 2018; Tran et al. 2017; Tang et al. 2023). They are a pilot products already such as *IoTCrawler* and *Shodan*.

However, the development of IoT search engines is not entirely the same as the development of "ordinary" search engines. It exists some challenges and threats. When webpages are uniform to some extent, the IoT network is highly heterogeneous and dynamic. A typical web search engine's data source is the web pages, metadata, and content. IoT content is far more complex as they provide very dynamic data. Instead of static content they usually provide the data streams. On the other hand, even the type of data can change. For example, a temperature sensor can provide floated point values (temperature), when it is working, Boolean value (false) when it is out of order, or the textual content (via its representative). Because of the nature of IoT, we cannot just reuse the principles of web page search engines.

In software engineering, it is common practice to use reusable software components and/or software services when it is required to address dynamism and agility. Component-based software engineering (CBSE) uses modules of higher granularity of the components. This enables to reduction the time required for the development, testing of component-based software significantly. Components are "hot swap" modules in software similar to the storage disks, power supplies, and other modules in contemporary hardware (mainly servers). As all the communication between software components is organized via Interfaces, each software component can be easily and quickly replaced by another one, which implements the same interface. After this, there is no need to perform testing of the overall system. A component-based system can be considered highly reliable and easily maintainable (Vale et al., 2016).

The goal of this paper is to survey existing component models and discuss their feasibility to be used in IoT search engines (IoTSE). The rest of the paper is organized as follows: Section 2 presents the main architectural parts of search engines and the state-of-art taxonomy of IoT search engines. Section 3 surveys the most popular software component models (CORBA, EJB, .NET, OSGi) and discusses their place in the overall architecture of dynamic Internet of things search engine. Section 4 shortly introduces related work in this area. Finally, the conclusions are made, and open questions are discussed.

2 Search engine concept in the IoT context

As presented by Brin and Page (1998), and by Bruce et al. (2010), main parts of the search engine are as follows:

1. A *Crawler*, or a bot, is a program that traverses the web to discover and download web pages. This is a critical component of a search engine because it enables the system to discover new web pages and update its index of existing ones.
2. *Indexer* : Once the crawler has downloaded a web page, the next step is to extract its content and store it in an index. An indexer is a program that processes the content of web pages and creates an index of words and their locations. This allows users to find relevant pages quickly by searching for specific words.
3. The *Query processor* is responsible for interpreting user queries and finding the most relevant web pages. This component usually involves a combination of natural language processing, machine learning, and other algorithms to match user queries with relevant pages in the index.
4. A *Ranking algorithm* is used to determine the order in which web pages are presented to users. Different search engines use different algorithms, but the basic idea is to assign a score to each page based on factors such as relevance, authority, and popularity.
5. The *User interface* is the part of the search engine that users interact with. This includes the search box, search results page, and other elements that make it easy for users to find what they're looking for.

Each IoT *search engine* must be able to perform at least two activities: discovery activity and search activity. During the *discovery activity* engine retrieves the list of IoT devices by scanning the local/global environment, IoT device-related websites, or cached databases. According to (Tran et al. 2019), more than 90% of the engines include discovery activities. After this list is made, the second activity – searching – is running. Its goal is to filter the former list by rejecting all the devices whose properties do not conform with the initial query. IoT search engines can be classified according to their meta-path. Meta-path reveals the source of the data for discovery and search and the target of these activities. Nguyen et al. (2019) distinguish 8 classes of IoTSE:

1. $R \rightarrow R$ class IoTSE
2. $D + R \rightarrow T \rightarrow R$ class
3. D → D
4. R → T → R + D
5. D → T → R
6. F → F
7. R → T → F
8. S → S

where R is Representative of IoT device (e.g. dedicated web page for its monitoring and control), D - Dynamic IoT content (e.g. not usual data stream), T - IoT device (aka Thing).

1st class (R-R) of IoT search engines is highly influenced by web search engines. The information about devices is taken from representatives only. No direct data gathering from IoT devices at the moment of search is performed.

The second class (D+R-TR) of search engines gets data not only from representatives of things but (what is more specifically) from the IoT devices directly as dynamic streams. The result of 2nd class IoTSE is the representatives. In other words, R-R class can be considered as a subset of D+R-TR, whit zero D component. 3rd class (D-D) goes beyond of D+R-TR class and gets the data from the very end sensors of Things, not just from the public observable states of things. 4th class (R-T-R+D), according to (Tran et al., 2019), is an extension of the R-R class. What is interesting, is that search engines from this class return not only links to IoT representatives but the data stream from them as well. 5th class (D-T-R) is a little bit similar to 2nd and 3rd classes. Typically they work using SPARQL queries over contextual information. As (Tran et al., 2019) observed in contrast with 2nd class IoT search engines, 5th class engines select things only by the data streams, not considering any other features (e.g. representatives). 6th class (F-F) is very interesting as the IoT devices are analyzed not by their representatives or data stream, but by their functionality. The functionality of things is exposed in a shared ontology. 7th class (RTF) of engines selects devices by its representatives. Its results include the functionality of selected things. As pointed out by Tran et al. (2019), this functionality is presented as RESTful Web services and is capable of self-describing with specifications written in the Web Application Description Language (WADL). In our context (CBSE) it is a very promising fact. And 8th class of IoTSE (SS) query on cached static information from IoT devices. In contrast to 3rd class, these IoTSE, do not acquire the newest data from IoT devices nor perceive dynamic data streams. However, then can be easily applied in the fields where the device state does not change often. The examples of IoT search engines are listed in Table 1.

Table 1: IoT search engines

Engine	Class	Source	URL
Shodan	N/A		https://www.shodan.io
ThingFul	DRTR?		https://www.thingful.net
IoTCrawler	DD?		https://iotcrawler.eu
ForwarDS-IoT	RR	(Gomes et al., 2015)	
DiscoWoT	RR	(Mayer, Guinard, 2011)	
ThingSeek	N/A	(Shemshadi, Sheng, Qin, 2016)	
IoT-SVK	DRTR	(Jin et al., 2011)	
CASSARAM	DD	(Perera, 2013)	
Snoogle	RT-R+D	(Wang, Tan, Li, 2010)	
ASAWoO	FF	(Mrissa, Médini, Jamont, 2014)	https://liris.cnrs.fr/asawoo
N/A	RTF	(Kamilaris, Papakonstantinou, Pitsillides, 2014)	
Microsearch	SS	(Tan et al., 2009)	

Table 2: The coverage of IoTSE functions

Function	CORBA	EJB	OSGi	.NET	WS
Crawler					
Indexer		(Arellanes, Lau, 2020)		(Fathy, Barnaghi, Tafazolli, 2018)	
QP					
RA	(Chang, Yuan, Lo, 2000)				
UI	(Chang, Yuan, Lo, 2000)				

3 Component-based approach

The component in our context is a reusable software module, having explicit interfaces, capable to discover IoT devices and/or getting their data. It is the subject of the third part of the composition and is strictly dependent on the middleware/framework.

The idea to combine IoT with software components and services is not very new. The group of Zhiming Liu (2010) has been working on software-hardware components fusion for a long time before the rise of IoT. In another reference, Ruppen et al. (2015) present a system based on model-driven architecture (MDA) which helps to bind IoT devices and RESTful web services in a semi-automated way. The component in (Ruppen et al., 2015) work is the pair of IoT devices - RESTFull service. In both cases, the component is a "piece" of the system having its hardware and software parts. In CBSE each component must have at least one interface (or Provided interface) in which it is implemented, and (optionally) can have a Required interface, which declares what interfaces are needed from other components to work properly. Distributed components communicate using a Framework, or Middleware, which encompasses main data structures, and services (e.g. networking, DB) as well.

In this section, we continue the architectural approach described in (Gula, Flakova, 2017; Giedrimas, Backys, 2022; Saari, Nurminen, Rantanen, 2022) and will analyze the most popular component-based technologies: CORBA, EJB, OSGi, and .NET.

3.1 CORBA

CORBA (Common Object Request Broker Architecture) is a middleware technology that provides a way for distributed applications to communicate with each other. CORBA was an industrial standard for the past two decades. They are still several legacy systems using this technology. It can be used in the development of search engines to connect different components of the system and provide a standard way for them to communicate. The use of the CORBA component model for web search engines is described in (Chang, Yuan, Lo, 2000). CORBA is supported by OMG consortium, which gives grates opportunities to embed CORBA components into any existing system. However, CORBA is only one technology that does not separate the processes of component development and the use of the components. CORBA components usually are not a subject of third-party composition. This does not let to use the "hot swap" advantage of CBSE.

Table 3: The coverage of IoTSE functions

Class	**CORBA**	**EJB and OSGi**	**.NET**	**WS**
RR	(Chang, Yuan, Lo, 2000)			
DRTR	(Chang, Yuan, Lo, 2000)			(Dang, Pham, Duong, 2018)
DD		(Arellanes, Lau, 2020)		(Arellanes, Lau, 2020; Dang, Pham, Duong, 2018)
RTRD	(Chang, Yuan, Lo, 2000)			
DTR		(Arellanes, Lau, 2020)		(Arellanes, Lau, 2020; Dang, Pham, Duong, 2018)
FF				(Dang, Pham, Duong, 2018)
RTF		(Arellanes, Lau, 2020)		(Arellanes, Lau, 2020)
SS				(Tan et al., 2009)

3.2 EJB and OSGi

EJB (Enterprise Java Beans) is a server-side component architecture for Java that can be used for building distributed applications, including search engines. EJB provides a set of services such as transaction management, security, and persistence, which can be useful in building complex distributed applications.

OSGi (Open Services Gateway initiative) is a modular framework for Java that provides a way to build complex applications using a set of reusable components. It can be used in the development of search engines to create a modular architecture that allows components to be developed and tested independently.

3.3 .NET

.NET is a software framework developed by Microsoft that can be used for building web applications, including search engines. It includes a variety of libraries and tools for developing web applications, such as ASP.NET for building web pages and MVC for creating web applications.

3.4 Web services

Web services provide a standardized way for software components to communicate with each other over the internet, using technologies such as XML, SOAP, JSON. This makes it easier to integrate different components into a single system, which is important for building complex IoT search engines. Microservices are a more recent approach to software architecture, where a system is broken down into small, independently deployable components that communicate with each other via lightweight protocols such as HTTP or messaging systems. This approach allows for greater flexibility and scalability in building IoT search engines, as different microservices can be developed and deployed independently and can be easily replaced or scaled up or down based on demand. We refer to both technologies as to WS. In analyzed papers most of pilot projects on IoTSE was made using web services and microservices.

3.6 Frameworks

As mentioned earlier, in component-based software engineering we rely not only on the components but on the frameworks as well. The most often used frameworks are:

1. Lightweight M2M (LwM2M): LwM2M is a protocol that is designed for use in IoT devices. It provides a standardized way for devices to communicate with servers, which can be useful for integrating data from IoT devices into a search engine.
2. CoAP protocol that is designed for use in IoT devices. It is a lightweight protocol that is well-suited for constrained environments and can be used to integrate IoT device data into a search engine.
3. Apache Kafka is a distributed streaming platform that is commonly used in IoT contexts. It can be used to ingest data from IoT devices in real-time and can be integrated with search engines to provide real-time search capabilities.
4. Apache Spark is a popular distributed computing platform that can be used for processing large volumes of data in near-real-time. It can be used to process data from IoT devices and integrate it with search engines.
5. Elasticsearch for IoT : Elasticsearch is a popular search engine that has been adapted for use in IoT contexts. It can be used to store and search data from IoT devices, and provides a variety of features that are optimized for IoT use cases, such as geospatial search and time series data.

4 Related work

The architectures of component-based IoTSE are described only in (Giedrimas, Backys, 2022; Gula, Flakova, 2017). Other papers cover this topic only partially. The idea to use the (reusable) workflow engines in the overall science gateway is architecturally like our approach. Glatard et al. (2017) refer to workflow engines as software components while presenting 6 software architectures: Tight integration, Service invocation, Task encapsulation, Pool model, Nested workflows with service invocation and Conversion, and Workflow conversion with service invocation. We assume that component-based IoTSE will have a backbone (instead of the science

gateways), and smaller parts - software components implementing different IoT search and discovery algorithms.
Other papers have weak (or negative) relations with software components; however, they are highly related to software architectures (Cambazoglu et al., 2007; Ozcan et al., 2012) and/or search engines (Kejriwal, 2021; Cambazoglu et al., 2007; Ozcan et al., 2012).

5 Conclusions and Future work

After the analysis, we came to the following conclusions:

1. Even though the market of IoTSEs is new and growing, enough different search engines is developed already. Fortunately, IoTSEs are not unique and can be classified into a limited number of classes. Each class of the IoTSE can deny an interface and each IoTSE from this class can be considered as a component implementing this interface.
2. The area of research (component models for IoTSE), is almost not covered by the scientific community nor the business applications. We found only a few sources. Surprisingly search engines provide some results about the topic, which led to broken links and non-existing pages. We assume that the papers were withdrawn because of the lack of maturity or experimental data.
3. The survey of the 5 most popular component-based models shows that most of the pilot projects on IoTSE were made using web services and microservices. More hardware-related component models such as OSGi and CORBA are least used for this purpose.
4. We do not find any evidence of component-based technology used for the development of the Crowler and Query processing elements of search engines.

Our future work on this topic includes the selection of one component model and experimental development of the IoTSE system.

References

Arellanes, D., Lau, K.K.: Evaluating iot service composition mechanisms for the scalability of iot systems. Future Generation Computer Systems 108, 827848 (2020). https://doi.org/https://doi.org/10.1016/j.future.2020.02.073,

Brin, S., Page, L.: The anatomy of a large-scale hypertextual web search engine. Computer Networks and ISDN Systems 30(1-7), 107117 (1998)

Cambazoglu, B.B., Karaca, E., Kucukyilmaz, T., Turk, A., Aykanat, C.: Architecture of a grid-enabled web search engine. Information Processing and Management 43(3), 609623 (2007). https://doi.org/https://doi.org/10.1016/j.ipm.2006.10.011, Special Issue on Heterogeneous and Distributed IR

Chang, Y.S., Yuan, S.M., Lo, W.: A new multi-search engine for querying data through an internet search service on corba. Computer Networks 34(3), 467480 (2000). https://doi.org/https://doi.org/10.1016/S1389-1286(00)00131-6,

Croft, W.B., Metzler, D., Strohman, T.: Search Engines: Information Retrieval in Practice. Addison-Wesley Professional (2010)

Dang, T., Pham, L.T., Duong, T.Q.: Building an intelligent search engine for iot using microservices architecture. Journal of Computer Networks and Communications 2018 (2018). https://doi.org/10.1155/2018/9259473,

Fathy, Y., Barnaghi, P., Tafazolli, R.: Large-scale indexing, discovery, and rankingfor the internet of things (iot). ACM Comput. Surv. 51(2) (Mar 2018).https://doi.org/10.1145/3154525

Giedrimas, V., Backys, G.: Component-based architecture of IoT search engine. Taikomieji tyrimai studijose ir praktikoje – Applied research in studies and practice 18(1), 100105 (Dec 2022),https://ojs.panko.lt/index.php/ARSP/article/view/183

Glatard, T., Étienne Rousseau, M., Camarasu-Pop, S., Adalat, R., Beck, N., Das, S., da Silva, R.F., Khalili-Mahani, N., Korkhov, V., Quirion, P.O., Rioux, P., Olabarriaga, S.D., Bellec, P., Evans, A.C.: Software architectures to integrate workflow engines in science gateways. Future Generation Computer Systems 75, 239255 (2017). https://doi.org/https://doi.org/10.1016/j.future.2017.01.005

Gomes, P., Cavalcante, E., Rodrigues, T., Batista, T., Delicato, F.C., Pires, P.F.: A federated discovery service for the internet of things. In: Proceedings of the 2nd Workshop on Middleware for Context-Aware Applications in the IoT. p. 2530. M4IoT 2015, Association for Computing Machinery, New York, NY, USA (2015). https://doi.org/10.1145/2836127.2836129

Gubbi, J., Buyya, R., Marusic, S., Palaniswami, M.: Internet of Things (IoT): A vision, architectural elements, and future directions. Future Generation Computer Systems-The International Journal of Escience 29(7), 16451660 (SEP 2013). https://doi.org/{10.1016/j.future.2013.01.010}

Gula, M., Fláková, K.: Proposal of component based architecture for internet of things: online laboratory case study. IFAC-PapersOnLine 50(1), 337342 (2017). https://doi.org/https://doi.org/10.1016/j.ifacol.2017.08.153, 20th IFAC World Congress

Jin, X., Zhang, D., Zou, Q., Ji, G., Qian, X.: Where searching will go in internet of things? In: 2011 IFIP Wireless Days (WD). pp. 13 (2011).

Kamilaris, A., Papakonstantinou, K., Pitsillides, A.: Exploring the use of dns as a search engine for the web of things. In: 2014 IEEE World Forum on Internet of Things (WF-IoT). pp. 100105 (2014). https://doi.org/10.1109/WFIoT. 2014.6803128

Kejriwal, M.: A meta-engine for building domain-specific search engines. Software Impacts 7, 100052 (2021). https://doi.org/https://doi.org/10.1016/j.simpa.2020.100052

Liu, Z., Morisset, C., Stolz, V.: rcos: Theory and tool for component-based model driven development. In: Arbab, F., Sirjani, M. (eds.) Fundamentals of Software Engineering. pp. 6280. Springer Berlin Heidelberg, Berlin, Heidelberg (2010)

Mayer, S., Guinard, D.: An extensible discovery service for smart things. In: Proceedings of the Second International Workshop on Web of Things. WoT '11, Association for Computing Machinery, New York, NY, USA (2011). https://doi.org/10.1145/1993966.1993976

Mrissa, M., Médini, L., Jamont, J.: Semantic discovery and invocation of functionalities for the web of things. In: 2014 IEEE 23rd International WETICE Conference. pp. 281286 (2014). https://doi.org/10.1109/WETICE.2014.50

Ozcan, R., Sengor Altingovde, I., Barla Cambazoglu, B., Junqueira, F.P., Özgür Ulusoy: A ve-level static cache architecture for web search engines. Information Processing and Management 48(5), 828840 (2012). https://doi.org/10.1016/j.ipm.2010.12.007, large-Scale and Distributed Systems for Information Retrieval

Perera, C., Zaslavsky, A., Christen, P., Compton, M., Georgakopoulos, D.: Contextaware sensor search, selection and ranking model for internet of things middleware. In: 2013 IEEE 14th International Conference on Mobile Data Management. vol. 1,pp. 314322 (2013). https://doi.org/10.1109/MDM.2013.46

Ruppen, A., Pasquier, J., Meyer, S., Rüedlinger, A.: A component based approach for the web of things. In: Proceedings of the 6th International Workshop on the Web of Things. WoT '15, Association for Computing Machinery, New York, NY, USA (2015). https://doi.org/10.1145/2834791.2834792

Saari, M., Nurminen, M., Rantanen, P.: Survey of component-based software engineering within iot development. In: 2022 45th Jubilee International Convention on Information, Communication and Electronic Technology (MIPRO). pp. 824828 (2022). https://doi.org/10.23919/MIPRO55190.2022.9803785

Shemshadi, A., Sheng, Q.Z., Qin, Y.: Thingseek: A crawler and search engine for the internet of things. In: Proceedings of the 39th International ACM SIGIR Conference on Research and Development in Information Retrieval. p. 11491152. SIGIR '16, Association for Computing Machinery, New York, NY, USA (2016). https://doi.org/10.1145/2911451.2911471

Tan, C.C., Sheng, B., Wang, H., Li, Q.: Microsearch: When search engines meet small devices. In: Proceedings of the 6th International Conference on Pervasive Computing. p. 93110. Pervasive '08, Springer-Verlag, Berlin, Heidelberg (2009). https://doi.org/10.1007/978-3-540-79576-6-6

Tang, J., Lu, X., Xiang, Y., Shi, C., Gu, J.: Blockchain search engine: Its current research status and future prospect in internet of things network. Future Generation Computer Systems 138, 120 141 (2023). https://doi.org/https://doi.org/10.1016/j.future.2022.08.008,

Tran, N., Sheng, Q., Babar, M., Yao, L.: A kernel-based approach to developing adaptable and reusable sensor retrieval systems for the web of things. In: 18th International Conference on Web Information Systems Engineering (WISE 2017) : proceedings. Lecture Notes in Computer Science, vol. 10569, pp. 315329. Springer, Springer Nature, United States (2017). https://doi.org/10.1007/978-3-319-68783-4-22

Tran, N.K., Sheng, Q.Z., Babar, M.A., Yao, L., Zhang, W.E., Dustdar, S.: Internet of things search engine. Commun. ACM 62(7), 6673 (Jun 2019).

