Environmental Assessment: Integration of Carbon footprint

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Due to the rise in population numbers the standard of living and the subsequent growth in human activities and production, environmental concern is intensifying and the current linear economy is becoming unsustainable. The idea of an environmentally conscious (green) supply chain management first began in the early 1970s; however, a systematic approach is still lacking today. The focus of this chapter is therefore to gain a clearer insight into environmental assessment for efficient greening of supply chains, to raise importance of the life cycle thinking and decarbonisation and to study and discuss the use of methods for environmental impact assessment. Comprehensive assessment of environmental impacts is crucial for supply chain managers to enable them to better understand the importance of environmentally sound business models while also emphasising sustainable development for the resilient future of decarbonisation since human activities are a major contributor of carbon dioxide and other greenhouse gases. Carbon footprint identifies and measures the impact and enables systematic minimisation of emissions from company's processes and business.

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1 Introduction

Due to the growing population, rising living standards, and the consequent increase in human activities and production, environmental concerns are becoming increasingly important. It is becoming clear that our planet can no longer regenerate itself and that resources are not being used sustainably (Obrecht & Knez, 2017). Since individual activities seriously impact upon the environment both locally and globally, environmental considerations are being increasingly integrated into economic activities. There is a prevailing belief that environmentally conscious and more sustainability-oriented practices can provide organizations with a competitive advantage, especially in the long term (Plouffe et al., 2011; Albino et al., 2009; Dangelico et al., 2017; Gerstlberger et al., 2014).

An extensive body of data has demonstrated that the current linear economy is unsustainable. Population growth and rising living standards demand increasing extraction of materials and higher consumption of food, water, and energy. As a result, the prices of these materials are rising, arable land and forests are disappearing, the long-term availability of clean water is becoming uncertain, and biodiversity is rapidly changing (The 2030 Water Resource Group, 2009; Alexandratos & Bruinsma, 2012; International Energy Agency, 2017). Given the projected trends, environmentally friendly economic models–such as the circular economy, life cycle-based eco-design, and sustainable supply chains–are expected to become not only a source of comparative advantage in achieving competitive strategies but also a potential response to anticipated socio-economic challenges in the coming decades (Bešter, 2017), as well as a systemic solution for the sustainable survival of the human species (Širec et al., 2018).

However, focusing on the environmental aspect in only one part of the supply chain (SC) is not sufficient for achieving effective improvements. Environmental impacts occur throughout the entire supply chain–from raw material extraction, production of materials and components, manufacture of the final product, its distribution and use, all the way to the end of its life cycle. A review of the literature shows that environmental goals, such as the EU's 20/20/20 targets, cannot be achieved solely through inter-organizational activities and measures but require collaboration along the entire value chain by leveraging synergies among supply chain stakeholders (Szegedi et al., 2017). For this reason, environmental management schemes (e.g., ISO 14001 or EMAS) also include the participation of various stakeholders across the entire supply chain. The complexity of sustainable supply chains, the circular economy, and eco-design call for collaboration among diverse stakeholders at multiple levels–making a systemic approach essential. Business leaders must recognize that economic and environmental goals are not mutually exclusive but can be achieved simultaneously (Preston, 2012; Lieder & Rashid, 2016; Ghisellini et al., 2016).

The concept of environmentally conscious (green) supply chain management (SCM) first appeared in academic literature in the early 1970s. The integration of the disciplines of green business practices and complex supply chains–including procurement, production, and logistics–gained prominence in the 1990s, particularly in the automotive industry (Szegedi et al., 2017). Many organizations still perceive their environmental impact very narrowly, typically limiting it to production activities at individual manufacturing sites (Ammenberg & Sundin, 2005). In contrast, one of the key trends in sustainability programs in industrialized countries is so-called life cycle thinking, which shifts the focus from the production site to various environmental and social factors associated with a product throughout its entire life cycle (UNEP, 2006). Life cycle thinking is based on the principle of pollution prevention, which aims to reduce environmental impacts at the source and to close the loop of materials and energy (European Commission, 2014). All products and services have a certain environmental impact, which can occur at any–or all–stages of a product's life cycle, including raw material extraction, production, distribution, use, and waste disposal (Denac et al., 2018). Companies with more developed traditional supply chains also tend to have more advanced green supply chain management (GSCM) systems (Szegedi et al., 2017).