Vale, T., Crnkovic, I., de Almeida, E.S., Silveira Neto, P.A.d.M., Cavalcanti, Y.a.C., Meira, S.R.d.L.: Twenty-eight years of component-based software engineering. J. Syst. Softw. 111(C), 128148 (Jan 2016). https://doi.org/10.1016/j.jss.2015.09.019

Wang, H., Tan, C.C., Li, Q.: Snoogle: A search engine for pervasive environments. IEEE Transactions on Parallel and Distributed Systems 21(8), 11881202 (2010). https://doi.org/10.1109/TPDS.2009.145

RESEARCH IN PROGRESS

AN EXAMINATION OF ANTECEDENTS AND CONSEQUENCES OF TECHNOSTRESS AMONG UNIVERSITY STUDENTS: TASK -TECHNOLOGY FIT PERSPECTIVE

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Drawing on the task-technology fit framework, this study examines the antecedents and consequences of technostress students face in an online/blended-learning environment. The effect of task, technology, and individual students' characteristics was hypothesized as predictors of technostress. The impact of technostress was also examined on students' satisfaction with online learning and expected performance. Preliminary findings based on a sample of 261 university students suggest that tasks requiring interdependence and cooperative learning caused higher technostress, while technology characteristics such as perceived ease of use and usefulness negatively effect technostress. Students' conscientiousness positively affect perceptions of technostress. Unlike previous research, which examined a few antecedents of technostress, this study provides a more nuanced understanding of the causes of technostress in an online higher educational context.

Keywords:
technostress, interdependence, ease of use, conscientiousness, self-efficacy online learning

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1 Introduction

Universities are pursuing technology-enhanced learning as an important agenda for the upgradation of students' learning experiences. Newer learning methods (e.g., flipped classrooms and blended learning) are ways to incorporate the digitalization of teaching and learning resources. This technology-enhanced delivery of instructions enriches students' learning experience and improves their knowledge acquisition and access to learning resources (Brooker, Corrin, De Barba, Lodge, & Kennedy, 2018; Tuapawa, 2017). However, these new forms of learning require time, skills, and effort investments and may create strain for the students (Mehta et al., 2019; Paul & Glassman, 2017). As a result, students can experience technostress –distress associated with the need to use and adapt to new digital technology (Gaudioso, Turel, & Galimberti, 2017; Vuori, Helander, & Okkonen, 2019). Although the use of technology itself can be a source of technostress, the optimal fit among tasks, technology, and individual characteristics can alleviate this stress (Ayyagari et al., 2011). In addition, technology can be a source of motivation for individuals when it eases the task and enables them to achieve the desired outcome in an efficient manner (Cascio & Montealegre, 2016). There can be situations where task, technology, and individual capabilities present a poor fit, which causes technostress, and individuals engage in a coping process to manage that stress. The following sections explain the main constructs of this study, the methodology employed to assess the hypotheses, and the preliminary findings.

2 Literature Review and Theoretical Framework

2.1 Task Technology Fit (TTF)

Task-technology fit (TTF) theory suggests an interrelationship of three components. First, task requirements, technological functionality, and individual capabilities should be matched to achieve optimal performance (Goodhue, 1995; Goodhue & Thompson, 1995). For example, a task may require a different level of detail, and individuals performing this task will use different cognitive and physical resources (capabilities) to complete the task when technological functionality (e.g., tools used, support services available) matches with the task requirements, individual experience high motivation. Furthermore, individual characteristics represent attributes of their technological proficiency and capabilities to perform the assigned task. Internal resources such as self-efficacy, conscientiousness motivation, and experience using different technologies can contribute to high TTF perceptions. A high level of TTF perceptions will increase technology utilization as it matches the task requirements and individual characteristics. On the contrary, distress and frustration are experienced when technology characteristics do not match task requirements and individual capabilities.

2.1.1 Task Requirements

Tasks requiring collaboration and interaction among students are essential for students' learning (Laurillard, 1993; Ramsden, 1992). Although prior research on collaborative learning has mainly focused on students' face-to-face interactions, it is unclear how technology and teamwork can be integrated. Furthermore, the extent and depth of interaction are expected to be limited in an online learning environment, and students experience anxiety and frustration in collaborative learning activities (Bakhtiar, Webster, & Hadwin, 2018). Causes of anxiety stem from delayed responses from group members, misinterpretation, and worrying about grades affected by other members' performance (Donelan and Kear, 2018).

2.1.2 Technological Characteristics

Technological characteristics related to ease of use and usefulness determine the utilization of any technological change. However, the adoption of technology is usually beyond the control of a user because the use of technology is based on compliance (decided by the university). Thus, involuntary adoption of not-so-useful technology creates a perception of demands-resources misfit. Individuals perceive that technology does not help facilitate the completion of required tasks and believe there could be better ways to accomplish the task. These perceptions increase stress and anxiety (Sami & Pangannaiah, 2006).

2.1.3 Individual Characteristics

Self-efficacy is people's self-appraisal of their abilities to perform the designated tasks (Bandura, 1986). Positive self-appraisal in any situation significantly affects perceived stress. In addition, individuals with high self-efficacy can learn new skills and adapt to technological changes (Ellen, Bearden, & Sharma, 1991).

Conscientiousness is a personality trait that directs an individual's attention toward personal growth and work accomplishment. Personality predisposes individuals to pursue certain goals, espouse particular values, and behave differently (Lazarus & Folkman, 1984). Individuals high in conscientiousness place greater emphasis on personal growth and success. Thus, any changes that can reduce their opportunities for success and growth make them stressed (Rodell & Judge, 2009). Changes in the learning environment by introducing technology and collaborative task requirement can be stressful for conscientious students as it may reduce their prospects of growth and accomplishments.

2.2 Technostress

Technostress is described as "a modern disease of adaptation caused by an inability to cope with new computer technologies in a healthy manner" (Brod, 1984, p.16). Technostress captures five dimensions: 1. techno-overload (a perception of overload experienced due to excessive use of technology), 2. techno-invasion (feeling of no boundaries between personal and work life), 3. techno-complexity (difficulties in learning technology and related features), 4. techno-insecurity (job insecurity due to technology) and 5. techno-uncertainty (difficulty in keeping pace with technological changes).

2.3 Satisfaction with online learning and expected performance.

Students can find online learning an exhausting experience because the deluge of information, the expectation of fast response, and the integration of learning into their daily lives affect their satisfaction with learning and performance (Yin et al., 2018). Exhaustive experience can deplete students' mental resources, thus reducing their willingness to participate (Ayyagari et al., 2011) actively, lowering their satisfaction (Kim et al., 2015), and weakening performance (Ayyagari et al., 2011)

2.4 Hypotheses.

H1: Collaborative learning and goal interdependence positively affect the perceptions of technostress.

H2: Technology characteristics (ease of use and usefulness) negatively affect the perceptions of technostress.

H3: Self-efficacy belief negatively affects the perceptions of technostress.

H4: Conscientiousness positively affects the perceptions of technostress.

H5: Technostress negatively affects satisfaction with online learning.

H6: Technostress negatively affects students' expected performance.

3 Method

Data for this study was collected by distributing an online survey to undergraduate students of one of the United Arab Emirates' private sector universities. Students were enrolled in a management course that was delivered online. Participation in this study was voluntary, and anonymity of responses was ensured. Nevertheless, 470 students were invited, and 261 completed responses were received.

3.1 Measures.

- *Cooperative Learning* (7-items) and *goal interdependence* (4-items) scales by Johnson and Johnson (1983) were used to operationalize task requirements.
- Technology characteristics of *perceived ease of use* and *usefulness* of online learning were assessed using 12 items measure of Davis (1989).
- *Self-efficacy belief* was measured by the 7-item scale of Bandura et al. (1996).
- *Conscientiousness* was measured by Hendriks et al. (1999) 20 traits inventory.
- *Technostress* was measured by Brooks et al. (2017) on 23 items scale.
- *Learning Satisfaction* was measured by Cao et al. (2018) 4-item scale.
- *Expected performance* was measured by Blasco-Arcas et al. (2013) 3-item scale.

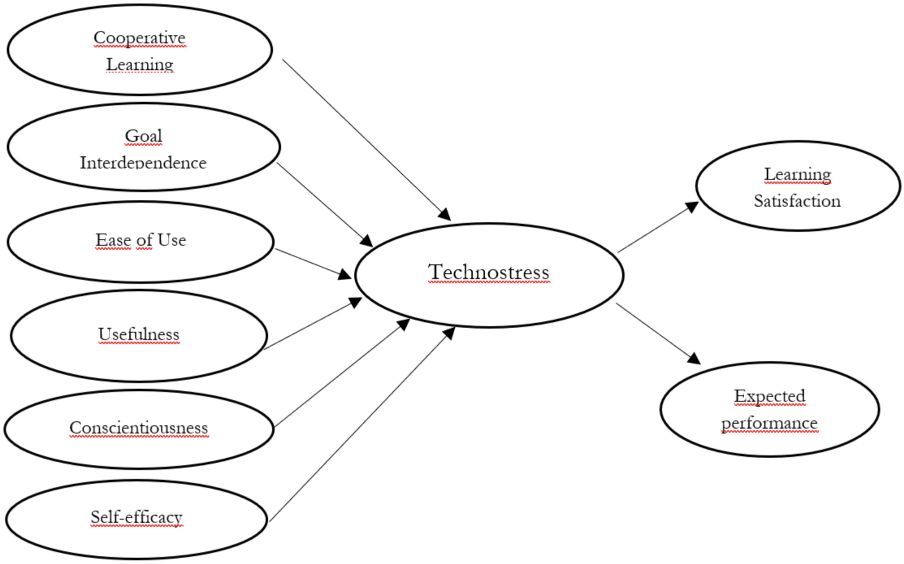

Figure 1: Hypothesized research model

3.2 Analyses and Results.

Path analysis was conducted using AMOS 25. Results are presented in Table -1.

Table 1: Hypotheses testing results.

Hypotheses and Paths	Coefficient	T Statistics	P-values	Supported?
H1: Collaborating learning -> Technostress	0.127**	3.93	0.000	Yes
Goal Interdependence -> Technostress	0.253**	7.93	0.000	Yes
H2: Ease of use -> Technostress	-0.103**	-3.70	0.000	Yes
Usefulness -> Technostress	-0.100**	-2.77	0.000	Yes
H3: Self-efficacy -> Technostress	-0.057	-1.33	0.184	*No*
H4: Conscientiousness -> Technostress	0.303**	9.85	0.000	Yes
H5: Technostress -> Learning Satisfaction	-0.228*	-2.33	0.020	Yes
H6: Technostress -> Expected Performance	-0.134	-1.38	0.166	*No*

*** p<.01 , * p<.05.*

These preliminary findings support our hypothesized model and highlight that technostress results from three interrelated components: technology, task, and individual characteristics. In addition, this study contributes to the existing literature on technostress by identifying task characteristics (collaborative learning and goal interdependence) and individual characteristics (self-efficacy and conscientiousness), which are rarely examined along with technological characteristics as predictors of technostress.

Our findings indicate that when institutions are rolling out technology-enhanced learning, they need to be aware of the ensuing technostress which may impact the academic performance of students, resulting in more dropouts. In order to reduce the technostress, the institutions should focus on all three sets of factors i.e., personal dispositions, environment, and technology-related factors. This calls for a holistic approach to the management of technostress among the student population. These findings represent a work in progress due to the small sample size, and efforts are underway to invite more respondents to replicate these findings with a bigger sample. The next step would be to study the organizational and group-level variables (such as organizational strategy and unit-level goals) to assess their moderating influences on students' technostress and related outcomes.

References

Ayyagari, R., Grover, V., & Purvis, R. (2011). Technostress: Technological antecedents and implications. MIS quarterly, 831-858.

Bakhtiar, A., Webster, E. A., & Hadwin, A. F. (2018). Regulation and socio-emotional interactions in a positive and a negative group climate. Metacognition and Learning, 13, 57-90.

Bandura, A. (1986). Fearful expectations and avoidant actions as coeffects of perceived self-inefficacy.

Bandura, A., Barbaranelli, C., Caprara, G. V., & Pastorelli, C. (1996). Mechanisms of moral disengagement in the exercise of moral agency. Journal of personality and social psychology, 71(2), 364.

Blasco-Arcas, L., Buil, I., Hernández-Ortega, B., & Sese, F. J. (2013). Using clickers in class. the role of interactivity, active collaborative learning and engagement in learning performance. Computers & Education, 62, 102–110.

Brod, C. (1984). Technostress: The human cost of the computer revolution. Basic books.

Brooks, S., Longstreet, P., & Califf, C. (2017). Social media induced technostress and its impact on internet addiction: A distraction-conflict theory perspective. AIS Transactions on Human-Computer Interaction, 9(2), 99-122.

Brooker, A., Corrin, L., De Barba, P., Lodge, J., & Kennedy, G. (2018). A tale of two MOOCs: How student motivation and participation predict learning outcomes in different MOOCs. Australasian Journal of Educational Technology, 34(1).

Cao, X., Masood, A., Luqman, A., & Ali, A. (2018). Excessive use of mobile social networking sites and poor academic performance: Antecedents and consequences from stressor-strain-outcome perspective. Computers in Human Behavior, 85, 163–174.

Cascio, W. F., & Montealegre, R. (2016). How technology is changing work and organizations. Annual review of organizational psychology and organizational behavior, 3, 349-375.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS quarterly, 319-340.

Donelan, H., & Kear, K. (2018). Creating and collaborating: Students' and tutors' perceptions of an online group project. International Review of Research in Open and Distributed Learning, 19(2).

Ellen, P. S., Bearden, W. O., & Sharma, S. (1991). Resistance to technological innovations: an examination of the role of self-efficacy and performance satisfaction. Journal of the academy of marketing science, 19, 297-307.

Gaudioso, F., Turel, O., & Galimberti, C. (2017). The mediating roles of strain facets and coping strategies in translating techno-stressors into adverse job outcomes. Computers in Human Behavior, 69, 189-196.

Goodhue, D. L. (1995). Understanding user evaluations of information systems. Management science, 41(12), 1827-1844.

Goodhue, D. L., & Thompson, R. L. (1995). Task-technology fit and individual performance. MIS quarterly, 213-236.

Hendriks, A. J., Hofstee, W. K., & De Raad, B. (1999). The five-factor personality inventory (FFPI). Personality and individual differences, 27(2), 307-325.

Johnson, D. W., & Johnson, R. T. (1983). Social interdependence and perceived academic and personal support in the classroom. The Journal of Social Psychology, 120(1), 77-82.

Kim, H. J., Lee, C. C., Yun, H., & Im, K. S. (2015). An examination of work exhaustion in the mobile enterprise environment. Technological Forecasting and Social Change, 100, 255–266.

Laurillard, D. (1993). Balancing the media. Journal of educational Television, 19(2), 81-93.

Lazarus, R. S., & Folkman, S. (1984). Stress, appraisal, and coping. Springer publishing company.

Mehta, A., Morris, N. P., Swinnerton, B., & Homer, M. (2019). The influence of values on E-learning adoption. Computers & Education, 141, 103617. https://doi.org/10.1016/j.compedu.2019.103617

Paul, N., & Glassman, M. (2017). Relationship between internet self-efficacy and internet anxiety: A nuanced approach to understanding the connection. Australasian Journal of Educational Technology, 33(4).

Ramsden, P., & Moses, I. (1992). Associations between research and teaching in Australian higher education. Higher Education, 273-295.

Rodell, J. B., & Judge, T. A. (2009). Can "good" stressors spark "bad" behaviors? The mediating role of emotions in links of challenge and hindrance stressors with citizenship and counterproductive behaviors. Journal of Applied Psychology, 94(6), 1438.

Sami, L. K., & Pangannaiah, N. B. (2006). "Technostress" A literature survey on the effect of information technology on library users. Library review, 55(7), 429-439.

Tuapawa, K. (2017). Interpreting experiences of students using educational online technologies to interact with teachers in blended tertiary environments: A phenomenological study. Australasian Journal of Educational Technology, 33(1).

Vuori, V., Helander, N., & Okkonen, J. (2019). Digitalization in knowledge work: the dream of enhanced performance. Cognition, Technology & Work, 21(2), 237-252.

DOCTORAL CONSORTIUM

A PROPOSAL FOR A STUDY OF THE PROCESS ASPECT OF THE INTEGRATED LIFELONG TREATMENT OF HEALTHCARE TO PATIENTS

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Healthcare is in crisis. On the one hand, the population is ageing, on the other hand, we are faced with a lack of resources: human, spatial and financial. That means that we have to make the health system more efficient. During a period of treatment, patients come into contact with a variety of health providers at different levels of the health system. That leads to the gaps between different instances of treatment. According to experiences in other fields, such as industry, a process-oriented view of health treatment could be one of the components of a successful solution. We wonder: How does viewing the medical treatment a patient receives throughout their life as a process affect the gaps between different instances of treatment?

Keywords: healthcare, patient, integrated lifelong treatment, business process

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1 Introduction

Healthcare is in crisis. On the one hand, the population is ageing, which increases the number of patients requiring healthcare and necessitates ever greater amounts of medical treatment.

While new treatment methods and new drugs help people live longer and enjoy better treatment outcomes, they also require ever greater financial investment.

On the other hand, we are faced with a lack of resources: human (shortfall of doctors and other health workers), spatial and financial.

We cannot exercise a significant impact on the requirements or the restrictions, which means that we have to make the health system more efficient.

During a period of treatment, patients come into contact with a variety of health providers at different levels of the health system.

Let us give a few examples.

In Slovenia, 99.3% (source: NIPH, 2023) of children are born in a maternity unit. 99.4 % of births are attended by skilled health personnel in the Members of the European Union (*Proportion (%) of Births Attended by Skilled Health Personnel - European Health Information Gateway*, 2022). This is their first encounter with health treatment and treatment. After discharge from hospital, the newborn is visited by a home care nurse, who provides care to the baby and encouragement to the mother. The baby undergoes systematic checks, with health professionals monitoring their development in a paediatric clinic, vaccinating them and providing a number of other services. When a patient falls ill in Slovenia, they usually visit a primary-level general practitioner (GP), who provides treatment. In more complex cases, the GP sends the patient to a specialist.

In the event of an acute illness or an injury, the patient attends an emergency centre, where they begin acute treatment. In more serious cases, acute treatment continues in hospital. After the patient's condition improves, they move to non-acutFcroe treatment and an extended period of hospital treatment. After their discharge from hospital, treatment continues at primary level. If the patient is referred for rehabilitation, this takes place when they are still in hospital, and may continue at a health resort.

After discharge from hospital, treatment, care and health promotion may also be provided by a home care nurse. For older patients, treatment and care may continue in a care home, with palliative care often being provided at medical institutions as well.

Patients can therefore be treated as follows in the course of their life:

- at primary level: by a general practitioner, family doctor or paediatrician,
- at secondary level: by specialists in specialist clinics and in hospitals (a patient may also move between hospital departments),
- at tertiary level: at University Medical Centre, where the patient may move between clinics,
- rehabilitation may be performed by hospitals, health resorts and private physiotherapists,
- home care services,
- home help, day centres for the elderly, care homes, hospices.

According to experiences in other fields, such as industry (Hammer, 2015; Hammer & Champy, 1995, 2003; Keen, 1997; Keen & Knapp, 1995; Urh et al., 2022), a process-oriented view of health treatment could be one of the components of a successful solution. It could increase quality of treatment and reduce unnecessary healthcare treatment, the duplication of medical examinations and treatment time, thereby improving treatment outcomes, reducing hospitalisation rates and, not least, bringing down costs. The benefits of improving treatment outcomes and reducing hospitalisation and sick leave rates are manifold. Patient satisfaction and quality of life improve: they do not have to spend money on treatment, and can use this renewed period of health to create new value.

The digital transformation of processes also adds a new dimension.

2 Problem definition

The study will look at patient treatment in all periods of life as a process. This process takes place in an environment we will refer to as the 'health system'. During a period of treatment, patients come into contact with a variety of health providers at different levels of the health system. Whether a patient's treatment is successful in a given period frequently depends on previous medical treatment and the information available on that treatment.

More than 99% of babies born in Europe are attended by skilled health personnel. (*Proportion (%) of Births Attended by Skilled Health Personnel - European Health Information Gateway*, 2022), while patients are usually treated by their GP or occasionally by specialists in other institutions. During a hospital stay, they are treated by yet another set of hospital staff. Treatment often involves nurses, physiotherapists, pharmacists or psychologists.

The problems we can identify are the following:

P1 Organisational and informational gaps arise during medical treatment at different healthcare providers. (Bürkle et al., 2017; Amelung et al., 2021)

P2 Attending health workers are not always apprised of the activity of previous treatments. (Amelung et al., 2021)

P3 Attending health workers are not always apprised of the drugs that have been prescribed in the course of previous treatment or the drugs that the patient is currently taking. (Bürkle et al., 2017; Žerovnik et al., 2018).

P4 Fragmented care tend to foster duplication and the inefficient use of resources, producing gaps in the care of patients with multimorbidities and reducing overall health sector capacity by pushing the best health care workers to focus on single diseases (WHO Global Strategy on People-Centred and Integrated Health Services Interim Report, 2015).

P5 Whether a patient's treatment is successful in a given period frequently depends on previous medical treatment and the information available on that treatment.

The main goal of the doctoral dissertation is to look at patient health treatment as a business process – that is, as the integrated lifelong treatment of patient healthcare. We would like to demonstrate that viewing treatment over the course of a patient's life as a process has a significant positive impact on reducing the gaps between different instances of treatment and thereby improve the medical care given to a patient.

An organisational process is the organisation (Rant, 2001; Rant, 2007)

- of inputs – for example, people, equipment, energy, procedures, materials, information;
- of a sequence of work activities;
- of the coordination of actions between the people (and occasionally machines) involved in the activities required to produce
- a certain end-result or output
- that has value to the customer and to investors.

If we look at the process of integrated lifelong treatment of healthcare to patient, we can regard the individual elements in the above definition as:

- As inputs we regard
  - health workers: GPs, specialists, nurses, home care nurses, physiotherapists, care workers;
  - information – medical reports, discharge letters, recommendations, prescriptions, procedures, treatment results.
- Work activities are instances of healthcare treatment at different healthcare levels – primary, in specialist clinics and in hospital.
- The end-result is the outcome of treatment.
- The customer is the patient – a newborn baby, a patient, an injury victim, a person taking part in preventive treatment.

Based on previous research, we expect that it will be possible to propose and implement a new "integrated organisational model for lifelong integration of patient care" using appropriate digital technologies. This means that it is expected that digital transformation of processes will be required for the implementation of the model (Davenport & George, 2018; Raskino & Waller, 2015; Sajja, 2017; Van Veldhoven & Vanthienen, 2022).

2.1 Research question

How does viewing the medical treatment a patient receives throughout their life as a process affect the gaps between different instances of treatment?

3 Methodology

3.1 Research approaches

The following research approaches will be employed:

3.1.1 Case Study Research Methodology

(Yin, 2018; Kljajić Borštnar, 2021)

This involves an in-depth study of a certain situation (integrated healthcare), which differs markedly from existing treatment practices.

3.1.2 Design Science Research

If we develop a new conceptual organisational model, we will also make use of Design Science Research (Hevner, 2007; Hevner et al., 2004)

3.1.3 Systems Development Life Cycle (SDLC)

To analyse the problem, we will use the Systems Development Life Cycle model (Dennis et al., 2014; Valacich et al., 2017).

This study will use the first two activities of this methodology: planning and analysis. We will use Directly observing users (Valacich et al., 2017) and Analyzing procedures and other documents (Valacich et al., 2017).

3.1.4 Methodology for resolving a problem and methodology for building systems

(Gričar & Piskar, 1988)

3.2 Working procedure

We will conduct

1. a literature review
2. an analysis of the current situation
3. a definition of the problems
4. an analysis of the problem
5. a proposed solution
6. an evaluation

4 Preliminary/expected results

4.1 Literature review

We are reviewing the literature in several broad fields:

- Literature in the field of integrated lifelong treatment of healthcare to patients.
- Literature in the field of business processes.
- Literature in the field of system theory.
- Literature in digital transformation.

Based on the findings from the literature, we will elucidate the problems identified by the authors.

We are reviewing the literature on the basis of the following key words: seamless, cross-sector treatment, integrated care, coordinated care, seamless coordinated care, Re-Engineered Discharge (RED), seamless transition (for patient), person-centred care co-ordination, integral treatment, holistic care, continuous patient care.

We have found studies on specific transitions between activities (from hospital to home care, transitions between the treatment of children and adolescents or adults (Nadarajah et al., 2021)) and on specific areas (eating disorders, EDs) (Nadarajah et al., 2021; Wade, 2022), chronic heart failure (Yang et al., 2022), heart attack (Robyn Blackadar & Mishaela Houle, 2009), anorexia nervosa (Stocker et al., 2022), frail older people (D. Kodner, 2012).

However, we did not find studies of integrated lifelong treatment of healthcare to patients.

The business process literature focuses mainly on business processes in industry, not on business processes in healthcare (Dumas et al., 2018; Hammer, 2015; Hammer & Champy, 1995, 2003; Keen, 1997; Keen & Knapp, 1995; Urh et al., 2022).

4.2 Further results

We will carry out an analysis of the existing situation.

With the help of real-world data collected by the National Institute of Public Health, we will attempt to provide evidence for the problems we have identified regarding organisational and informational gaps. It is not enough for data to exist. It must be used. (Stevens et al., 2022) define the flow of data through the ecosystem: collection, transfer, processing and interpretation. (Rant, 2010) establishes that the data process comprises: the receipt of data, data control, the preparation of a database, a standard report and analysis, and the dissemination of data and information.

We have obtained the number of discharge letters reported to the central repository of patient data (CRPD). We have obtained information on the number of hospitalisations completed in hospitals. We will also try to obtain information on the number of times doctors have viewed discharge letters in the CRPD. This will help us to demonstrate that attending health professionals are not always apprised of the course of previous treatments.

We have obtained data on prescriptions issued, and will attempt to obtain information on the number of times prescriptions have been viewed. This will help us to demonstrate that attending health workers are not always apprised of the drugs that have been prescribed in the course of previous treatment or the drugs that the patient is currently taking.

From both aspects we will define the problems, analyse them and make a proposal for a solution, which we will also evaluate.

4.3 Scientific contribution

Medical treatment must place the patient at the centre and connect medical professionals around him. We can see treatment of a patient as a business process and individual types of medical treatment as phases and activities within this process. In process terms, we can deal with the general practitioner as the owner of the process, in conjunction with the patient and his family. Here the GP operates on the 'case manager' or 'care manager' principle. They manage the treatment process as a whole, calling on specialists in other fields for more in-depth activities.

Access to information on previous instances of medical treatment must be provided to those currently providing healthcare at any level. This can be provided by a single repository: the central electronic health record (EHR). In Slovenia this is the Central Registry of Patient Data (CRPD).

We are looking for the intersection between business processes, healthcare and digital transformation (Figure 1).

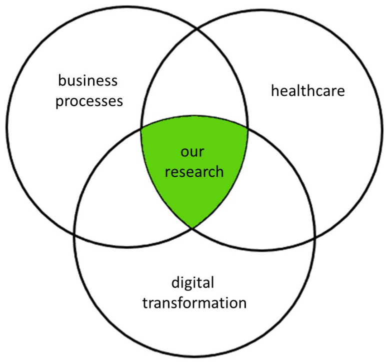

Figure 1: The intersection between business processes, healthcare and digital transformation

4.4 Objectives of the doctoral dissertation and the envisaged scientific research results

The aim of the research is to look at healthcare treatment to a patient as a business process, i.e. as the integrated lifelong treatment of healthcare to a patient. We would like to demonstrate that viewing treatment over the course of a life as a process can have a positive impact on reducing the gaps between different instances of treatment and thereby improve the medical care given to a patient.

The objectives of the doctoral dissertation are:

- To explore the literature in the field of integrated lifelong treatment of healthcare to patients – examination of the theoretical premises.
- To bring together the theoretical premises in this field.
- To determine the stakeholders in integrated lifelong patient treatment.
- To research the problems (challenges and difficulties) that arise in healthcare treatment (analysis of the problem).
- To lay the foundations for an integrated organisational model of integrated lifelong treatment of healthcare to patients.

4.5 Potential results of the study and the importance of those results

The results of the study will contribute to an in-depth understanding of the process view of integrated lifelong treatment of healthcare to patients. The findings will therefore contribute to knowledge in this field, as they will build on previous studies in this field.

The result will also contain a presentation of the conceptual organisational model of integrated lifelong treatment of healthcare to patients based on theoretical findings and practical experiences. This will enable us to describe healthcare treatment as a business process from birth to death.

In addition to activities in terms of organisation, we will also look in detail at the information systems associated with those activities. This requires us to set the following requirements:

1. Access to data on all instances of healthcare treatment is required if the work is to be successful.
2. Access to information on previous instances of medical treatment must be provided to those currently providing healthcare at any level.
3. A single repository is required – central EHR. An example of this is the Slovenian Central Registry of Patient Data.

5 Future development

In our research, we aim to show that looking at lifelong healthcare as a process has a significant positive impact on reducing the gaps between different treatments and, as a result, can improve patient care.

The implementation of such a view is beyond the scope of our research and may be a challenge in the future.

It would also be interesting to longitudinally monitor the results of the introduction of a process view of lifelong healthcare and to compare them in terms of the consequences of different treatments.

References

Amelung, V., Stein, V., Suter, E., Goodwin, N., Nolte, E., Ran, ·, & Editors, B. (2021). Handbook Integrated Care Second Edition.

Bürkle, T., Denecke, K., Lehmann, M., Zetz, E., & Holm, J. (2017). Integrated care processes designed for the future healthcare system. Studies in Health Technology and Informatics, 245, 20–24. https://doi.org/10.3233/978-1-61499-830-3-20

Davenport, T. H., & George, W. (2018). Why So Many High-Profile Digital Transformations Fail. Harvard Business Review, march 09, 2018. https://hbr.org/2018/03/why-so-many-high-profile-digital-transformations-fail

Dennis, A., Wixom, B. H., & Roth, R. M. (2014). Systems analysis and design. John Wiley & Sons. http://www.saigontech.edu.vn/faculty/huynq/SAD/Systems_Analysis_Design_UML_5th ed.pdf

Dumas, M., La Rosa, M., Mendling, J., & Reijers, H. A. (2018). Fundamentals of business process management: Second Edition. Fundamentals of Business Process Management: Second Edition, 1–527. https://doi.org/10.1007/978-3-662-56509-4/COVER

Gričar, J., & Piskar, S. (1988). Sistemski inženiring : celostna sistemska metodologija za ustvarjalno reševanje problemov (B. Lipičnik, Ed.). ZOP - Zavod za organizacijo poslovanja.

Hammer, M. (2015). What is business process management? Handbook on Business Process Management 1: Introduction, Methods, and Information Systems, 3–16. https://doi.org/10.1007/978-3-642-45100-3_1

Hammer, M., & Champy, J. (1995). Preurejanje podjetja : manifest revolucije v poslovanju. Gospodarski vestnik.

Hammer, M., & Champy, J. (2003). Reengineering the Corporation: A Manifesto for Business Revolution (Collins Business Essentials). 272. http://www.amazon.com/Reengineering-Corporation-Manifesto-Revolution-Essentials/dp/0060559535

Hevner, A. R. (2007). A Three Cycle View of Design Science Research. Scandinavian Journal of Information Systems, 19(2).

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. MIS Quarterly: Management Information Systems, 28(1), 75–105. https://doi.org/10.2307/25148625

Keen, P. G. W. (1997). The Process Edge : Creating Value Where It Counts. Harward Business School Press.

Keen, P. G. W., & Knapp, E. M. (1995). Every manager's guide to business processes : a glossary of key terms & concepts for today's business leader : a glossary of key terms & concepts for today's business leader. Harvard.

Kljajić Borštnar, M. (2021). Raziskovanje informacijskih sistemov.

Kodner, D. (2012, February 7). Integrated care models for frail older people | The King's Fund. https://www.kingsfund.org.uk/audio-video/dennis-kodner-integrated-care-models-frail-older-people

Nadarajah, A., Dimitropoulos, G., Grant, C., Webb, C., & Couturier, J. (2021). Impending Transition From Pediatric to Adult Health Services: A Qualitative Study of the Experiences of Adolescents With Eating Disorders and Their Caregivers. Frontiers in Psychiatry, 12. https://doi.org/10.3389/FPSYT.2021.624942

Proportion (%) of births attended by skilled health personnel - European Health Information Gateway. (2022). https://gateway.euro.who.int/en/indicators/hfa_598-7070-proportion-of-births-attended-by-skilled-health-personnel/

Rant, Ž. (2001). Kontinuirano učenje kot stalnica v procesni organizaciji : magistrska naloga. [Ž. Rant].

Rant, Ž. (2007). Procesi obstajajo tudi v zdravstvu = Processes exist also in health care. In V. Rajkovič (Ed.), Ustvarjalna organizacija (p. Str. 1592-1599). Moderna organizacija.

Rant, Ž. (2010). Prenova procesa obdelave podatkov : študija primera. Organizacija, 43(6), str. A246-A254.

http://organizacija.fov.uni-mb.si/index.php/organizacija-si/article/viewFile/1218/988

Raskino, M., & Waller, G. (2015). Digital to the Core: Remastering Leadership for Your Industry, Your Enterprise, and Yourself. Bibliomotion, Inc.

Robyn Blackadar, & Mishaela Houle. (2009). The Alberta Cardiac Access Collaborative: Improving the Cardiac Patient Journey. Healthcare Quarterly, 13(Sp), 85–90. https://www.longwoods.com/product/21104

Sajja, P. S. (2017). Essence of Systems Analysis and Design: A Workbook Approach. Springer Verlag, Singapore.

Stevens, G., Hantson, L., Larmuseau, M., & Verdonck, P. (2022). A human-centered, health data-driven ecosystem. Discover Health Systems 2022 1:1, 1(1), 1–12. https://doi.org/10.1007/S44250-022-00011-9

Stocker, A., Rosenthal, L., Mesquida, L., Raynaud, J. P., & Revet, A. (2022). Adult and child and adolescent psychiatrists' experiences of transition in anorexia nervosa: a qualitative study. Journal of Eating Disorders, 10(1). https://doi.org/10.1186/S40337-022-00610-0

Urh, B., Kern, T., & Krhač Andrašec, E. (2022). Model ocenjevanja učinkov organizacijskih sprememb. 1011–1025. https://doi.org/10.18690/UM.FOV.3.2022.73

Valacich, J. S., George, J. F., Columbus, B., New, I., San, Y., Cape, F. A., Dubai, T., Madrid, L., Munich, M., Montréal, P., Delhi, T., São, M. C., Sydney, P., Kong, H., Singapore, S., & Tokyo, T. (2017). Modern Systems Analysis and Design 8th Edition. www.pearsoned.com/permissions/.

Van Veldhoven, Z., & Vanthienen, J. (2022). Digital transformation as an interaction-driven perspective between business, society, and technology. Electronic Markets, 32(2), 629–644. https://doi.org/10.1007/s12525-021-00464-5

Wade, T. D. (2022). A systematic review: Solutions to problems caused by age transition between eating disorder services. European Eating Disorders Review. https://doi.org/10.1002/ERV.2945

WHO global strategy on people-centred and integrated health services Interim Report. (2015). www.who.int

Yang, Y. F., Hoo, J. X., Tan, J. Y., & Lim, L. L. (2022). Multicomponent integrated care for patients with chronic heart failure: systematic review and meta-analysis. ESC Heart Failure. https://doi.org/10.1002/EHF2.14207

Yin, R. K. (2018). Case Study Research and applications, 6th edition. Paper Knowledge . Toward a Media History of Documents, 414.

Žerovnik, Š., Locatelli, I., & Kos, M. (2018). Brezšivna skrb pri zdravljenju z zdravili v Sloveniji. Farmacevtski vestnik, 69(3).

DOCTORAL CONSORTIUM

UNDERSTANDING PSYCHOLOGICAL CONTRACTS IN THE CONTEXT OF ORGANIZATIONAL CHANGE PROCESSES RELATED TO DIGITAL GOVERNMENT TRANSFORMATION

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Digital transformation has revolutionized public sector organizations, bringing both opportunities and challenges. This research proposal suggests an exploration of the impact of Digital transformation on public sector employees' psychological contracts and the challenges faced by civil servants in response to this change. The study proposes a study consisting of four parts. The research methodology combines qualitative and quantitative approaches to capture the dynamic nature of psychological contracts and psychological contract breach in the public sector. The research aims to explore the distinct characteristics of civil servants' dynamic psychological contracts in the context of digital government transformation and how they experience psychological contract breaches during continuous organizational change processes. The study highlights the need for understanding employees' tactics to manage psychological contract breaches and improve sustainable employability during digital transformation related change. The implications of the study will contribute to the effective implementation of digital transformation in the public sector and enhances our understanding of employee perspectives on managing psychological contracts.

Keywords: psychological contracts, digital transformation, organizational change, public sector, Bled eConference

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1 Introduction

The rapid pace of technological, economic, and social developments in the last decade has resulted in a digital transformation (DT) affecting activities and processes in the Dutch economy and society (EZK, 2021 p.6; Digitale Overheid, 2021). Digital technologies have become vital (Keijzer, 2021), not only for our society (Digitale Overheid, 2021), but also for the development and the execution of governmental processes and services (FreedomLab, 2021). For the Dutch Government, the ambition is to embrace innovations as set out in their plan: "Towards a safe, people-oriented, transparent, effective digital future", (Digitale Overheid, 2021).

While digitization offers opportunities to make public administration more effective, efficient, transparent and fair, it also increases the risk of rigid enforcement, with an excessive focus on measurable and controllable matters (Freedomlab, 2021), as seen for example in the challenges the Dutch Tax Authorities faces. Examples of other challenges faced during digitalization are the air traffic control project (iCAS), the complexity of the Environmental Act software, and the new communication system C2000 of the Dutch police departments.

More generally, the constantly evolving public sector and its employees are facing many new challenges in response to digitization (Groeneveld, Kuipers & Van der Voet, 2022; Van der Wal, 2017a; 2017b). Traditionally, public values such as legality, equal treatment, and efficiency have been critical within public administration, with processes and formal hierarchy determining accountability and political legitimacy. However, with the accelerated change caused by digital transformation, values such as responsiveness, resilience, and innovation are becoming increasingly important in response to the VUCA environment (Groeneveld et al., 2022).

Nowadays, civil servants are expected to balance the contradicting bureaucratic values and innovation values, (Figure 1), placing them in a difficult and ambiguous position especially since political and societal tolerance for error and experimentation with taxpayers' money is minimal (Van der Wal, 2017a).

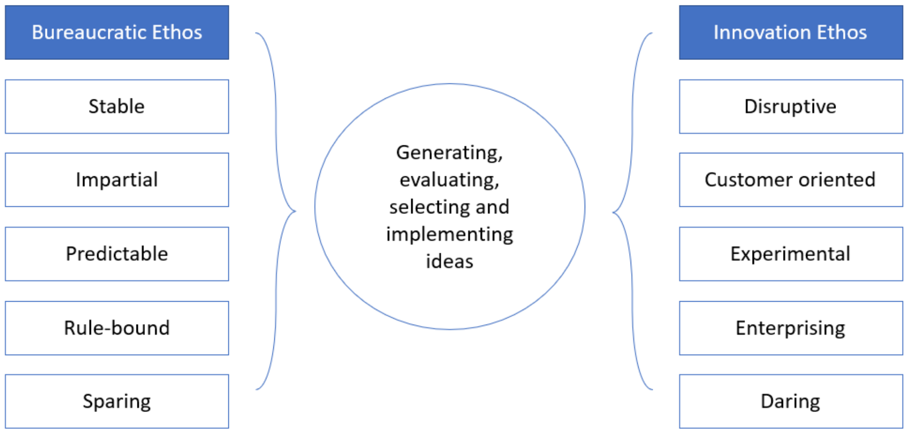

Figure 1: Position of civil servants, source: Van der Wal (2017a)

Since most public sector employees are intrinsically motivated to work for the government (BKZ, OCW & CBS, 2022), the conflicting values caused by DT (FreedomsLab 2021) deeply affect civil servants and their psychological contracts (PCs). Although the importance of an individual's ability to adapt to (the digital) changes is underscored, (BKZ, OCW & CBS, 2022) there is a need to understand how to align the motivation of people working in the public sector with these changes associated with DT and how to manage the impact. It is this need that has triggered this research.

This research aims to contribute to the academic and societal debate on PCs in the context of change by exploring the distinct characteristics of civil servants' dynamic PCs in the context of digital transformation in public sector organizations. More specifically, the focus is on how civil servants' experience PC breaches during continuous organizational change processes related to digital transformation and what repair tactics are used to prevent and repair PC breaches. Subsequently, the practical goal is to research concrete managerial and employees' tactics to prevent and repair PC breaches in public sector organizations adopting new ways of working supported by digital technology. This can improve sustainable employability and enhance work engagement and performance.

We thus postulate the following research question:

How do organizational change processes caused by digital government transformation impact psychological contracts of employees?

To answer this question the following sub-research questions are formulated:

SRQ1: What is known in existing literature from an employee's perspective on characteristics of the public sector, digital transformation, and psychological contracts?

SRQ2: How do civil servants perceive the dynamics in their psychological contract in the context of digital transformation?

SRQ3: To what extent does digital transformation influence the psychological contracts of civil servants?

SRQ4: What tactics can public sector employees employ to manage psychological contracts breaches during digital transformation?

The structure of this research proposal is as follows: In section 2 the proposed methodology is described. In section 3, the theoretical background of the research is presented. The 4th section provides a description of the aimed results.

2 Methodology

This chapter outlines the methodology proposed to investigate the impact of digital transformation on psychological contracts of public sector employees.

Several authors have suggested that a combination of qualitative and quantitative research is required to capture how PC and PC breach develop in dynamic environments (Achnak & Hansen, 2019; Weinhardt et al., 2019 ; Wiechers et al., 2022). Therefore, this proposed research begins with a systematic literature review (study 1) to further explore the existing research, followed by a qualitative multiple-case study (study 2) and a quantitative daily diary study (study 3). The research is concluded by a design study focused on repair tactics of public employees (study 4), with the aim to support public managers in managing the dynamic PCs of civil servants in the context of DT. Figure 2 visualizes the research questions and research designs.