It is also clear that commitment to eco-design and sustainable development within an organization is a key factor for driving improvements, while environmental labels serve as a powerful tool for communicating with consumers–particularly those with a green orientation. Since business leaders are inherently interested in achieving business benefits alongside environmental improvements, environmental labels are a persuasive means of achieving both. On the one hand, they help enhance the company's image, attract environmentally conscious consumers, compete in green public procurement, differentiate in highly competitive markets, and reduce fees for waste or the use of hazardous substances. On the other hand, they also deliver direct environmental benefits–such as lower material and energy consumption, reduced waste generation, improved efficiency, and decreased water usage.

The aim of this chapter is to provide a better understanding of the greening of supply chains, to emphasize the importance of the life cycle principle for supply chain managers, and explore and discuss the use of various methods, principles, and tools such as carbon footprint, eco-design, and environmental labels in supply chain management. Therefore, case studies of best practices in life cycle assessment and eco-design related to carbon footprint are presented in order to enhance our knowledge of environmental issues and incorporate it into supply chain management. A comprehensive collection of such tools, principles, methods, and real-world problem-solving examples is crucial for supply chain managers, as it enables them to better understand and appreciate environmentally friendly business models and underscores the importance of sustainable development for businesses as well.

2 Integration of the life cycle concept into supply chain management

Organizations are increasingly aware of their environmental impacts and are taking measures to reduce these impacts by incorporating cleaner production within the organization, improving energy efficiency to reduce energy consumption among end consumers, optimizing transportation and distribution, or dematerializing production to reduce costs. Due to the growing energy shortages, particularly in the EU, Cerovac et al. (2014) point out that it is not only the amount of energy used in production that matters, but also the mix of energy sources used within the supply chain. However, all of these measures are partial and do not cover all the environmental impacts associated with a company's supply chain. Rising material costs, linked to resource depletion, stricter environmental regulations–especially in the EU–and increasing consumer environmental awareness are driving companies to adopt more comprehensive measures. When discussing sustainable supply chains, supply chain managers must consider all stages of the product life cycle, which include not only individual links in the supply chain but the entire supply chain. If only production, logistics, or the use of a particular product are considered, only partial environmental burdens can be identified. Such analyses can be misleading and may not address the most significant environmental impacts, making it impossible to implement the most appropriate environmental improvements. This idea is the core principle of life cycle thinking, which means that environmental impacts should be considered at all stages of the life cycle, including raw material sourcing, production, distribution, use, and the end-of-life phase, which in supply chain management (SCM) is often linked to reverse logistics. The emphasis is on incorporating comprehensive environmental burdens and addressing them according to their significance throughout the entire supply chain. The challenge here is that life cycle thinking requires collaboration from all stakeholders/members of the supply chain and can be particularly problematic for small and medium-sized enterprises (SMEs) that do not have enough bargaining power with larger and stronger suppliers. Nevertheless, it must be clear that sustainable production and consumption can be achieved through both bottom-up and top-down approaches or by implementing new business models (Lukman Kovačič et al., 2017), meaning that this is not only the responsibility of top management but a commitment from the entire organization.

2.1 Life cycle stages of a product or process

To design environmentally friendly products or services, it is essential to first assess their environmental impact throughout the entire life cycle. Life Cycle Assessment (LCA) has often been defined as the appropriate method for comprehensively evaluating the environmental impacts of a given product, as it assesses environmental impacts at all stages of the life cycle and provides a good overview of numerous environmental impacts that may not be immediately apparent. However, due to the large volume of data required and included in LCA, it is an extremely complex and time-consuming method for evaluating environmental impacts (Obrecht & Knez, 2017).