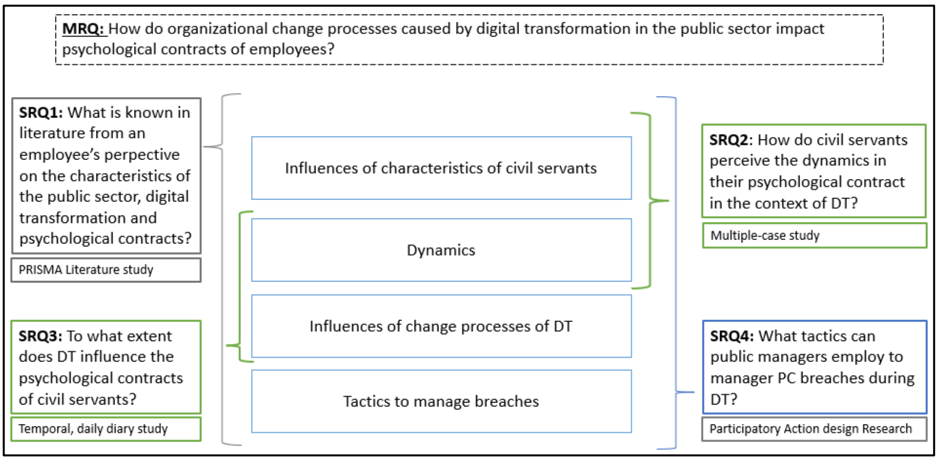

Figure 2: Research design

Study 1

The first study is a systematic literature study that utilizes the PRISMA-approach (Page et al., 2020), resulting in a transparent research process visual in a flowchart of the research process as well as a literature synthesis as results. Inclusion criteria for the review will be based on relevance to the research question, date of publication and quality of the research (Page et al., 2020). Aim is to create an assessable overview of existing literature from an employee's perspective on characteristics of the public sector, digital transformation, and psychological contracts.

Study 2

In a qualitative research design, the understanding of experiences requires open or semi-structured interviews with room to elaborate on concepts (Verhoeven, 2014). Study 2 adopts a qualitative design and comprises of in-depth, semi-structured interviews with the purpose of gaining a deeper understanding of how civil servants experience their PC dynamics in the context of DT (SRQ2).

To capture the dynamic narrative of PC breaches and responding employees' actions, the so-called Critical Incident Technique will be applied. In this approach, the interview starts with a specific incident, which forms the starting point for the reconstruction of a chronological and meaningful narrative over time for the respondent (Langley & Meziani, 2020). This technique is well suited to capturing recollections of vivid PC breaches and the responses to these by both parties to the employment contract (Conway & Briner, 2005).

Through collaboration with the iPoort and iPartnership networks as well as via part-time students of Master of Informatics, suitable case studies (i.e. finished projects) will be selected from the government's digital transformation programs. Organizations and participants will be selected through a purposive sampling (Yin, 2017). The focus will be on public organizations of different sizes with civil servants closely situated to civilians.

Study 3

The third study is a deductive quantitative study (Verhoeven, 2014) and aims to measure relationships between the key factors of DT and the PCs of civil servants in answering SRQ3. A temporal daily diary study will be conducted as it has the capability to study processes over time, asses day-to-day experiences and enable repeated measurements. This design increases the validity and reliability of the study's outcomes and captures the dynamic nature of PCs. Additionally, its benefit over a cross-sectional questionnaire method is the possibility of examining immediate affective responses, limiting the risks of poor recall of events (Conway & Briner, 2005). To capture the nested within-person processes, the study will be set up in two different public sector organizations undergoing a technology implementation process as part of a larger digitalization program. This provides the researchers the possibility to integrate a prospective view as a factor influencing the sense-making process after the PC breaches experienced by respondents.

The daily survey is administered online and uses push messages to initiate response. Including daily mood ratings, validated measures of PC, organizational change, and digital transformation, as well as demographic questions. The data will be analyzed using multi-level mediation modelling, with the key variables examined within-person for their impact on employee's PCs over the process of the technology implementation.

Study 4

To answer SRQ4 a Participatory Action Design Research (PADR) is performed with a focus on possible tactics of public employees facing and recovering from PC breach in the context of DT. PADR is an especially relevant research design when the research is conducted based on local needs of multiple public organizations (Venable et al., 2017). This study builds on the outcomes of all previous studies, and uses participative activities that are distinct in the PADR methodology, which allow to validate previous studies and lead to actionable organizational interventions.

3 Theoretical Background

Preliminary research has been conducted in writing this research proposal. These results are described in this chapter.

DT has a significant impact on society and is an important cause of today's VUCA-environment. According to Van der Wal (2017b), this is especially true in public sector organizations, making the work of a 21st century public sector employee more challenging. Specifically, digital technologies profoundly reshape working arrangements in the public sector, and digitization may trigger a depersonalization of workplaces, impacting the social organizational climate (Dunleavy et al., 2005; Palumbo, 2021). Digital transformation requires a rethinking of employees' skills, responsibilities, and competencies, as well as the overall structure of organizations and working values, culture in government (Tangi et al., 2021; Vial, 2019). Despite these challenges, research on digital transformation in the public sector, also known as 'digital government transformation', is still scarce, particularly from an employee perspective (Mergel et al., 2019; Tangi et al., 2021).

An important perspective when studying organizational changes from an employee perspective is that of the psychological contract (PC) (Rousseau et al., 2018; Wiechers et al., 2022). One of the key concepts in the PC is reciprocity, which refers to the principle that if one party fulfills their (implicit) obligations, the other party will respond in kind. This is in accordance with Adam's (1965) need for equity theory in public administration (literature on the public sector). Psychological contract theory is based on Social Exchange Theory, which postulates that employees and employers engage in exchanges whereby each party to the exchange reciprocates the other's contribution (Blau, 1964). Rousseau (1995) argued that perceived employer obligations motivate to engage in positive attitudes and work behaviors as expected reciprocity in the exchange relationship causes employees to attempt to restore balance if an imbalance is perceived. This reciprocity can operate at three levels of the exchange, at the same time:

- Transactional contracts involve highly specific exchanges of narrow scope which take place over finite periods (e.g., provide labour for pay);
- Relational contracts are broader, more amorphous, open-ended, and more subjectively understood by parties (e.g, extra work effort in exchange for promotion opportunities);
- Ideological contracts, defined as an espousal to a cause, whereby employee contributions are dependent on the belief that their organization serves a higher purpose (e.g.., public sector organizations serving the public) (Blau, 1964; Rousseau, 1995).

Guest (2004) found that organizational change is a predictor of PC breach, something Conway, Kiefer, Hartley and Briner (2014) confirmed for public organizations. A breach indicates a change of the mutual obligations, which affects the employee's attitudes (Rousseau, 1995), and may be reciprocated by employees through disengagement (Zhao et al., 2007), reduced work effort, or even leaving the company (Bal et al., 2008; Conway & Briner, 2002). After a perceived breach there is a period of 'sense-making' in which the employee goes through a rationalization process, after which the employee can experience the negative feelings of a PC violation. Given that DT is a source of continuous, and often less predictable, change process (Vial, 2019), it can be argued that DT affects PC over time and may lead to breaches on a weekly or even daily interval (Griep & Van Tilborgh, 2018; Wiechers et al, 2022). Subsequently, this can lead to the above-mentioned employee attitudes which can result in unsuccessful implementation of digitalization. However, it is yet unclear how the dynamic nature of the PC and the sense-making process of an employee is affected by a continuous change.

After a perceived PC breach, the importance of timely and adequate feedback of the organization for the PC's recovery is essential (Rousseau et al., 2018; Van der Schaft et al., 2020). However, it is noteworthy that there is a lack of understanding about managerial tactics in this regard (De Ruiter et al., 2016). To enable adequate response, it is necessary to expand our understanding of appropriate tactics (behaviours) of public employees after a perceived breach.

The consideration of public sector context is essential to understanding employee behavior (Coyle-Shapiro & Kessler 2003). It is therefore, necessary to take the characteristics of the public sector into account when studying PC dynamics, as the public sector differs fundamentally from the private sector (Meijer et al., 2022; Pandey & Wright, 2006). Even though the destabilizing impact of organizational change on employment relationships have been studied in both private and public sectors (Conway et al., 2014), literature on PC in the public sector is showing a considerable knowledge gap. Perry and Wise (1990) provide some insights as they found that even after a breach of perceived obligations, employees with a strong commitment to the public sector choose to remain engaged, because not to do so would be conflicting with their personal values. Moreover, Bunderson (2001) indicated that ideologies can shape PC and influence subsequent reactions to breach. This incorporation of ideology into the PC helps to explain why some employees may remain loyal to an organization after breaches in the transactional and ideological levels of the PC (Thompson & Bunderson, 2003). While public sector motivation (Perry & Wise, 1990) is commonly known in public administration, the notion of this motivation in the public sector is overlooked in the PC literature.

4 Expected results

This research aims to contribute to both practical and scientific fields. The expected results are outlined in this chapter.

The field of DT is currently emerging, while that of PCs is a well-established academic field. However, there is limited research on the combination of PC and DT, particularly with respect to the public sector. This study aims to address PC in the public sector as the consideration of context is essential to the understanding of employees' attitude and behaviors. Furthermore, it provides insight into contextual considerations in understanding how employees manage PCs.

Moreover, the phenomenon of DT in relation to organizational change is distinct from past IT-related organizational changes and cannot be fully explained using existing theoretical models (Markus & Rowe, 2018). To leverage and extend current knowledge, it is necessary to evaluate the compatibility between DT and established theoretical models in the field of organizational change (Hanelt et al., 2021). In response to the current VUCA environment with DT as driver for organizational changes, the need arises to understand the PC theory in the context of DT. This context of continuous change will enhance our understanding of the management of dynamics of PC, for which scientific attention has been growing (Rousseau et al., 2018; Griep & Cooper, 2019). Additionally, the context of continuous change poses the possibility to take the effect of prospectively expecting more PC breaches into account as a variable in employees' sense-making process, this will be innovative as this is an academic field that traditionally has been researched retrospective.

Dunleavy et al. (2005) emphasize the importance of effectively guiding technology-centered changes in government. Different managerial skills are needed to govern change related to DT, as it often involves disruption of the status quo (Tangi et al., 2021). Even though DT could predict PC breaches, there is still a noteworthy lack of understanding of managerial actions suitable in managing breaches in PC (De Ruiter, 2017). This research addresses the knowledge gap on tactics used by employees (Henderson et al., 2020; Rousseau et al., 2018) by developing an artifact that takes the complexity of DT, the dynamics of PC and characteristics of the public sector into account.

the practical contributions we aim to achieve are:

1. Improving the sustainable employability of civil servants by reducing the occurrence and impact of PC breaches;
2. developing managerial tactics tailored to the unique challenges of digital technology implementation;
3. Improving our understanding, from an employee perspective, how DT projects can be better organized to prevent unwanted outcomes as mentioned above.

Ultimately, this research will enhance our understanding of how public sector organizations and employees can manage PCs during times of change related to DT.

References

Achnak, S., & Hansen, S. D. (2019). 12. The role of time and timing in psychological contract research. In: Griep, Y & Cooper, C. (Eds.) *Handbook of research on the psychological contract at work*, *(pp. 243-252),* Edward Elgar Publishing.http://doi.org/10.4337/9781788115681

Adams, J. S. (1965). Inequity In Social Exchange. Advances in Experimental Social Psychology, 267–299. https://doi.org/10.1016/s0065-2601(08)60108-2

Bal, P. M., De Lange, A. H., Jansen, P., & Van Der Velde, M. E. G. (2008). Psychological contract breach and job attitudes: A meta-analysis of age as a moderator. Journal of Vocational Behavior, 72(1), 143–158. https://doi.org/10.1016/j.jvb.2007.10.005

Blau, P. (1964). Exhange and Power in Social Life. Wiley.

Bunderson, J. S. (2001). How work ideologies shape the psychological contracts of professional employees: doctors' responses to perceived breach. Journal of Organizational Behavior, 22(7), 717–741. https://doi.org/10.1002/job.112

Conway, N., & Briner, R. B. (2002). A daily diary study of affective responses to psychological contract breach and exceeded promises. Journal of Organizational Behavior, 23(3), 287–302. https://doi.org/10.1002/job.139

Conway, N., & Briner, R. B. (2005). Understanding Psychological Contracts at Work:A Critical Evaluation of Theory and Research: A Critical Evaluation of Theory and Research. OUP Oxford.

Conway, N., Kiefer, T., Hartley, J., & Briner, R. B. (2014). Doing More with Less? Employee Reactions to Psychological Contract Breach via Target Similarity or Spillover during Public Sector Organizational Change. British Journal of Management, 25(4), 737–754. https://doi.org/10.1111/1467-8551.12041

Coyle-Shapiro, J. (2003). The Employment Relationship in the U.K. Public Sector: A Psychological Contract Perspective. Journal of Public Administration Research and Theory, 13(2), 213–230. https://doi.org/10.1093/jopart/mug018

De Ruiter, M., Schalk, R., & Blomme, R. J. (2016). Manager Responses to Employee Dissent About Psychological Contract Breach. Management Communication Quarterly, 30(2), 188–217. https://doi.org/10.1177/0893318915623238

De Ruiter, M. (2017). Beyond repair? The role of supervisory leadership in the context of psychological contract Breach. Gildeprint

Digitale Overheid. (2021). I-strategie Rijk 2021-2025: doorpakken op digitale transformatie. In digitaleoverheid.nl. https://www.digitaleoverheid.nl/document/i-strategie-rijk-2021-2025/

Dunleavy, P., Margetts, H., Bastow, S., & Tinkler, J. (2005). New public management Is dead--long live Digital-Era Governance. Journal of Public Administration Research and Theory, 16(3), 467–494. https://doi.org/10.1093/jopart/mui057

FreedomLab. (2021). Toekomstverkenning Digitalisering 2030. In Rijksoverheid. https://open.overheid.nl/documenten/ronl-6381adb2-3806-4f21-8ffd-613784a3ecdd/pdf

Henderson, K. E., Welsh, E. T., & O'Leary-Kelly, A. M. (2020). "Oops, I Did It" or "It Wasn't Me:" An Examination of Psychological Contract Breach Repair Tactics. Journal of Business and Psychology, 35(3), 347–362. https://doi.org/10.1007/s10869-019-09624-z

Griep, Y., & Cooper, C. (Eds.) (2019). Handbook of Research on the Psychological Contract at Work. Edward Elgar Publishing.

Griep, Y., & Vantilborgh, T. (2018). Let's get cynical about this! Recursive relationships between psychological contract breach and counterproductive work behaviour. Journal of Occupational and Organizational Psychology, 91(2), 421–429. https://doi.org/10.1111/joop.12201

Groeneveld, S., Kuipers, B., & Van der Voet, J. (2022). Anders kijken naar publiek leiderschap: Naar een duurzame bijdrage aan het oplossen van maatschappelijke problemen: Essay in opdracht van Bureau Algemene Bestuursdienst in het kader van traject Visie op Leiderschap. In Algemene Bestuursdienst. Leiden Leadership Centre (Universiteit Leiden). https://www.algemenebestuursdienst.nl/organisatie/documenten/publicatie/2022/01/27/anders-kijken-naar-publiek-leiderschap

Guest, D. (2004). Flexible employment contracts, the psychological contract and employee outcomes: an analysis and review of the evidence. International Journal of Management Reviews, 5–6(1), 1–19. https://doi.org/10.1111/j.1460-8545.2004.00094.x

Hanelt, A., Bohnsack, R., Marz, D., & Marante, C. (2021). A Systematic Review of the Literature on Digital Transformation: Insights and Implications for Strategy and Organizational Change. Journal of Management Studies, 58(5), 1159–1197. https://doi.org/10.1111/joms.12639

Keijzer, M. C. G. (2021). Aanbiedingsbrief bij update Nederlandse Digitaliseringsstrategie 2021. In Rijksoverheid (Nr. 00000001003214369000). Geraadpleegd op 10 maart 2023, van https://open.overheid.nl/documenten/ronl-bb8a0829-c6ab-4781-8088-4fe8f2eda0c7/pdf

Langley, A., & Meziani, N. (2020). Making interviews meaningful. The Journal of Applied Behavioral Science, 56(3), 370-391

Markus, M. L., & Rowe, F. (2018). Is IT Changing the World? Conceptions of Causality for Information Systems Theorizing. Management Information Systems Quarterly, 42(4), 1255–1280. https://doi.org/10.25300/misq/2018/12903

Meijer, A., Ingrams, A., & Zouridis, S. (2022). Public Management in an Information Age: Towards Strategic Public Information Management. Bloomsbury Publishing.

Mergel, I., Edelmann, N., & Haug, N. (2019). Defining digital transformation: Results from expert interviews. Government Information Quarterly, 36(4), 101385. https://doi.org/10.1016/j.giq.2019.06.002

Ministerie van Binnenlandse Zaken en Koninkrijksrelaties [BKZ], Ministerie van Onderwijs, Cultuur en Wetenschap [OCW], & Centraal Bureau voor de Statistiek [CBS]. (2022). Kernrapport Werkonderzoek 2022: Uitkomsten van het Werkonderzoek 2022. In Rijksoverheid. Venster voor Medewerkers (ICTU). https://www.rijksoverheid.nl/documenten/publicaties/2022/11/22/kernrapport-werkonderzoek-2022-beschikbaar-inzicht-in-werkaantrekkelijkheid-bij-de-overheid

Ministerie van Economische Zaken en Klimaat [EZK]. (2021). [Kamerstuk] Nederlandse Digitaliseringsstrategie 2021. In Rijksoverheid. Geraadpleegd op 2 maart 2023, van https://www.rijksoverheid.nl/documenten/kamerstukken/2021/04/26/ nederlandse-digitaliseringsstrategie-2021

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T., Mulrow, C. D., Shamseer, L., Tetzlaff, J., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E., Mayo-Wilson, E., McDonald, S., Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ, n71. https://doi.org/10.1136/bmj.n71

Palumbo, R. (2021). Does digitizing involve desensitizing? Strategic insights into the side effects of workplace digitization. Public Management Review, 24(7), 975–1000. https://doi.org/10.1080/14719037.2021.1877796

Pandey, S., & Wright, B. E. (2006). Connecting the Dots in Public Management: Political Environment, Organizational Goal Ambiguity, and the Public Manager's Role Ambiguity. Journal of Public Administration Research and Theory, 16(4), 511–532. https://doi.org/10.1093/jopart/muj006

Perry, J. L., & Wise, L. R. (1990). The Motivational Bases of Public Service. Public Administration Review, 50(3), 367. https://doi.org/10.2307/976618

Punch, K. F. (2016). Developing Effective Research Proposals. Sage.

Rousseau, D. (1995). Psychological contracts in organizations: Understanding written and unwritten agreements. Sage.

Rousseau, D. M., Hansen, S. E., & Tomprou, M. (2018). A dynamic phase model of psychological contract processes. Journal of Organizational Behavior, 39(9), 1081–1098. https://doi.org/10.1002/job.2284

Tangi, L., Janssen, M., Benedetti, M., & Noci, G. (2021). Digital government transformation: A structural equation modelling analysis of driving and impeding factors. International Journal of Information Management, 60, 102356. https://doi.org/10.1016/j.ijinfomgt.2021.102356

Thompson, J. A., & Bunderson, J. S. (2003). Violations of Principle: Ideological Currency in the Psychological Contract. Academy of Management Review, 28(4), 571–586. https://doi.org/10.5465/amr.2003.10899381

Van der Wal, Z. (2017a). De 21e-eeuwse overheidsmanager: Een reis door tijd, plaats en context. In Caop. CAOP. https://www.caop.nl/app/uploads/2019/05/OenA-2017-44-De_21e-eeuwse_overheidsmanager.pdf

Venable, J. R., Pries-Heje, J., & Baskerville, R. L. (2017). Choosing a Design Science Research Methodology. The 28th Australasian Conference on Information Systems.

Verhoeven, P. S. (2014). Wat is onderzoek?: praktijkboek methoden en technieken voor het hoger onderwijs.

Van der Wal, Z. (2017b). The 21st Century Public Manager. Bloomsbury Publishing.

Van Straalen, M. (2021). Verkenningsrapport HEO met regie naar verantwoordelijkheid. Vereniging Hogescholen. https://www.vereniginghogescholen.nl/system/knowledge_base/attachments/files/000/001/244/original/Verkenningsrapport_HEO_met_regie_naar_verantwoordelijkheid_-_VH_-_september_2021_-_def.pdf?1636551020

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. Journal of Strategic Information Systems, 28(2), 118–144. https://doi.org/10.1016/j.jsis.2019.01.003

Weinhardt, J., Griep, Y., & Sosnowska, J. (2019). Toward a formal dynamic and computational modeling approach to better understand psychological contract dynamics. In: Griep, Y & Cooper, C. (Eds.) Handbook of Research on the Psychological Contract at Work (pp. 292-315),

Edward Elgar Publishing. http://doi.org/10.4337/9781788115681

Wiechers, H., Coyle-Shapiro, J. A., Lub, X., & Have, S. T. (2022). The tremors of interconnected triggers over time: How psychological contract breach can erupt. Journal of Organizational Behavior, 43(7), 1172–1189. https://doi.org/10.1002/job.2645

Yin, R. K. (2017). Case Study Research and Applications: Design and Methods. SAGE Publications, Incorporated.

Zhao, H., Wayne, S. J., Glibkowski, B. C., & Bravo, J. (2007). The impact of psychological contract breach on work-related outcomes: A meta-analysis. Personnel Psychology, 60(3), 647–680. https://doi.org/10.1111/j.1744-6570.2007.00087.x

DOCTORAL CONSORTIUM

PRESENTATION OF THE DISPOSITION DRAFT

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The Covid19 crisis situation heralded long-term changes in the way health services are provided and accessed. The standards on which these services are based, or should be based, play an important role in ensuring their quality. Telehealth should be regarded as the people centred holistic service not merely as a technological solution. In the thesis I will illuminate how the methods, the procedures and the protocols which form the service of telehealth, are just as important as the technological solution or infrastructure itself. For such understanding, standards of telehealth need to be considered throughout the service development and implementation. In the process the highest service quality can be achieved if we leverage the support of properly developed assessment tools, based on specific standards. This paper will present the disposition draft of the thesis that will propose a model for evaluating services in every phase of their evolution and implementation.

Keywords:
telehealth,
assessment,
standards,
DEXI
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eConference

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1 Introduction

Problem definition

Standards of telehealth (TH) **services** are not yet set in national, EU and international strategies (WHO)[1]. Further on, the stages of implementation, if any, should be investigated and researched. Analysis and anticipated steps toward comprehensive solutions should be proposed.

Standards and accreditation processes are a well known and broadly used quality assurance in all fields of development, production and services. Yet due to the novelty of telehealth and related areas or sub-areas, the standards as well as accreditation programs are being developed alongside the increased need and sporadic implementation of services in daily professional and general population activities.

The still current COVID-19 pandemic and its effects have significantly increased interest in innovative health solutions, specifically also in the field of telehealth services.

Key points of the problem (I want to address in my thesis)

In the flood of information and new solutions, potential customers, suppliers and end users are wondering which of telehealth services are useful, necessary and tested. What is the level of their quality and suitability to a specific need?

Older adults, patients and chronic patients are (potential) major users of telehealth services. Many are particularly vulnerable users, as they can need a greater degree of trust and guidance in choosing and deciding on a particular service. The issues are especially relevant at this time as we tackle the ongoing issues of the pandemic - as part of which telehealth services are being increasingly considered. The crisis situation thus heralded long-term changes in the way health services are provided at

[1] WHO Global strategy on digital health 2020-2025 reference on standards The strategic objective promotes standards for safety, security, privacy, interoperability, and the ethical use of data within and outside the health sector….interoperability standards…requirements for digital health in the design of norms and standards products…global minimum standards for electronic patient health records. etc.; https://www.who.int/docs/default-source/documents/gs4dhdaa2a9f352b0445bafbc79ca799dce4d.pdf

or accessed from a distance, namely through telehealth. The standards on which these services are based, or should be based, play an important role in ensuring their quality.

There are only a few international and independent standards of services in this area. So, on one side standardisation institutions and user associations call on stakeholders to co-operate and co-create in the research and development.

On the other side, developers and users of telehealth services often do not have a clear understanding of the necessity of standards to ensure service quality. Furthermore, the meaning of the term 'telehealth service' itself can carry different orientations or emphases.

The knowledge, on the side of the developers, of the complementary perspectives of the technological and service part of the solutions should be understood in order for the final product to be relevant, appropriate and to truly benefit the end user in a long-term sense.

Telehealth should be regarded as a service or resource mediated by technology that people use to access or provide health and wellness-related services, regardless of their location. Of course the technological infrastructure and service compositions will be discussed in the thesis but the importance of **understanding the service as a whole**, will be explained in the context of the need for standardisation and accreditation.

Furthermore, for telehealth service to be successful, it needs to gain the trust of physicians; health and social care and support providers; as well as formal and informal carers. Only then will telehealth solutions truly serve a purpose that relates to the overall health of a person.

In the thesis I will illuminate how the methods, the procedures and the protocols which form the service of telehealth, are just as important as the technological solution or infrastructure itself. "Non-optimal" solutions are usually more likely to be related to acceptability, training, availability and, consequently, usability, than to the technological component itself or the possible "complexity" of the technical part.

Technological solutions, which are only a part of the service of telehealth, are thus considered as likely to be successfully implemented only when certain service standards are achieved. The development and **implementation** of such standards as part of digital health strategies are still in their infancy.

In the near future, more attention and focus will be needed to establish operational procedures that can ensure appropriate quality standards for both the technological part and the services themselves. Only in this way will the developers and service providers be able to respond appropriately to the increase and changes in needs, demand and user choices.

It is recognised that many telehealth services, especially those that relate to tele- and video-consultation with health staff are now being developed in an emergency. However, the standards within which services operate remain a matter of common interest, possibly heightened in importance for all the stakeholders involved.

Telehealth is now no longer just an alternative form of health(care), so the development of standards, certifications and regulations must also be included in national priorities. This will ensure not only technological quality, but equally important quality of service.

Following the necessity for standardisation is also the issue of accreditation. More and more medical service providers want to develop their expertise through the accreditation process or gain approval of the quality for their services.

1.1 Structure of the disposition of the doctoral dissertation

1. Problem definition

- 1.1. Significant research in the field of Telehealth Standardization and Accreditation Programs - International State of the art research and praxis
- 1.2. Research and praxis in Slovenia

2. Objectives of doctoral dissertation

- 2.1. Expected original contribution to science

3. Assumptions and potential limitations

4. Intended research methods

5. Intended chapters and subchapters

6. Basic literature

7. Analysis of the originality of the topic

7.1. Justification of the originality of the topic

7.2.1. Inquiries on Science citation Index SCI (WoS)

7.2.2. EBSCO (eBook Collection (EBSCOhost)

7.2.3. EBSCOhost, Academic Search Complete (ERIC)

7.2.4. ProQuest (Interdisciplinary - Doctoral dissertations only)

8. Proposal of a potential mentor

9. Proposal for the scientific discipline of the competent department

10. Professional biography of the candidate

11. Biography of the candidate

11.1. 1.01 Original science article

11.2. 1.08 Published scientific conference paper

11.3. 1.12 Published scientific paper abstract at the conference

11.4. 2.01 Scientific monography

11.5. 2.12 Final report on research results

11.6. 2.14 Project documentation (design concept project, implementation project)

APPENDIX 1

Criteria for the quality of Telehealth services

1.2 Significant research in the field of Telehealth Standardization and Accreditation Programs

1.2.1 International State of the art research and praxis

As a part of the thesis research I found that the subject is so novel and even undefined to that level that under the same term there are different services in praxis.

I decided to start organising the terms so that the demarcation and definition of terms might further serve the standardisation of processes and also contribute to the rise of the quality of services. For that purpose I prepared a paper for the FOV Portorož Conference that was held in March 2023 titled *Demarcation and usage of the terms Telehealth, eHealth, Telemedicine and Digital health*. I decided to examine the worldwide occurrence of each phrase using the Scopus database in pursuit to add to the definition of the concepts of these services. Other similar terms or sub-terms will be a subject of further studies. A total of 95,884 documents contained one of the four terms in the title, abstract or keyword. Telemedicine was the most common term, with 64,149 documents referring to it, followed by e-health by 23,754 and then telehealth with 22,387 and Digital health with 8,599 documents. Articles were the most common type for the four key terms, followed by review articles and conference papers .

Table 1: Number of documents with telehealth, e-health, telemedicine and digital health and their combinations in title, abstract and keyword for the period 1964 – 2022

	Title	Abstract	Keyword	Title or Abstract or Keyword
Telehealth	6,048	10,065	17,769	22,387
eHealth	7,310	13,724	15,476	23,754
Telemedicine	12,883	21,735	57,278	64,149
Digital health	2,509	4,619	4,553	8,599
Telehealth or eHealth or Telemedicine or Digital health	28,771	46,696	78,657	95,884

source: Scopus

In Table 1 we can see the number of documents referring to each term and their combinations in title, abstract and keyword. The majority of these articles (95%) were in English, (see Table 2) and 10 articles were also written in Slovenian language.

In the search all journal categories, all languages and dates of the publication to the exception of the year 2023 for accurate statistics were included.

Table 2: The top three languages of the articles retrieved using the four search terms telehealth, e-health telemedicine and digital health in the title, abstract or keyword

	no.	%
English	91,601	95
German	1,592	1,6
French	985	1,02

source: Scopus

The distribution over time, by document type and by country was provided by Scopus functionalities.

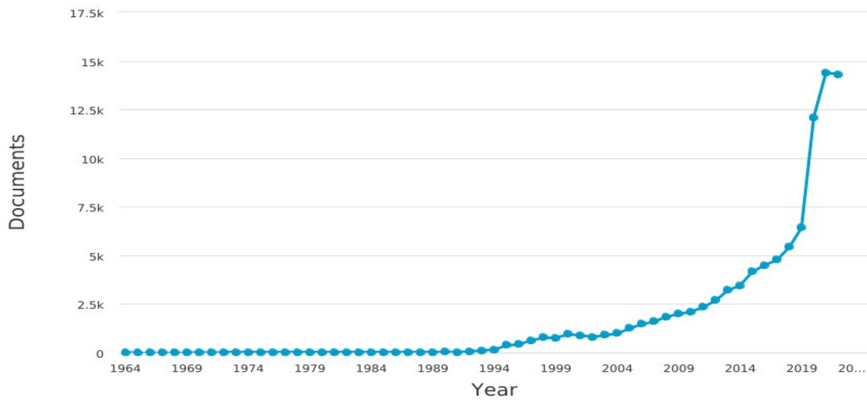

Figure 1: Number of documents per year total

The findings of the research exposed that the terms telehealth, e-health, telemedicine and digital health are frequently used reciprocally or interchangeably. I noted that the diversity in the use of the four concepts indicates the vagueness of the concepts and the need for a more precise definition of services and the establishment of certain definitions.

The conclusion regarding various usage of terms in the literature was that Telehealth, e-health, telemedicine, and digital health are concepts that have emerged due to advancements in technology in the last two decades and are still being defined.

Different levels of acceptance and use of the four terms points to the ambiguity in definition and in understanding specifics of each concept and the concrete service that is behind that particular concept. Telemedicine being the earliest and most popular term is followed by the term telehealth and e-health, based on the number of publications in the Scopus database. Least used also due to its novelty is the term Digital health. The number of publications is steadily increasing for all of the four terms as it was also foreseen by the authors in the past decade.

While these terms are related, they have distinct differences that need to be understood. In order to reach such understanding, the protocols of the service that is behind each term needs to be defined. Only then the process of standardisation can begin as the proper terms will be used by practitioners, developers and financiers. The terms will be defined by the individual parts of the service that are characteristic of it and actually fall under a specific service title.

Further research will be needed in order to prepare a more precise demarcation of services. That might further serve the standardisation of processes and also contribute to the rise of the quality of services.

1.2.2 Research and praxis in Slovenia

Slovenia is witnessing a progress in development of telehealth solutions on local and national level. Some overviews have been done in the past 3 years that give us some insight into the situation.

In June 2022 I have prepared a brief assessment in regards to standards for Telehelath including Telemedicine, of all listed Telemedicine services. As a basis I used an article by Rant and Rudel (2020) and compared it with online search in June 2022 to verify the services are still operabile. The results showed that there were four kinds of services available at the time of the assessment, namely (1) national, developed by the NATIONAL INSTITUTE OF PUBLIC HEALTH (National eHealth, Teleradiology, Teletransfusion, Tele-Stroke, Teleconsultations, etc.) (2) national /semi-privat, developed by TELEKOM SLOVENIA, (eHealth, eCare, e-WorkHealth, etc.) (3) national / research developed by The Medical University Ljubljana (Telefarm) and (4) national / private developed by private companies (MKS Cezar, T-Med Gluco, Gospodar Zdravja, etc.), total 21 services provided by 14 entities in Slovenia.

Further research is planned for the thesis that will include literature search and **an updated list** of all available Telehealth services (Telehealth, Telemedicine, Telecare etc.).

2 Objectives of doctoral dissertation

Based on many years of research and practical work and case studies in the international environment, I realised that it is possible to provide better quality of TH services.

In the thesis I will be introducing a decision-making model and an appropriate decision-making tool, that will present a possibility for determining suitability of various Telehealth services according to TH standards and suitability according to criteria for specific services.

As a part of the research work I will prepare a **unique model of assessment for Telehealth services** that will serve as a tool during the planning of the solution or during the development phase. It will also serve for possible upgrading of the existing services.

The intended outcome of the dissertation is a **model for the evaluation of services** (according to a certain standard that can be included as a condition) to increase the quality of TH and their standardisation in order to achieve the highest quality possible also for passing the accreditation processes.

2.1 Expected original contribution to science

Such a model does not yet exist in the proposed form, according to the best of my research and knowledge and it represents an original innovation in the field of Telehealth.

In the disposition of the doctoral dissertation I will further present the research gaps, assumptions and potential limitations, intended chapters and subchapters, basic literature and the analysis of the originality of the topic.

3 Intended research methods

The research method is in the process and will need further input and fine tuning.

Proposed method is the following:

1. Development of the criteria tree with stocks of value with sufficiently clear descriptions.
2. A set of criteria for the DEXI model.

For example: if the acceptance of telehealth services and how they are evaluated by users is a model example, then the proposal can be from here on for more demanding and advanced evaluations according to standards and pre-accreditation procedures that will be used by developers.

3. Testing of the model I. (End-user group)

Focus groups of 8 - 10 users will test the services and answer the questionnaire in the laboratory environment.

The focus group will rate the usability of the app, services, etc. according to the DEXI model.

I need to further decide if

a) The focus group has available set of services for them to choose from or
b) The focus group chooses the existing or hypothetical services
c) Is the first entry their proposal - e.g. they choose from a set of services or do they enter services themselves.

For example Samsung Health App, Telekom eOskrba, Smart watch xx, Monitoring patients Caesar, eHealth - some of these services, e.g. eRecipe
Telecap, etc.

4. Testing the model II. (Expert group)

We forward the written answers to experts - an expert group, who will also evaluate based on these opinions.

The testing can be organised as a focus group or individual testing.

F.e. user group of 3 experts that talk to each other in a controlled environment and give a qualitative assessment or they propose assessment individually. These options will be considered also relating to the availability of experts.

Each assessment will be done only one time for one application.

Previously to the testing the questionnaire will be proposed to the ethical commission for review.

In the disposition I will propose the (1) Planned course of research work and (2) Display of the basic elements of the assessment model.

4 Proposal of a potential mentor

Proposed mentor for the thesis is the associate professor dr. Uroš Rajkovič, University of Mariboru, Faculty for organisational sciences, Kidričeva cesta 55a, Kranj.

4.1 Proposal of a potential co-mentor

Proposed co-mentor is professor dr. Malcolm Fisk, De Montfort University, Faculty for Computing, Engineering and Media, School of Computer Science and Informatics, The Gateway, Leicester, LE1 9BH.

5 Proposal for the scientific discipline of the competent department

A proposal for a scientific discipline: Organization and Management of Information Systems. Proposed department: Department of Informatics

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Many thanks to my colleague dr. Drago Rudel and mentors prof. dr. Malcolm Fisk and prof. dr. Uroš Rajkovič for indispensable advice and guidance.

References

Fatehi F., Wootton R. (2012). Telemedicine, telehealth or e-health? A bibliometric analysis of the trends in the use of these terms. J Telemed Telecare. 18(8), 460-4.

Samar Brencic N., Rudel D. (2021). Can a self-assessment tool help raise standards of eHealth and telemedicine services that are rapidly developing under COVID-19 emergency? JTTA journal Vol.16 suppl.

Samar Brencic N., Rudel D., Fisk M. (2021). The importance of standards for quality Telemedicine and eHealth services in COVID-19 pandemics, JTTA journal Vol.16 suppl.

Samar Brencic N., Rudel D. (2020). Standards of quality for telehealth services for older adults - their augmented significance in Covid-19 pandemics; 22th International multi-conference information society, Conference proceedings, 393 - 395.

Samar Brencic N., Rudel D. (2020). Pomen standardov za kakovostne storitve zdravja na daljavo (v času COVID-19 pandemije), Digitalni mostovi v zdravstvu : e-Kongres MI'2020 : zbornik prispevkov in povzetkov SDMI, ur. Tomaž Marčun, Ema Dornik Dostop do e-publikacije: https://sdmi.si/files/strokovna_srecanja/zbornik%20MI2020.pdf

Samar Brencic N. et al., Intuitive and intelligent solutions for elderly care, 2020. V Chaari, Lotfi ed.. Proceedings of the 2nd International Conference on Digital Health technologies, Advances in Predictive, Preventive and Personalised Medicine Series 12, Springer International Publishing, DOI 10.1007/978-3-030-49815-3.

Rudel, D., Fisk M. (2012). Telescope – telehealth services code of practice for Europe. Inform Med Slov; 17(1), 38-44.

Rudel, D., Fisk M. (2011). Definitions of Terms in Telehealth. Infor Med Slov, 16(1), 28-46. http://ims.mf.uni-lj.si/archive/16%281%29/21.pdf (Accessible 2011-10-12).

Rudel, D., Fisk M. (2018).Telehealth Quality Group EEIG, International Code of Practice for Telehealth Services, Ljubljana.

Thiel T., Deimel L., Schmidtmann D., Piesche K., Hüsing T., Rennoch J., Stroetmann V., Stroetmann K. (2018). SmartHealthSystems: International Comparison of Digital Strategies', Empirica, Bertlesmann Stiftung.

DOCTORAL CONSORTIUM

A QUANTITATIVE EXPERIMENT: INTER-TEAM RETROSPECTIVES IN SCALED AGILE PROGRAMS

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Despite the current popularity agile project management and scaling such frameworks, there is little academic research inquiring how to scale agile frameworks to be successful at the program level. Retrospectives, are understood to play an important role in attempts to successfully adjust scaled-up project frameworks. This research studies the particular impact of such meetings as a tool to scale a known success factor from agile projects and address current gaps highlighted in recent program management literature. To better understand the impact of retrospectives, a quantitative experiment, to inquire how program value is accomplished with inter-team retrospectives, is conducted. With the proposed research design, we intend to test if there is a measurable impact on program success and efficiency by introducing inter-team retrospectives based on current approaches from the literature. This will allow to better understand and further develop the retrospective meeting design on an inter-team level within scale agile programs.

Keywords: program management, inter-team, intra-team, scaled agile, software development

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1 Introduction

Since the introduction of agile software development with Scrum (Schwaber and Sutherland, 2020), agile project management[1] is receiving increasing popularity. With growing numbers of applied use cases across industries, interest of scaling such frameworks is increasing to benefit from its advantages on a larger scale. However, there is currently little academic research on agile program and portfolio management to be found in the peer-reviewed literature.

In small agile projects, the development team coordinates work through frequent informal interaction among themselves and with customers. The Scrum framework has dedicated meetings for planning, review, and retrospectives. Many teams use visual boards, like in Kanban, to show who is working on what and the status of work tasks, which are designed for project size endeavors. Strode et al. (2012) explain coordination in such environments with agile teams and propose a model for coordination strategy and coordination effectiveness.

For large-scale projects, there is less support in the academic literature as described by Dingsoyr et al. (2018b). Scrum prescribes regular meetings between Scrum teams ("Scrum of Scrums") in order to manage the interfaces between teams, covering the planning of upcoming activities and dependencies, not retrospectives.

As we see from this current body of knowledge, focus is primarily on upfront planning activities at the beginning of each iteration (i.e. "Sprint Planning"). Agile however is consider as a series of cycles that aim and allow for continuous improvement for which reason the concept of a retrospective was introduced on a project level. Inter-team retrospectives are currently not part of commonly referred to scaled agile frameworks (Toegl et al., 2023), despite the original characterization from Schwaber and Sutherland (2020, page 9): "*The purpose of the Sprint Retrospective is to plan ways to increase quality and effectiveness*".

To close these identified gaps and extend the range of research methodologies for agile program management, a quantitative experiment is conducted to assess if an inter-team retrospective is a scalabale success/factor for agile program management.

[1] Several definitions of project, program, portfolio and the respective management can be found in management literature. In this review, we are referring to the denitions stated by Ireland (2002).

The result of this study would significantly support academics as well as practitioners with further developing scaled agile frameworks, their key artifacts as well as help organizations to become more successful in their agile transformation and Change initiatives.

2 Problem definition

From a business perspective, agile projects have been very successful across organizations in particular for software development. To further apply this methodology on a larger scale, agile project frameworks need to be adjusted in order to be successfully scaled-up and bank in its benefits.

While different Scaled Agile frameworks include different approaches on scheduled and unscheduled inter-team communication, the current literature investigates specific case studies as done by Paasivaara et al. (2012) or Dingsoyr et al. (2018b). Dingsoyr therefor suggest to further explore this relationship between intra-team and inter-team coordination in other approaches and settings other than his case study. From Toegl et al. (2023) we know that the academic literature covers success factors of scaled agile programs but does not investigate how to actually scale success factors known from agile projects, such as retrospectives.