Figure 1 illustrates the life cycle stages of products and the system boundaries of LCA, focusing on all the major stages of the life cycle. Only after defining and assessing the environmental impacts throughout the entire life cycle can companies identify which impacts in their supply chain are most critical and begin to work towards environmental improvements or completely avoid these impacts. Typically (but not necessarily), the most common solution is to start optimizing the stages with the greatest environmental impact and those that seem to offer the most potential for savings.

LCA is the only standardized method (in the ISO 14000 series) for assessing environmental impacts throughout the entire life cycle. However, LCA alone is just the first step toward more environmentally friendly supply chains, as it only reveals environmental impacts without reducing them. The next step is, for example, the use of eco-design or similar tools that enable the reduction of environmental impacts identified through the environmental assessment. The essence of the life cycle perspective for most manufacturers is that their obligations are expanded and their (environmental and legal) responsibility does not end at the factory gates.

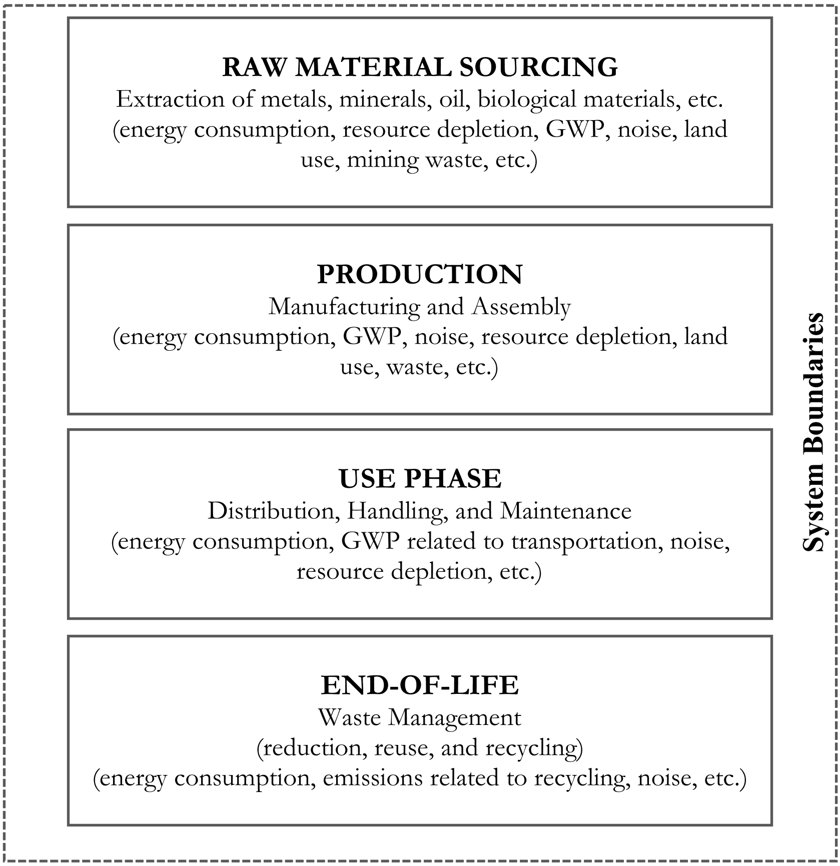

Figure 1: Lifecycle stages and system boundaries of the life cycle approach
Source: own

Case Study 2

IBM's and Apple's efforts to initiate life cycle thinking

IBM proposed an initiative based on the Electronics Industry Code of Conduct (EICC) to empower its partners in the market channels to adopt environmental measures. This meant that they did not focus solely on their own organization but sought to encourage the entire supply chain, across all stages of the product life cycle, to make improvements and become more transparent in presenting their environmental impacts to public stakeholders. They proposed four goals that their suppliers must meet, specifically:

- definition and implementation of an **Environmental Management System** (EMS);
- **measuring** existing environmental impacts and setting goals for their improvement;
- **public disclosure** of their parameters and also the results of the analysis;
- **"cascade"** these improvement requirements to all suppliers who are material suppliers of their (IBM's) products/components.