Communication as well as knowledge sharing and improvement to enable learning at inter-team levels and program levels show under-researched fields (Dingsoyr et al., 2018a). Understanding the impact of retrospectives as a tool of knowledge sharing and improvement as well as for inter-team communication as well remain to be researched as described in the literature by Stettina and Schoemaker (2018) and Dingsoyr et al. (2018c). As highlighted by Dingsoyr et al. (2018c),the central challenge in coordination is identifying the right form or artifacts, arenas, and degree of formalization in large endeavors, such as scaled agile programs, with high complexity - a typical indicator to apply an agile framework as stated by Salameh (2014).

As the literature reveals, e.g. the systematic literature review by Dikert et al. (2016), agile program management is limited to experience reports and case studies of already completed programs and projects given the practicability of retrieving data.

Others applied approaches are limited to exploratory studies such as Dingsoyr et al. (2018c). Table 2.1 summarizes the questions for this study:

Table 2.1: Research questions

ID	Research question
PS1	What is the effect of inter-team retrospectives on program/business output within an agile setting?
PS2	What is the effet of inter-team retrospectives on program efficiency within an agile setting?
PS3	What are advantages and disadvantages of the different formats of inter-team retrospectives?
PS3.1	How do formats of inter-team retrospectives evolve over time and iterations?

To find answers to these questions, close the identified gaps and extend the range of research methodologies for agile program management, a quantitative experiment is conducted to assess if an inter-team retrospective is a scalabale success/factor for agile program management. The result of this study would significantly support academics as well as practitioners with further developing scaled agile frameworks, their key artifacts as well as help organizations to become more successful in their agile transformation and Change initiatives.

It is the contention that inter-team retrospectives in agile programs have a direct impact on program success and evaluated by efficiency, stakeholder satisfaction, and the success of meeting wider business goals, the relationship is also subject to other intervening, moderator impacts that must be considered as part of this study. We will follow the approach of Serrador and Pinto (2015) to achieve consistent results as shown by their work in this field.

As a result, the proposed research model is shown in Fig. 2.1, highlighting not only the tested relationship between inter-team communication in agile programs and program success, but also the potential impact of various moderators on this direct effect.

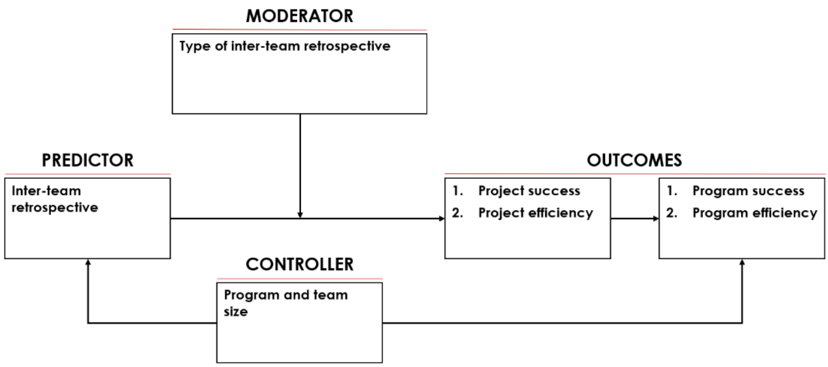

Figure 2.1: Research model

The type of inter-team retrospective type needs to be considered as a moderator because the time invested in such meetings has a significant impact on time spent and budget given the potentially high number of involved stakeholders and hence influencing project success and efficiency and subsequently program success and efficiency. However, in this research primarily focus on the impact created by the presence of such retrospectives. Table 3.3 provides an overview of retrospective formats considered in this study. The same assumption can be made on learning effects on managing defects to reduce error.

The central hypotheses (PS1, PS2) of this research are therefore about testing the effect of inter-team retrospectives as well as starting the investigation which format of inter-team retrospectives (Table 3.3) shows most effect. Table 2.2 provides an overview of the hypotheses and moderating effects that shall be investigated as part of this research.

Table 2.2: Hypotheses

	Hypotheses
HP1	Inter-team retrospectives have a positive impact on proram success.
HP2	Inter-team retrospectives have a positive impact on program efficiency.
HP3	The type/format of inter-team retrospective moderates the effect of retrospectives on program success.
HP4	The type/format of inter-team retrospective moderates the effect of retrospectives on program efficiency.

As the impact of the inter-team retrospective is expected to become more visible over time, meaning after a couple iterations, we want to assess the impact of the inter-team retrospective as a moderator. Following the approach of Treiblmaier and Putz (2020) in which a comparable multi-group field experiment was facilitated, we model inter-team retrospectives as a moderator between the program and project success as well as project efficiency and therefore program

success and efficiency and hypothesize for the statistical testing:

Table 2.3: Null hypotheses for testing program success

	Null hypotheses
H0	There is no effect on program success in an environment with inter-team retrospectives.
H1	There is an effect on program success in an environment with inter-team retrospectives (of format A or B).

Table 2.4: Null hypotheses for testing program efficiency

	Null hypotheses
H0	There is no effect on efficiency in an environment with inter-team retrospectives.
H1	There is an effect on efficiency in an environment with inter-team retrospectives (of format A or B).

3 Methodology, design and focus

We aim to research the impact of inter-team retrospectives within a simulated setting and compare it to the same setting without inter-team retrospectives. We consider program management success as the unit of analysis, following the approach of Shao et al. (2012).

A post-positivism perspective with a deductive approach is used in this study in order to operationalize the program success and program context concepts - broadly following Shao et al. (2012). An experiment is used to collect data which then allows for generalizable results within the design's boundaries. The applied research design is therefore considered to be Experimental Research.

Program business success shall be the output of the project team. Program efficiency shall be considered as reduction of error (defects). Stakeholder satisfaction to satisfy the expectations of project stakeholders is not considered to simplify the experiment.

We gather qualitative data from the participants in regards to PS3 via their results from the retrospectives to better understand how the adjusted intra-team as well as the inter-team retrospectives were perceived. To analyze data from these retrospectives, the success factors described by Hummel and Epp (2015) are applied for potential coding purposes.

3.1 Iterative research approach and Pre-studies

Following an agile approach, two pre-studies were conducted with graduate students from the University of Applied Sciences Joanneum (Graz, Austria) in autumn 2021 and 2022 to confirm the feasibility of the operating the experiment. The goal of these pre-studies was to test assumptions made and to test the operationalization of the experiment in terms of its complexity.

Findings of these pre-studies impacted the ratio of required Scrum Masters to teams (1:1), highlighted the need to play different games within a program to avoid competition (i.e. withholding information as well as mistrust between teams). In regard to the number of iterations conducted during the experiments, we raised the number of iterations..

3.2 Procedure and data collection

Data is collected during the experiment, as described in Table 3.1 and Table 3.2, by the Scrum Master typically every sprint or are calculated based on values provided from each project.

Table 3.1: Measures on program level

Dimension	Calculation of scores
Total program performance	Sum of each team’s actual points delivered across all sprints.
Total program defects	Sum of each team’s actual points delivered across all sprints.
Total program efficiency	Ratio of the total program performance to the total program defects.
Program sprint performance	Sum of each team's actual points delivered in a sprint.
Program sprint defects	Sum of each team's defects in a sprint.
Program sprint efficiency.	Ratio of the program sprint performance to the program sprint defects.

Table 3.2: Measures on project level

Dimension	Calculation of scores
Sprint performance	A team's actual points delivered in a sprint.
Sprint defects	Defects that occurred during a team’s sprint.

Further calculations of each team’s total performance/efficiency will be conducted. Inter-team retrospectives are considered as indicator variables (1 = took place; 0 = did not take place) for each program, team and sprint.

In this experiment, we are simulating programs following the Scrum of Scrum framework (Paasivaara et al., 2012), which is chosen given its lowest level of complexity once the concept of Scrum is introduced. We have multiple Scrum teams with a Scrum Master each, who will be responsible to collect the data. Other data is calculated based on their output.

3.3 Structure of the experiment

The experiment aims to simulate scale agile programs by playing agile games. To ensure comparable results, every program follows the same strategic goals.

The Ball Flow Game was chosen as a feasible game for the Scrum teams (Fowler et al., 2001) in the experiment given the comparison by Przybylek and Olszewski (2016) in which it scored high in the considered factors, such as easy-to-understand. In addition, its scoring mechanism in every iteration of the game made it a suitable candidate for this research.

The class-room activities described by Hurbungs and Nagowah (2019) Paper Planes (Heintz) and Pizza Game (Agile42) were chosen for the Scrum teams due to their suitability in a tertiary educational context as well as their objective to agile learning and teaching. In addition, we can apply the same scoring mechanism in every iteration of the games.

For this experiment, we time-box a complete sprint/iteration to 15 minutes. During these 15 minutes, every team has to complete all Scrum ceremonies. The actual play time of each game is defined as 3 minutes.

The Scrum Master is responsible to facilitate the game, stop the time and collect the results.

Adoption of Scrum-of-Scrum questions We can adapt questions used by Paasivaara et al. (2012) in the Daily Scrum to the needs of the retrospective, along with (Dingsoyr et al., 2018a) on the category "other teams to facilitate "double loop" learning from the framework of Argyris (1976).

Participants Participants are university students with no to little prior knowledge about agile project management. To further understand their knowledge, we perform a survey at the beginning of the experiment and dismiss students that have prior experience with the selected agile games.

As part of the experiment, a set of roles is required that follow the Scrum (Fowler et al., 2001) and Scrum of Scrum frameworks (Paasivaara et al., 2012). In this set-up, Release Manager and Product Manager can be neglected. The role of the Product Owner is replaced with a rule set and guidelines for each sprint. This information is available to the Scrum Masters from the beginning and during each iteration will be revealed to the project team. As part of this the Scrum Masters will receive separate information and is instructed to perform additional tasks, such as disrupting the process with adding three balls during a sprint as part of the Ball Point Game.

3.4 Types/formats of inter-team retrospectives

The different types or formats of inter-team retrospectives considered in this research are described in Table 3.3. Inter-team retrospectives are planned only for teams or representatives from the same program and not across multiple programs.

Table 3.3: Considered formats of inter-team retrospectives

Type	Short description
A	Inter-team retrospectives with by the team selected members of each Scrum team.
B	Inter-team retrospectives between the Scrum Masters of each Scrum team.
C	Inter-team retrospectives with all Scrum teams and all their members.
D	No inter-team retrospective.

We plan for team retrospectives after every sprint/iteration. Team retrospectives are planned once every team completed its team retrospective.

Type C is only mentioned for completeness and are not considered suitable for any real-world program. It is therefore not further considered in this experiment.

Sequence of sprints/iterations For this experiment, we plan to have nine sprints/iterations for each team in every program executed in parallel. Data is collected before, during and after each sprint/iteration.

3.5 Data collection approach

Data is collected to collect each team's output and defects and therefore its contribution to the program. We expect, this allows to understand the performance on a program as well as project level.

In general, the simplest relationships are examined firsthand then analysis continued using progressively more involved techniques. This includes a path-analysis of each scrum team over time.

Other potential moderators such as Product Vision/Goals, Project Complexity and Team Experience are not further considered as these factors are harmonized in all our programs within the given experimental design.

3.6 Statistical evaluation

The experiment provides a purposeful sample size with 30 inter-team retrospectives (10 for each program) with a total of 90 sprints (30 for each program), which is deemed sufficient for the statistical analysis with a regular t-test, as described by De Winter (2013). If required, the experiment can be scaled up include more teams in each program, however saturation is expected by 10 sprints. If we cannot confirm normal distribution with the gained data, the Mann-Whitney-U test can be used.

The Jonckheere's trend test could additionally be used to detect differences in the teams across the multiple sprints. In particular, we would expect to see a trend when comparing the project teams with inter-team retrospectives to the comparison project teams without inter-team retrospective over time.

3.7 Data quality

The data will be collected every sprint from the Scrum Masters and is limited to only very few input points. Photos of the retrospective boards with their sticky notes are taken in every sprint to collect the required data, which will be particularly relevant regarding PS3. Photos allow to track and validate not only the raised points, but additionally allow to count how often certain topics are raised within a retrospective. A retrospective board also allows to visually see where the majority of points are raised which allows to easily identify if things went well or not. As described by Schulze (2007), taking photos forces the participants to reect, while gaining insights on what is most significant. This simplicity is expected to provide sufficient meaningful data for every Scrum team in every iteration, compared to other media such as, e.g. video.

To ensure data is properly collected, the Scrum Masters will receive an introductory training in advance. All Scrum Masters will be PSM1 certified.

3.8 Validity and reliability

Following the structure and results of Brink (1993), the four threats (the researcher, the subjects participating, the situation and the methods of data collection and analysis) are addressed.

To reduce bias of the researcher by participating as well as the risk of reducing bias with data collection, the Scrum Masters will be responsible for data collection. They will receive an introductory training in advance, together with a retrospective guide and a fieldnote template that covers the required structure to cover and collect data of the required key success factors. Such a preparation is considered especially necessary to ensure the researcher is trusted by the Scrum Masters (Leininger and Reynolds, 1991).

Data will be collected every sprint and is limited to only very few input points, to ensure the amount of work is minimized.

Given the simplicity of the game and time constraints, the depth and variety of findings in retrospective meetings are expected to diverge little among teams when comparing to real-world large scale programs.

3.9 Ethics

Approval of the Ethical board of the University of Antwerp is expected before conducting the experiment.

The idea is to perform this primarily with adults, that are monetarily incentivized (e.g. EUR 1 / point) for each successfully delivered point.

4 Preliminary/Expected results

In terms of reserach methodology, researching inter-team retrospective with an experiment expands the toolbox for conducting research in the eld of agile program management.

Regarding the results of the experiment, the initial contention is that the simulated programs with inter-team retrospectives are more successful than those neglecting this ceremony. We expect that the null hypothesis described in Table 2.4 and in Table 2.3 are rejected. This means, a possible outcome could be, that we can show a statistically significant impact of inter-team retrospectives in terms of the business outcomes (program success and program efficiency), while identifying a better performing retrospective format. We additionally expect to gain knowledge how intra-team and inter-team retrospectives evolve over time. We expect to further gain knowledge on who become ambassadors to represent teams at inter-team retrospectives and how the team members utilize inter-team retrospectives to their project's benefit.

With this result, we believe found a success factor known from agile project management, that can be scaled to agile program management.

These results will allow us to undergo real-world tests with this format with lower managerial risks as the proposed concept resulted from thorough academic research. This knowledge could impact scaled agile frameworks in a way, that inter-team retrospectives become widely adopted.

Expected outcomes Type A and B retrospectives are expected to be the types with the most positive effect among the researched types. Additionally, as the iterations continue and changes in the set-up might be suggested by the intra-team as well as as the inter-team retrospectives, type A retrospectives might evolve into a type B retrospective, or alternatively, type B retrospectives might evolve into a type A retrospective.

5 Future development

This research is part of a broader research question part of the author's PhD. Tying three research studies together, a possible combined outcome could be, that we contributed to the body of knowledge in multiple ways and lay out a way on how to improve success of scaled agile programs.

Firstly, we identified an under-researched academic eld with high interest for practitioners and prepared an overview that supports further academic research more easily. The results of a systematic literature revealed that retrospectives are a known success factor in agile projects but academia barely researched on how to scale up this success factor to scaled agile programs.

The here described experiment is planned as the second paper to solve the "managerial puzzle" described in the author's PhD project.

Building on the results from this research paper, we want to gain in-depth knowledge on the perceived value of inter-team retrospectives, their connection to intra-team retrospectives and their evolution over time at a software service providing company, Parkside Interactive, in a third study. The best performing format of inter-team retrospective from the experiment will be taken as a starting point for this case study.

With these steps, we additionally close a number of previously identified research gaps and for the fist time analyze agile programs with a quantitative experiment.

References

Agile42. Pizza game. URL https://www.agile42.com/en/agile-teams/kanban-pizza-game.

C. Argyris. Single-loop and double-loop models in research on decision making. Administrative science quarterly, pages 363-375, 1976.

H. I. Brink. Validity and reliability in qualitative research. Curationis, 16(2):35-38, 1993.

J. C. De Winter. Using the student's t-test with extremely small sample sizes. Practical Assessment, Research, and Evaluation, 18(1):10, 2013.

K. Dikert, M. Paasivaara, and C. Lassenius. Challenges and success factors for large-scale agile transformations: A systematic literature review. Journal of Systems and Software, 119:87-108, 2016.

T. Dingsoyr, M. Mikalsen, A. Solem, and K. Vestues. Learning in the large - an exploratory study of retrospectives in large-scale agile development. In International Conference on Agile Software Development, pages 191-198. Springer, Cham, 2018a.

T. Dingsoyr, N. B. Moe, T. E. Faegri, and E. A. Seim. Exploring software development at the very large-scale: a revelatory case study and research agenda for agile method adaptation. Empirical Software Engineering, 23(1):490-520, 2018b.

T. Dingsoyr, N. B. Moe, and E. A. Seim. Coordinating knowledge work in multiteam programs: Findings from a large-scale agile development program. Project Management Journal, 49(6): 64-77, 2018c.

M. Fowler, J. Highsmith, et al. The agile manifesto. Software Development, 9(8):28-35, 2001.

J. Heintz. Agile airplane game. URL http://gistlabs.com/2011/06/agile-airplane-game/.

M. Hummel and A. Epp. Success factors of agile information systems development: A qualitative study. In 2015 48th Hawaii International Conference on System Sciences, pages 5045-5054.

IEEE, 2015.
V. Hurbungs and S. D. Nagowah. A practical approach to teaching agile methodologies and principles at tertiary level using student-centred activities. Agile and Lean Concepts for Teaching and Learning: Bringing Methodologies from Industry to the Classroom, pages 355-389, 2019.
L. R. Ireland. PMI Lexicon of Project Management Terms. Project Management Institute, Inc., 2002.
M. Leininger and C. Reynolds. Culture care diversity and universality theory. Nursing, 1991.
M. Paasivaara, C. Lassenius, and V. T. Heikkila. Inter-team coordination in large-scale globally distributed scrum: Do scrum-of-scrums really work? In Proceedings of the ACM-IEEE international symposium on Empirical software engineering and measurement, pages 235-238, 2012.
A. Przybylek and M. K. Olszewski. Adopting collaborative games into open kanban. In 2016 Federated Conference on Computer Science and Information Systems (FedCSIS), pages 1539-1543. IEEE, 2016
H. Salameh. What, when, why, and how? a comparison between agile project management and traditional project management methods. International Journal of Business and Management Review, 2(5):52-74, 2014.
S. Schulze. The usefulness of reflexive photography for qualitative research: A case study in higher education. South African journal of higher education, 21(5):536-553, 2007. 14
K. Schwaber and J. Sutherland. The scrum guide. Scrum Alliance, 2020.
P. Serrador and J. K. Pinto. Does agile work? A quantitative analysis of agile project success.
International Journal of Project Management, 33(5):1040-1051, 2015.
J. Shao, R. Mueller, and J. R. Turner. Measuring program success. Project Management Journal, 43(1):37-49, 2012.
C. J. Stettina and L. Schoemaker. Reporting in agile portfolio management: routines, metrics and artefacts to maintain an effective oversight. In International Conference on Agile Software
Development, pages 199215. Springer, Cham, 2018.
D. E. Strode, S. L. Huff, B. Hope, and S. Link. Coordination in co-located agile software development projects. Journal of Systems and Software, 85(6):1222-1238, 2012.
D. Toegl, T. Huygh, and S. De Haes. Retrospectives in scaled agile: A systematic literature review. Working paper, 2023.
H. Treiblmaier and L.-M. Putz. Gamification as a moderator for the impact of intrinsic motivation: Findings from a multigroup field experiment. Learning and Motivation, 71:101655, 2020.

DOCTORAL CONSORTIUM

THE MULTI-CRITERIA DIGITAL AND SUSTAINABLE MATURITY ASSESSMENT MODEL

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European Union (EU) recognized the strong need for digital and sustainable transition of enterprises and societies. Although digital technologies can contribute to achieving sustainable goals, many of enterprises still struggle with challenges of digitalization and digital transformation, especially SMEs, which due to limited resources often lag behind larger enterprises. In the paper, we focus on SMEs, since they represent majority of EU economy, and are strong contributor to the number jobs and GDP. To achieve goals for successful digital and sustainable transition, which are adopted by European Commission, it is important to use proper strategies. This is not possible without understanding the current state and predict the impact of given measures and develop new business models that can be derived from digital transformation, sustainability, and circular economy. There are several available tools for digital maturity assessment available and SMEs can estimate their position in digital journey. However, to our knowledge, no tool, which would enable assessment of digital maturity and its impact on achieving sustainability goals, is currently available. Such a model could help SMEs to assess current state and plan for proper strategy to achieve digital transformation towards sustainability goals.

Keywords:
SMEs, regulation, sustainability, digital transformation, twin transition, maturity assessment model

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1 Introduction

Many crises in Europe and worldwide, caused by Covid-19, war in Ukraine, population growth and environmental exploitation, resulting shortage of natural sources and natural disasters, have led the European Commission to prepare the strategy for twin green and transition. Both strategies- EU digital strategy and green deal, are heading to the same goal- to make digital strategy work for people, while helping to achieve a target of a climate-neutral Europe by 2050 (European Commission, 2020c). Digital regulatory framework is combined under EU digital strategy and consists of several regulations and directives (European Commission, 2020c).

Twin transition is one of the most important paradigms in the current time. Irreversible changes and further damage on the planet Earth can only be avoided with greater responsibility from each individuum, adjustments in business with the changes in business models and adopted legislative (Vidmar, 2021).

EU framework for the twin transition aims to achieve sustainability, combat climate change and environmental degradation with harnessing digital technologies for sustainability and prosperity, and to empower citizens and business (Muench et al., 2022). Green transition, addressing environmental performance (planet) is only one of the elements in the triple bottom line of sustainability, besides economic performance (profitability) and social performance (people), (Dao et al., 2011) which all need to be addressed in the forthcoming economy. The transformation from pure economic success in linear economy to shared value which is including not only individual (economic) success, but the success of the society is the basis for the sustainable or circular economy (Brenner, 2018).

The area is currently regulated by the Directive as regards disclosure of non-financial and diversity information by certain large undertakings and groups (NFRD directive) from 2014, which only affects large enterprises from 2018 and anticipates reporting in the annual reports on five dimensions and four sub-dimensions in pdf format with low reliability of reporting (European Commission, 2014).

Under the EU Green Deal (European Commission, 2019) new directives and new standards are under preparation, also obliging SMEs for preparation of standardized reports, including financial taxonomy.

In the paper, we will focus on SMEs, which represent 99 % of European economy. Unfortunately they are lagging in adopting new development principles both in the digital transformation and consequently sustainability (Gorgels et al., 2022).

2 Problem definition

The problem addressed in our research is focused to the twin transition of SMEs. SMEs represent 99% of the European economy; they provide 100 million of jobs and contribute 50% of Europe's GDP. (Gorgels et al., 2022). At the same time, only 25% of EU SMEs work on green products or services and only 17% have successfully integrated digital technology. SMEs contribute about 65% of overall employment in the economy, but they are also responsible for around 60% of all greenhouse gas emissions by enterprises(European Commission, 2020a). New regulatory framework is setting rules for SMEs for mandatory reporting and taking actions towards the twin transition. The digital and sustainable maturity assessment model can help them with easier adopting to the regulations but also help them design new strategies for future development of their enterprises.

We can observe that many enterprises are facing challenges with establishing digital capabilities, competences, and changes of the organizational culture (Pucihar, 2020). With the emerged need for sustainable transformation of the world around us, and the simultaneous ongoing digital transformation, it is necessary for enterprises to find parallels in development of their business models. Digitalization is giving us the possibility to re-create the environment we live in, even though the population is rising, especially in the cities. In the cities, the impact of digital technologies is already recognized through the sharing economy business models (Hildebrandt et al., 2018). Dealing with the twin transition, digital transformation, and the innovation of digital business models already guided entrepreneurs towards pro-growth mentality and openness to changes (Ferreira et al., 2022). Recent research shows that sustainability and digitalization can integrate principles and strategies(Vidmar, 2021). The research investigated which information technology, organizational and business environment factors influence changes in business models, with the focus on its digitalization. The research also focused on the impact of business model changes on the three components of sustainable performance: economic, environmental, and social.

European Commission can influence European market by setting rules, that is why the twin transition(Muench et al., 2022) with the digital strategy(European Commission, 2020c) and European green deal (European Commission, 2019) targeted the same outcome – to create a climate neutral Europe by 2050 with including various factors of everyday life(Muench et al., 2022).

EU Green deal includes different goals and therefore reporting standards about achieving those goals. Main goals are dedicated to environment, Europe to be the first climate-neutral continent by 2050, with at least 55% less net greenhouse gas emissions by 2030, compared to 1990 levels and planting additional 3 billion of trees in EU. EU green deal will represent a series of benefits, fresh air, clean water, healthy soil, and biodiversity, renovated, energy efficient buildings, healthy and affordable food, more public transport, cleaner energy and cutting edge clean technological innovation, longer lasting products that can be repaired, recycled, and reused, future-proof jobs and skills training for the transition with globally competitive and resilient industry(European Commission, 2019). Goals and expected results are affecting the economy, which will have to transform to comply with the demands and to ensure the sustainable products. At the same time, the directives CSRD (European Commission, 2023), EU Taxonomy (European Commission, 2020b), ESRS standards(EFRAG, 2021) and CSDD directive(European Commission, 2022), will significantly influence the operations of the enterprises.

Some of the key characteristics of SMEs are limited financial and human resources, operation in economic or geographic niches and in uncertain markets and policy environments, which all represent challenges for the sustainable transition (Gorgels et al., 2022). SMEs also meets difficulties in influencing wider business environment and they are often owned and managed by the same person, on whom depend on all the values and beliefs(Kljajić et al., 2021a). SMEs were forced to proceed with the digital transformation in the last years, because of their competition, but also Covid-19 pandemic push. Both transformations, digital and sustainable, need to start from the current state of the individual enterprise, which we can also state as maturity. From there, enterprises can plan strategies and further development.

The maturity can be defined as "the state of being complete, perfect or ready" (Lasrado et al., 2015), the assessing the maturity of digitalization reflects the degree of digital transformation in the company (Alsufyani & Gill, 2021), which represents long and uninterrupted process, covering technology, culture, company strategies, staff, and end user needs (Nasiri et al., 2022).

Our research emerges from the limited abilities of SMEs to design their own strategies for twin transition. In Slovenia, national digital maturity assessment model was developed in 2020 and it is under constant improvements. This assessment model enables individual SME to assess its current state in the digital transformation journey and compares themselves with its competition. In addition, the tool also provides automatically generated report with recommendations for further development (Kljajić Borštnar & Pucihar, 2021). National digital maturity assessment model is a result of many studies and expert group involvement, and it gains from outcomes of already existing digital maturity models in other countries. The aim of our research is to extend the existing tool with sustainability criteria and adjusting existing digital and organizational readiness assessment criteria will provide multi-criteria digital and sustainable maturity assessment tool. SMEs will use the measured score for orientation on their position on the market as well for the planning of future investments to gain compliance and benefits from twin transition to create future strategies connected to their needs for digitalization and green transition goals. The national level of collecting data enables policy makers to customize proper instruments to help SMEs, based on aggregated and analysed data.

3 Methodology

As the umbrella methodology for the proposed research, we follow the design science research methodology (DSR) , with the main goal the development of organization- informatics artefact to solve the relevant business needs, based on the existing knowledge (Hevner et al., 2004). The proposed solution – artefact- will be multi-criteria model for the assessment of the digital and sustainability maturity.

Based on the scientific and expert literature review, existing models, policy literature and research, we will conduct the conceptual research model and determine the initial set of criteria for the assessment of digitalization and sustainability maturity. In the next step we will determine value ranges and validate the criteria set through the semi- structured interviews with experts on the digitalization and sustainability fields. Semi-structured interview provides the additional questions, which were not planned, but they can significantly contribute to the model development and understanding of the problem (Kallio et al., 2016).

The model we will develop will be the multi attribute decision model, which are considered as useful decision-making tools in the complex situations with evaluation process with including all the relevant factors, which can affect the decision (Kljajič et al., 2021b).

We will develop multi-criteria assessment model and will test it on the 6-10 SMEs to confirm its sensibility for differences among enterprises.

In the development phase of multi-attribute decision making model, we will use the DEXi program – a software which is freely available. DEXi method requires the decomposition of the decision problem into smaller problems with lower complexity and easier to solve (Bohanec, 2020).

In the last step we will evaluate the model and analyse the data from SMEs, with which we will confirm the suitability of the further usage of the model in practice. One of the goals is test of the model in practice to achieve opinions and recommendations for the improvements of the model.

3.1 Literature review

Initially we wanted to establish the time when the topics of digitalization and sustainability became of more importance, regarding the number of published sources. Through the knowledge bases Web of Science, Scopus and ProQuest Dissertations and Thesis we've searched for the key words "digitalization" and "sustainability", collected the results, and presented the median through the Figures 1 and 2, presenting the number of articles with included keyword digitalization (Figure 1) and sustainability (Figure 2). Because we assume that some of the articles are the same, published in different knowledge base, we did not calculate the sum, but took the median.

We assume that the number of articles as well represent the importance of the topics. In the Figure 1 and Figure 2 we can see that both topics became relevant in early 19th Century, but raising relevance in the last 10-15 years, while now they represent one of the most important topics.

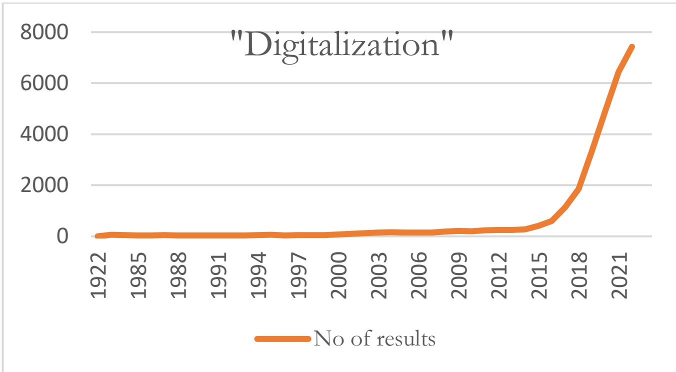

Figure 1: Number of articles on the keyword "digitalization"

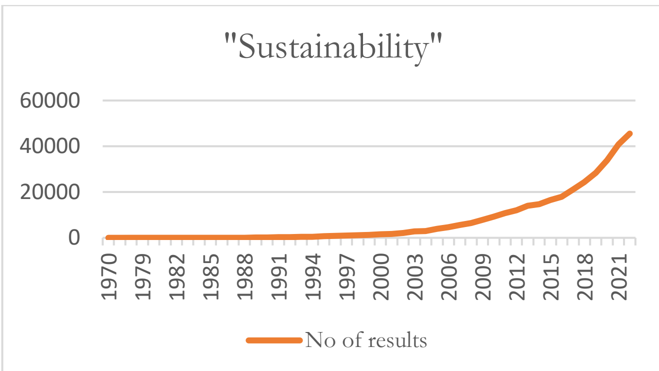

Figure 2: Number of articles on the keyword "sustainability"

In the next step, we used three knowledge bases: Scopus, Web of Science and ProQuest Dissertations and Thesis, to search by the key words listed below. We were adding the concepts, applied to the research problem, to narrow the selection. In this process, we concluded that for the research problem – the design of multi-criteria model for digital and sustainable maturity assessment in SMEs - there is no articles in knowledge bases, we searched. In the Scopus and Web of Science there is only one article, which is dealing with twin transition model for SME as well digital and sustainable maturity, but it is strictly focused on the manufacturing enterprises.

The key words, which were used in the search, are:

- Digitalization
- Sustainability
- Digitalization AND sustainability
- Digital AND maturity AND assessment
- Sustainable AND maturity AND assessment
- Digital AND maturity AND maturity AND assessment AND SME
- Digital AND Sustainable AND maturity AND Assessment AND SME AND model
- Digital AND Sustainable AND maturity AND Assessment AND SME AND multi-criteria AND model
- Twin transition AND sustainability AND digital AND model AND SME

Table 1: Inquires in the ProQuest Dissertations and Theses Global database

Database	Key word (the combination of key words)	Number of results in the database
ProQuest Dissertations and Theses Global	Digitalization	8919
	Sustainability	227448
	Digitalization AND sustainability	2727
	Digital AND maturity AND assessment	576
	Sustainability AND maturity AND assessment	409
	Digital AND sustainability AND maturity AND assessment	157
	Digital AND Sustainable AND maturity AND Assessment AND SME	564
	Digital AND Sustainable AND maturity AND Assessment AND SME AND model	564
	Digital AND Sustainable AND maturity AND Assessment AND SME AND model AND multi-criteria	54
	"Twin transition" AND sustainability AND "digital maturity assessment" AND model AND SME	0
	"digital maturity assessment" AND "sustainability" AND "multi criteria model"	0

Table 2: Inquiries in the Web of Science database

Database	Key word (the combination of key words)	Number of results in the database
Web of Science	Digitalization	21.112
	Sustainability	375.239
	Digitalization AND sustainability	1712
	Digital AND maturity AND assessment	449
	Sustainability AND maturity AND assessment	403
	Digital AND Sustainable AND maturity AND Assessment	23
	Digital AND Sustainable AND maturity AND Assessment AND SME	3
	Digital AND Sustainable AND maturity AND Assessment AND SME AND model	2
	Digital AND Sustainable AND maturity AND Assessment AND SME AND multi-criteria AND model	0
	Twin transition AND sustainability AND digital AND model AND SME	1

Table 3: Inquiries in the Scopus database

Database	Key word (the combination of key words)	Number of results in the database
Scopus	Digitalization	32136
	Sustainability	348195
	Digitalization AND sustainability	1749
	Digital AND maturity AND assessment	730
	Sustainability AND maturity AND assessment	407
	Digital AND Sustainability AND maturity AND Assessment	45
	Digital AND Sustainable AND maturity AND Assessment AND SME	6
	Digital AND Sustainable AND maturity AND Assessment AND SME AND model	5
	Digital AND Sustainable AND maturity AND Assessment AND SME AND multi-criteria AND model	0
	Twin transition AND sustainability AND digital AND model AND SME	1

Besides the sources, which we will study and sort in the following process, we have found approximately 50 other sources, including directives, regulations, guidelines, and recommendations, used to regulate the field from the European Commission. Literature review will give us the basis for preparation of the list of criteria, which will be the base for multi-criteria model for digital and sustainable maturity assessment of SME in Slovenia.

4 Expected results

Main expected result is the developed and validated multi-criteria model for assessment of digital and sustainability maturity of SMEs. With our model, SMEs will be able to assess their current situation on the market, the position towards the competitors and strategize the future steps for successful digital and sustainable transition. At the same time and on the larger, aggregated scale, the model will enable the decision makers to design proper politics and programs to support the development, resilience and market respond of SMEs. The model must distinguish between different levels of both, digitalization and sustainability stage separately, and on the other hand measure impact of digitalization on achieving sustainability goals. The assessment sensibility can be reached with the setting of proper rules of the decision-making model - tool.

5 Future developments

Further systematic literature review is the first step in the designing of the multi-criteria model. In the preparation of systematic literature review, we are about to research the existing literature review on related areas. We are not going to timely limit the overview of the related literature, since both fields are developing for many years, even though the intersection of both fields just recently began. That is why we need an interdisciplinary approach to understand and combine both fields. Main areas of review will be digital maturity assessment, sustainability maturity assessment and both assessments combined, especially into the model.

Through the literature review, we will search for theoretical papers and already used methodologies and principles and the basis and knowledge to identify the criteria for the model. Once, when criteria will be defined, we will validate them through the interviews with experts on the fields of sustainability and digitalization. We are planning 6 interviews, 3 with the sustainability experts and 3 with experts in the field of digitalization.

When the criteria are determined and validated through the interviews, we will combine them into the multi-criteria decision support model, and once again validate it with the expert focus group.

After the model is validated through the expert focus group, we will test and validate it again with 15 SMEs.

References

Alsufyani, N., & Gill, A. Q. (2021). A Review of Digital Maturity Models from Adaptive Enterprise Architecture Perspective: Digital by Design. Proceedings - 2021 IEEE 23rd Conference on Business Informatics, CBI 2021 - Main Papers, 1, 121–130. https://doi.org/10.1109/CBI52690.2021.00023

Bohanec, M. (2020). IJS delovno poročilo DEXi: Program for Multi-Attribute Decision Making User's Manual.

Brenner, B. (2018). Transformative sustainable business models in the light of the digital imperative-a global business economics perspective. In Sustainability (Switzerland) (Vol. 10, Issue 12). MDPI. https://doi.org/10.3390/su10124428

Dao, V., Langella, I., & Carbo, J. (2011). From green to sustainability: Information Technology and an integrated sustainability framework. Journal of Strategic Information Systems, 20(1), 63–79. https://doi.org/10.1016/j.jsis.2011.01.002

EFRAG. (2021, April). ESRS standards. https://www.efrag.org/lab6?AspxAutoDetectCookieSupport=1

European Commission. (2014). DIRECTIVE 2014/95/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL - o f 22 October 2014 - amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32014L0095

European Commission. (2019). A European Green Deal. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

European Commission. (2020a). Unleashing the full potential of European SMEs. https://doi.org/10.2775/218854

European Commission. (2020b). EU taxonomy for sustainable activities. https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en

European Commission. (2020c, February 19). A Europe fit for the digital age. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age_en

European Commission. (2022). Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) no 537/2014, Directive 2004/109/EC and Directive 2013/34/EU, as regards corporate sustainability reporting. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32022L2464

European Commission. (2023, January). Corporate sustainability reporting. https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en

Gorgels, Stefan., Priem, Maximilian., Blagoeva, Tsvetelina., Martinelle, A., Milanesi, Giulio., European Commission. Directorate-General for Internal Market, I., DIW econ., & PwC. (n.d.). Annual report on European SMEs 2021/2022 : SMEs and environmental sustainability : background document.

Hevner, March, Park, & Ram. (2004). Design Science in Information Systems Research. MIS Quarterly, 28(1), 75. https://doi.org/10.2307/25148625

Hildebrandt, B., Hanelt, A., & Firk, S. (2018). Sharing Yet Caring: Mitigating Moral Hazard in Access-Based Consumption through IS-Enabled Value Co-Capturing with Consumers. Business and

Information Systems Engineering, 60(3), 227–241. https://doi.org/10.1007/s12599-018-0532-6

Kallio, H., Pietilä, A.-M., Johnson, M., & Kangasniemi, M. (2016). Systematic methodological review: developing a framework for a qualitative semi-structured interview guide. Journal of Advanced Nursing, 72(12), 2954–2965. https://doi.org/10.1111/jan.13031

Kljaji´c, M., Borštnar, K., & Pucihar, A. (2021a). electronics Article. https://doi.org/10.3390/electronics

Kljaji´c, M., Borštnar, K., & Pucihar, A. (2021b). electronics Article. https://doi.org/10.3390/electronics

Kljajić Borštnar, M., & Pucihar, A. (2021). Multi-Attribute Assessment of Digital Maturity of SMEs. Electronics, 10(885). https://doi.org/10.3390/electronics

Lasrado, L., Vatrapu, R. K., Andersen, K. N., Lasrado, L. A., & Vatrapu, R. (2015). MATURITY MODELS DEVELOPMENT IN IS RESEARCH: A LITERATURE REVIEW Democratic and technological innovation: An inquiry into the relations of power, technology and democracy in Greenlandic e-democracy View project Collaborative Representations View project MATURITY MODELS DEVELOPMENT IN IS RESEARCH: A LITERATURE REVIEW. https://doi.org/10.13140/RG.2.1.3046.3209

Muench, Stefan., Stoermer, Eckhard., Jensen, Kathrine., Asikainen, Tommi., Salvi, Maurizio., Scapolo, Fabiana., & European Commission. Joint Research Centre. (2022). Towards a green & digital future : key requirements for successful twin transitions in the European Union.

Nasiri, M., Saunila, M., & Ukko, J. (2022). Digital orientation, digital maturity, and digital intensity: determinants of financial success in digital transformation settings. International Journal of Operations and Production Management, 42(13), 274–298. https://doi.org/10.1108/IJOPM-09-2021-0616

Pucihar, A. (2020). The digital transformation journey: content analysis of Electronic Markets articles and Bled eConference proceedings from 2012 to 2019. Electronic Markets, 30(1), 29–37. https://doi.org/10.1007/s12525-020-00406-7

Vidmar, D. (2021). VPLIV INFORMACIJSKIH TEHNOLOGIJ NA TRAJNOSTNO USPEŠNOST ORGANIZACIJ.

DOCTORAL CONSORTIUM

VALIDATION OF DATA MATURITY CRITERIA FOR SMALL AND MEDIUM-SIZED ENTERPRISES

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Data is a fundamental source for any business to operate and to develop. Inefficient data management can lead to lack or a flood of data and consequently non-optimal business decisions. This is particularly evident in small and medium-sized enterprises (SMEs), which often lag behind due to limited resources (financial, human, time, knowledge). To support SMEs in understanding how to manage and utilize data effectively we propose a data maturity assessment multiple-cirteria model. Important criteria were identified from the literature and have been validated through semi-structured interviews with seven Slovenian SMEs. The results suggest some new criteria to describe the data maturity, relevant to Slovenian SMEs.

Keywords:
data,
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data maturity criteria,
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1 Introduction

In today's society, there is an increasing focus on the transition from traditional to digital business, dictated by rapid and constant changes in the business environment and in society in general. The driving force of these changes is digital transformation, which leads organizations to a new way of doing business, changes in business processes, development of new products and services, and new business models (Kraus et al., 2021). An important part of digital transformation is also the data that the organization creates and captures throughout the business process. Data is the foundation of any information system, and its effective control and management is becoming increasingly important due to its exponential growth. According to the European Commission, organizations that invest in data-driven innovation experience 5% to 10% faster growth (European Commission, 2022). Access to, control and management of data is thus becoming an increasingly important strategic resource and a necessity for the further organizations' development. While large enterprises usually have a clear overview of their data and well-organized data management, small and medium-sized enterprises (SMEs) usually lag behind in this endeavor, as they often have limited human, financial and knowledge resources. To help enterprises assess their level of maturity in data management, a number of data maturity assessment models have been developed and proposed. Current data maturity assessment models are not tailored to SMEs, since they are too extensive or incomplete in the number of criteria proposed, too complex in their structure, or focused on large enterprises. Therefore, there is a need to develop a new data maturity assessment model, that will be tailored to SMEs and will include an appropriate set of criteria that SMEs can use to systematically and comprehensively assess data maturity.