With this concept, they can trace the footprint of each phase of raw material extraction and product manufacturing, thereby influencing the potential for improving the environmental impact throughout the entire supply chain. Senior executives are aware that an environmentally friendly business development path is a legal obligation, and it is becoming increasingly profitable.

Since environmental analyses are often expensive and time-consuming, and their interpretation requires certain prior knowledge of environmental assessment methods, environmental impacts, company processes, etc., organizations are establishing departments and hiring experts capable of integrating the concepts of lean, smart, and green supply chains. They also focus on identifying and reducing environmental burdens beyond the walls of the company, thus adopting a life cycle thinking approach. Apple has already done this and reported its results in a consumer-friendly and straightforward way, as shown in Figure 2.

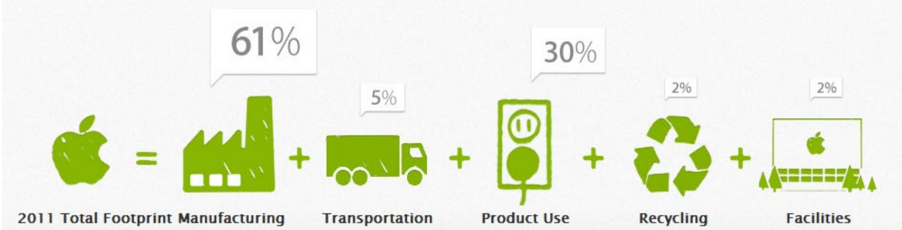

Figure 2: Apple's communication with stakeholders on environmental impacts with an integrated life cycle perspective

Source: summarized by Apple, 2012

3 Carbon footprint

Carbon footprint is a measure used to estimate the amount of greenhouse gases emitted into the atmosphere by an individual, organization, or society through their activities, processes, and operations. It is expressed in mass units, typically in tons of CO2 equivalent (CO2eq).

The background of carbon footprint calculation is based on the understanding that human (anthropogenic) activity is the primary cause of most environmental challenges. The most prominent cause is the use of fossil fuels (such as coal, oil, and gas) and other sources associated with the release of greenhouse gases (GHGs). The increasing concentration of these gases has long-term negative consequences for the climate, such as global warming, changes in precipitation patterns, sea level rise, ocean acidification, desertification, and more.

In order to adapt to and mitigate the effects of climate change, the interest in reducing greenhouse gas (GHG) emissions is recognized at various levels and promoted through international agreements (e.g., the Paris Climate Agreement) and EU-level regulations (e.g., formerly the IPPC Directive, and from 2024 onwards, the Corporate Sustainability Reporting Directive – CSRD). However, to reduce GHG emissions, we must first understand the emissions generated by a specific product, process, organization, or individual. Carbon footprint is a measure of GHG emissions that should also incorporate the life cycle perspective–meaning it should account for total GHG emissions throughout the lifetime of a product, for example–from raw material extraction to processing/reuse after the end of its primary life.

The calculation of a carbon footprint involves identifying and quantifying all sources of greenhouse gas emissions generated by an individual, organization, or process. These sources can include direct emissions, such as those from transportation and manufacturing facilities, as well as indirect emissions resulting from electricity production, transportation, product manufacturing, and other activities. The calculation is carried out using various methodologies based on emission factors, energy consumption data, emissions from specific sources, and other parameters. For an accurate assessment, it is important to consider the entire life cycle of a product or service, including production, transportation, use, and waste disposal or end-of-life reuse.