In this paper, we present the results of data maturity criteria validation based on seven Slovenian SMEs. To obtain the results, we followed a design science research approach (Hevner, 2007) and conducted semi-structured interviews (Adams, 2015). Based on the interviews conducted with the SMEs, we will develop a final list of criteria and data maturity assessment scales that will represent the basis for development of a data maturity multi-criteria assessment model for SMEs.

2 Theoretical findings

The previous literature on data maturity models is disperse and focuses on different fields, from data maturity models for the public sector and Open Government (Çaldağ & Gökalp, 2022; Okuyucu & Yavuz, 2020; Rahmatika et al., 2019), to Big Data (Coleman et al., 2016; Comuzzi & Patel, 2016) and data analytics (Mach-Król, 2022), data-driven logistics (Muehlbauer et al., 2022), and data-driven decision making (Nijzink, 2020). Further, we present a few papers that are often cited in the field of data maturity.

(Comuzzi & Patel, 2016) developed a maturity model that would help organizations to generate and appropriate value from Big Data. The proposed model assess the data maturity through five main domains: Strategic alignment (Strategy); Organisation (People and Culture); Governance; Data (management and data analytics) and Information technology (IT infrastructure). The limitation of the proposed model is that it does not provide specific suggestions on what steps an organization should take to improve Big Data maturity and the capabilities mentioned above. The model also lacks some of the criteria for a comprehensive assessment of data maturity, such as data quality, data security, use of data to support decision making, etc.

(Coleman et al., 2016) proposed a Big Data maturity model specifically for SMEs to advance in data maturity and also proposed recommendations. The model assess the data maturity through seven domains: business strategy; data management; people and analytical skills; technological infrastructure; enterprise adoption (engagement in data-centric management) and data governance. Although the proposed model is intended for SMEs, it focuses on data analytics, which is only one of the elements needed for a comprehensive data maturity assessment. (Peña et al., 2018) proposed a data maturity model for the SMEs in a healthcare sector, using the ELECTRE methodology, based on the ISO 15504. The assessment of data maturity is based on the four data maturity domains: people (human resources), processes, technology and data. The structure of the model is more difficult for SMEs to understand, since it is based on the set of mathematical expressions and operations. It is also not clear how SMEs have organized data storage, whether there is organized any training in the data management field and what is the level of awareness and mindset of employees related to data management, which represent an important part of organizational culture and a basis for a comprehensive data maturity assessment.

3 Problem definition

The fundamental problem is that the majority of SMEs do not exploit the potential of data for decision-making, which translates in a lower responsiveness to the dynamic demands of the environment and lower competitiveness. Although various software solutions are available to organizations (enterprise software solutions (ERP and CRM), human resource management (HRM) solutions, document systems) that allow them to manage the data generated during the execution of business processes, the implementation of such solutions is still low (SURS, 2021). The implementation and use of business software solutions is the basis for being able to capture, manage, share and store data. This ensures the entire lifecycle of data management, otherwise a comprehensive approach to data management is not possible. Since SMEs usually lack resources (financial, human, time, skills), they need a comprehensive, systematic and easy-to-use tool to help them assess the state of their data and understand the next steps to data maturity. For a comprehensive assessment of an organization's data maturity, several criteria must be considered: Use of digital technologies and software solutions, data quality, data security, organizational culture, human resources, strategy, data lifecycle, use of data for decision making and others. Therefore, we need to consider data maturity as a multi-criteria problem.

4 Methodology

As a research approach, we followed a design science research (DSR) (Hevner et al., 2004) (Figure 1). The final solution will be a developed IT artifact – in our case, a data maturity assessment model for SMEs. Design science research refers to the iterative sequence of expert activities, to produce an innovative product (artifact).

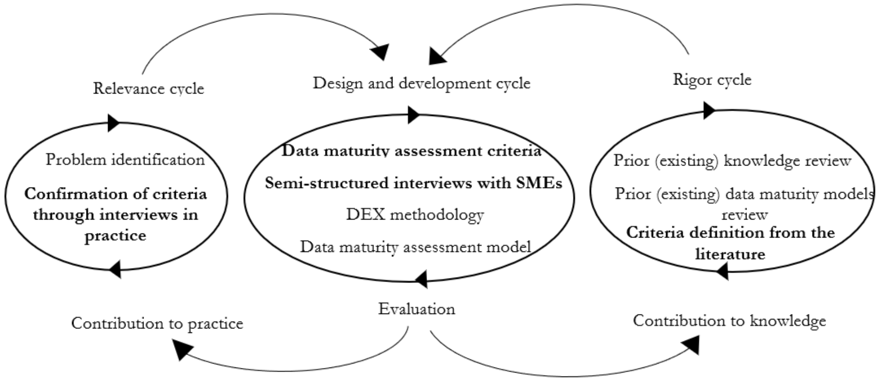

Figure 1: Methodology process - adapted from
(Hevner, 2007)

Based on the literature review, we defined a preliminary list of criteria to be used to assess the data maturity of SMEs (rigor cycle). After formulating a preliminary list of criteria, we prepared the interview questions. We used a semi-structured interview, as this allowed us to include additional questions that were initially not planned. Based on the literature reviewed that addressed the data maturity assessment of the SMEs and the prepared preliminary list of criteria, we defined the interview questions and conducted the semi-structured interviews with a total of seven SMEs. Before conducting the interviews, we obtained information about each SME from the SME website, such as the their business area, number of employees, and whether they had a social media presence, which helped us to define the final list of interview questions for the criteria validation. After interviewing the SMEs, we prepared a transcript of each interview and analyzed the results. The findings obtained from the interviews represent the results of the validation of the data maturity criteria and the feedback to our existing knowledge and literature (relevance cycle).

5 Preliminary/Expected results and future developments

5.1 Preliminary results

In the following, we present the results of data maturity criteria validation of the 7 interviewed SMEs (SMEs A to G), of which one is micro-sized (SME A), three are small (SMEs E, F, and G) and three are medium-sized enterprises (SMEs B, C, and D). The interviewed SMEs operate in different business sectors – telecommunication (SMEs A and B), manufacturing (SMEs C, E, F and G) and healthcare sector (SME D). The results of the criteria validation are presented in Tables 1 through 7. The (X*) in Tables (1-7) indicates that the SMEs are either using only partial solutions (i.e. Internet of Things only) or the implementation of solution (i.e. e-business implementation) is still in the planning phase.

Validation of criteria presented in Table 1 shows that criteria related to the implementation of Microsoft solutions (e.g. Office 365) and e-signing proved irrelevant for assessing the data maturity of SMEs. Since all interviewed SMEs use the Microsoft Office software, we can not identify any significant differences that would indicate how data mature each of the interviewed SME is based on the use of the Microsoft solutions. In this context this criterion is irrelevant and will be removed for data maturity assessment. Similarly, the criterion of e-signing implementation is irrelevant as it can be integrated as part of e-business and also does not help us to differentiate the data maturity level of the SMEs.

Table 1: Use of digital technologies and software solutions by SMEs

	SMEs						
Technologies & software solutions	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Accounting programs	X	X	X	X	X	X	X
Human resource (HR) management software solutions		X	X	X	X	X	X
Enterprise software solutions (ERP, CRM)		X	X	X*	X	X*	X*
Microsoft Office – i.e. Office 365, Office 2019	X*	X	X	X*	X	X	X
Document system		X	X	X	X	X	
Sales and marketing programs		X	X	X	X		
Basic programs for data analysis - Excel		X	X		X	X	X
Programs for data analysis - internal program (own solution)				X		X	
Advanced data analytic programs – i.e. Microsoft Power BI, Tableau, SAS BI, Qlik Sense			X		X		
Social media (i.e. Facebook, LinkedIn, Instagram …)	X	X	X	X	X	X	X
Advanced technologies (Artificial intelligence, high performance computing (HPC), digital twin, Internet of Things, robotics)		X*	X*		X*	X*	
Implementation of E-business	X*	X	X	X*	X*	X	X*
Implementation of E-signing		X	X	X	X	X	

The interview results related to data lifecycle criteria (Table 2) show that SMEs are not yet fully exploiting the potential and value of the data they have. One of the most relevant criterion to assess the data maturity of SMEs is data innovation, but the results show that the main use of data is still focused on supporting the day-to-day business operations. Innovation based on data or data-driven innovation (Babu et al., 2021) refers to the new value creation based on data, such as conducting market analyses for particular products, adaptation to the market and to customers, development, upgrade and introduction of new products and services, improving the competitive nature of organization. Therefore, data innovation is most important criterion to include for data maturity assessment.

During the SME interviews, we found that SMEs prefer to store their data within the company, and are less willing to use cloud services to store their data. Nevertheless, the criterion of data storage is important in assessing SMEs' data maturity, as it can show different maturity levels of SMEs, from those that still store their data on paper or only on their computers, to those that are more mature and also use cloud solutions. The validation also revealed that an SME that has a document system may also have electronic archiving. Despite the fact that electronic archiving is part of the document system, it is important to consider it as an independent criterion. The distinction according to the level of archiving (paper archiving, digital archiving, certified digital archiving) shows how mature an SME is in this context and is therefore a relevant criterion for evaluating the data maturity of SMEs.

Table 2: Data lifecycle by SMEs

	SMEs						
Data lifecycle	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Internal data capture	X	X	X	X	X	X	X
External data capture (publicly available data)	X*	X	X	X*	X*	X	X*
Data Capture - Social Media					X		
Data storage - company servers	X	X	X	X	X	X	
Data storage - NAS server	X	X		X		X	
Data storage - cloud		X	X		X		
Data analysis - Excel		X	X		X	X	X
Data analysis - internal program				X		X	
Data analysis - advanced tools (e.g. PowerBI)			X		X		
Data analysis - Social networks (Facebook, LinkedIn, Instagram)					X		
Data use - support of business and daily activities	X	X	X	X	X	X	X
Data use - development of new products and services					X	X	
Data use - market trends predictions				X		X	
Data use - strategic level		X	X			X	
E-archiving			X	X	X*	X	

The reporting of data is another criterion to consider as it differentiates the SMEs from those who only report on data that is mandatory by the legislation, such as report on packaging and financial data (taxes, financial records) and those who alredy report data related to sustainability. The case of SME F has shown a need to include an additional criterion related to regulation and the sustainability aspect (i.e. reporting on CO_2 consumption), that we need to consider for a comprehensive data maturity assessment of SMEs.

Table 3: Data security implementation by SMEs

		SMEs						
		A	**B**	**C**	**D**	**E**	**F**	**G**
Data security	Care for data security - each individual							X
	Care for data security - own IT department							
	Care for data security - person (administrator)		X		X	X	X	
	Care for data security - external contractors (outsourcing)		X	X	X*		X	
	Security mechanisms - backup copies of data and documents	X	X		X		X	X*
	Data access - granted appropriate rights to access data		X		X	X	X	
	Information security policy			X	X	X	X	

Regarding data security (Table 3), none of the SMEs have an employee or IT security expert specifically responsible for data security, and the majority of SMEs prefer external contractors (outsourcing). The results of the criteria validation showed that the first criterion related to care for data security (care for data security - each individual) seem to be not relevant, as only one SME (SME G) stated that it has no one to take care of data security and that is the responsibility of each individual. But from the view of assessing the data maturity of SMEs, it can show the differences in the organization and appointment of the roles (i.e. each individual, data security administrator, IT department, data steward).

Table 4: Data quality strategy and data quality review results by SMEs

		SMEs						
		A	B	C	D	E	F	G
Data quality	Establishment of a data quality strategy			X		X	X	
	A formally written strategy for data quality					X	X	
	Data quality review			X*	X	X	X	
	Data quality assessment				X	X	X	

Data quality is one of the most important criteria to ensure accurate decisions based on validated data. Although the validation results of the data quality criteria in Table 4 appear to be less relevant to SMEs, all criteria must be included to obtain a comprehensive data maturity assessment.

Table 5: Establishement of data management strategy and investments in data management by SMEs

		A	B	C	D	E	F	G
Data management strategy	Established data management strategy					X		
	A formally written data management strategy					X		
Investments	Information infrastructure investments	X	X	X	X	X	X	X
	Data management investments					X		X

The results in Table 5 show that the criteria related to data management strategy and investment in data management do not seem to be so relevant when assessing SMEs' data maturity, as only one SME (E) indicated that it already has this data aspect in place and attaches high importance to it. Only one other SME (SME G) indicated that they always use part of their investments specifically for improving data management. Despite the fact that the majority of SMEs only invests in information infrastructure, it is important to also consider the investments in data managent and to start implementing a data management strategy, either as part of the business strategy as this is a fundamental basis for the transition to a data-driven enterprise as indicated by (Davenport & DalleMule, 2017).

Table 6: Organizational culture and human resources by SMEs

		A	B	C	D	E	F	G
Organizational culture	Awareness of efficient data management	X*	X*	X*	X*	X	X	X*
	Spreading the culture of efficient data management among employees		X*	X*		X	X	
Human resources (HR)	Education and training in the field of data management			X	X*	X	X	
	Encouragment of employees for better data management	X	X	X		X	X	X
	Open communication	X	X	X	X	X	X	X
	External contractors - involved		X	X*	X		X	X*
	External contractors - not involved	X				X		

The results of Table 6 show that 4 out of 7 interviewed SMEs organize training and education for their employees so that they can better manage their data and acquire additional skills. This indicates that organizing training and educadion on data management is an important criterion to consider, even though interviewed SMEs currently educate their employees mainly on how to use Excel. The criterion of open communication is highly relevant, as the results in Table 6 show that open communication is present in all 7 interviewed SMEs, and for this reason must be considered when assessing SMEs' data maturity.

From the results in Table 7, SMEs are beginning to consider the use of data at a strategic level as well, but they agree that intuition and experience must also be considered. In the case of SME C, they are particularly committed to basing their decisions on data. The director of SME C stated that 70% of strategic decisions are based on data and the remaining 30% are based on soft factors, reflecting the environment and employee attitudes. The situation is similar in SME F, where the percentage of data-driven decisions is 50%. Other SMEs are not yet ready to adopt this mindset. When we asked SMEs whether they have adequate data when making strategic decisions, the answers were mixed. Three of seven SMEs interviewed (C, D and F) stated that the data are adequate. In the case of SME A and B the adequacy of data for strategic decisionsis is not so relevant. At the moment they are more focused to provide the data to support the operating of the business and then start to build from that point further. Based on this observations the criterion related to the adequacy (relevance) of data for decision-making is important to include for assessing the data maturity of SMEs.

Table 7: Establishment of data-driven decision making on strategic level

		A	B	C	D	E	F	G
Decision making (strategic decisions)	Intuition-driven decision making							
	Intuition-driven + data-driven decision making	X*	X	X	X	X	X	X*
	Data-driven decision making							
	Data sources for decision-making - CRM, ERP			X	X*	X	X	X*
	Data sources for decision-making- (from Excel)	X	X	X	X	X	X	
	Data sources for decision-making (Geographic information systems (GIS)		X					
	Adequacy of data in decision-making	NR	NR	X	X	X	X	X*

NR – Not relevant

5.2 Expected results and future developments

The semi-structured interviews we conducted with the seven SMEs revealed opportunities for the inclusion of new criteria, such as those related to regulation and the sustainability aspect (i.e. reporting on CO2 consumption, packaging) and the need to remove some of the currently proposed criteria (i.e. e-signing, implementation of Microsoft Office solutions). Since only the results of 7 interviewed SMEs are presented, we expect to add additional criteria or remove some of the currently proposed criteria in future research, as shown by the results of the criteria validation in this paper. In future research, we will focus on formulating the final list of data maturity criteria for SMEs and finalising the definition of the measurement scales, which will help us develop the first version of a multi-criteria data maturity model for SMEs. We expect that we will need to develop the model in several iterations before the final version.

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References

Adams, W. (2015). Conducting Semi-Structured Interviews. In J. Wholey, H. Hatry, & K. Newcomer (Eds.), Handbook of Practical Program Evaluation (4th ed.). Jossey-Bass. https://doi.org/10.1002/9781119171386.ch19

Babu, M. M., Rahman, M., Alam, A., & Dey, B. L. (2021). Exploring big data-driven innovation in the manufacturing sector: evidence from UK firms. Annals of Operations Research, 1–28. https://doi.org/10.1007/S10479-021-04077-1

Çaldağ, M. T., & Gökalp, E. (2022). The maturity of open government data maturity: a multivocal literature review. Aslib Journal of Information Management, 74(6), 1007–1030. https://doi.org/10.1108/AJIM-11-2021-0354

Coleman, S., Göb, R., Manco, G., Pievatolo, A., Tort-Martorell, X., & Reis, M. S. (2016). How Can SMEs Benefit from Big Data? Challenges and a Path Forward. Quality and Reliability Engineering International, 32(6), 2151–2164. https://doi.org/10.1002/QRE.2008

Comuzzi, M., & Patel, A. (2016). How organisations leverage Big Data: a maturity modl. Industrial Management & Data Systems, 116(8), 1468–1492. https://doi.org/10.1108/IMDS-12-2015-0495

Davenport, T. H., & DalleMule, L. (2017). The 2 Types of Data Strategies Every Company Needs. Harvard Business Review. https://hbr.org/2017/05/whats-your-data-strategy

European Commission. (2022). Data Act. https://digital-strategy.ec.europa.eu/en/library/data-act-factsheet

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design Science in Information Systems Research. MIS Quarterly, 28(1), 75–105. https://doi.org/10.2307/25148625

Kraus, S., Jones, P., Kailer, N., Weinmann, A., Chaparro-Banegas, N., & Roig-Tierno, N. (2021). Digital Transformation: An Overview of the Current State of the Art of Research. SAGE Open, 11(3), 21582440211047576. https://doi.org/10.1177/21582440211047576

Mach-Król, M. (2022). Conceptual Framework for Implementing Temporal Big Data Analytics in Companies. In Applied Sciences (Vol. 12, Issue 23). https://doi.org/10.3390/app122312265

Muehlbauer, K., Wuennenberg, M., Meissner, S., & Fottner, J. (2022). Data driven logistics-oriented value stream mapping 4.0: A guideline for practitioners. IFAC-PapersOnLine, 55(16), 364–369. https://doi.org/https://doi.org/10.1016/j.ifacol.2022.09.051

Nijzink, H. J. (2020). Data-driven Decision-making Maturity. http://essay.utwente.nl/85376/

Okuyucu, A., & Yavuz, N. (2020). Big data maturity models for the public sector: a review of state and organizational level models. Transforming Government: People, Process and Policy, 14(4), 681–699. https://doi.org/10.1108/TG-09-2019-0085

Peña, A., Bonet, I., Lochmuller, C., Tabares, M. S., Piedrahita, C. C., Sánchez, C. C., Giraldo Marín, L. M., Góngora, M., & Chiclana, F. (2018). A fuzzy ELECTRE structure methodology to assess big data maturity in healthcare SMEs. Soft Computing, 23(20), 10537–10550. https://doi.org/10.1007/S00500-018-3625-8

Rahmatika, M., Krismawati, D., Rahmawati, S. D., Arief, A., Sensuse, D. I., & Dzulfikar, M. F. (2019). An Open Government Data Maturity Model : A Case Study in BPS-Statistics Indonesia. 2019 7th International Conference on Information and Communication Technology (ICoICT), 1–7. https://doi.org/10.1109/ICoICT.2019.8835352

SURS. (2021). Elektronska izmenjava informacij znotraj podjetij, po velikosti podjetij glede na število zaposlenih in samozaposlenih, Slovenija, letno. https://pxweb.stat.si/SiStatData/pxweb/sl/Data/-/2965311S.px/table/tableViewLayout2/

36TH BLED ECONFERENCE DIGITAL ECONOMY AND SOCIETY: THE BALANCING ACT FOR DIGITAL INNOVATION IN TIMES OF INSTABILITY

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The Bled eConference, organised by the University of Maribor, Faculty of Organizational Sciences, has been shaping electronic interactions since 1988. The theme of the 36th conference is "Digital Economy and Society: The Balancing Act for Digital Innovation in Times of Instability". In times of instability, which include political, economic, resource, health, and environmental challenges on the one hand, and technological disruption on the other, it is critical to ensure that digital innovation continues to lead to the right and sustainable solutions that are tailored to the needs of all people, enterprises and society. It is very important to keep in mind the protection of our planet, including fauna and flora. These efforts include adopting appropriate regulatory frameworks, fostering digital literacy and skills development, promoting inclusive access to digital technologies, and addressing the ethical, social and environmental implications of digital transformation. The papers in this conference proceedings address digital transformation of enterprises, artificial intelligence and data science solutions, decision analytics for business and societal challenges, new, digital and data driven business models, digital consumer, digital education, digital health, digital ethics, restructured work and solutions for smart and sustainable cities. We continue to provide an open forum for academia, including students, industry, and policy makers where everyone can contribute to creating a better world.

Keywords: digital economy, digital society, digital transformation, digital innovation, instability, balancing

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