The calculation and presentation of the carbon footprint are also crucial steps in raising awareness about negative climate impacts and identifying opportunities for their reduction. By measuring their carbon footprint, individuals, companies, and organizations can be encouraged to adopt measures to reduce greenhouse gas emissions, such as improving energy efficiency, using renewable energy sources, making changes in production and consumption patterns, adopting sustainable mobility, or substituting energy-intensive materials with less resource-intensive alternatives.

In the EU and around the world, the most widely recognized framework in recent years has been the so-called GHG Protocol Standard, which is a globally accepted framework for measuring and reporting corporate greenhouse gas (GHG) emissions. It provides guidelines and principles for companies to measure, quantify, and report GHG emissions and to improve their performance in a consistent and transparent way.

Developed by the World Resources Institute (WRI, 2012), the standard helps companies understand their own carbon footprint and manage emissions effectively. It contains a set of guidelines and methodologies that establish a common language and approach for measuring GHGs.

The GHG Protocol Standard for measurement and reporting includes three main scopes:

Scope 1: direct GHG emissions: this includes emissions from sources that are owned or controlled by the organization, such as fuel combustion in company-owned vehicles or emissions from on-site production facilities.

Scope 2: indirect GHG emissions are from purchased electricity, heat, or steam. These are emissions associated with the generation of purchased energy that is consumed by the organization.

Scope 3: other indirect GHG emissions. These emissions occur along the value chain or depending on the activities of the organization, such as emissions from the supply chain, transportation, employee commuting, and the use and disposal of products. These emissions are not mandatory to report but they can often be higher than those under Scope 1 and Scope 2.

The GHG Protocol provides specific methodologies and guidelines for calculating emissions in each area, including emission factors, data collection approaches, and reporting requirements. Tracking enables organizations to accurately measure and report GHG emissions, set emission reduction targets, and implement strategies to reduce their environmental impact.

The GHG Protocol Standard has become a widely accepted framework for corporate sustainability reporting and is used worldwide for monitoring emissions.

3.1 Advantages and disadvantages of carbon footprint calculation

Advantages of carbon footprint calculation:

1. Identification of key emission sources. Calculating the carbon footprint helps identify the key sources of greenhouse gas emissions. This enables targeted efforts to reduce emissions, as it allows organizations to focus on sectors or activities that have the greatest impact on the carbon footprint.
2. Awareness and education. Calculating the carbon footprint enables individuals, companies, and organizations to become aware of their contribution to climate change. This promotes awareness of their environmental and climate impact, which is the first step toward taking actions to reduce their impacts and their carbon footprint.

3. Monitoring progress. Calculating the carbon footprint allows for monitoring progress in reducing emissions over time. By comparing past data with current figures, it is possible to determine whether emission reduction efforts are improving or not, and adjust strategies as needed.
4. By comparing past data with current figures, we can determine whether the implementation of measures to reduce impacts (emissions) is improving or not, and adjust strategies and actions as needed.

Despite the advantages, it is important to also highlight the shortcomings:

1. The carbon footprint focus is solely on GHG emissions, which constitutes just one of many potential impacts that a particular process, product, organization, or individual can have on the environment.
2. It does not consider water consumption, land use, eutrophication, carcinogenicity, radiation, which are included in more comprehensive environmental assessments, such as Life Cycle Impact Assessment (LCIA).
3. Sometimes, the calculation requires large amounts of data and complex conversion factor methodologies, which can be difficult for employees in organizations not directly involved in the field to understand. A particular challenge is obtaining accurate and reliable data for the entire life cycle of a product or service.
4. Lack of standardization. There is a lack of uniform standards and methodologies for calculating the carbon footprint, which can lead to inconsistent results between different calculations. This can make comparisons between entities difficult and hinder effective monitoring of progress.
5. Disregard for indirect effects. The carbon footprint calculation focuses on direct greenhouse gas emissions but may overlook other indirect effects (i.e., "Scope 3"). This is voluntary, even though it can sometimes be more significant than direct emissions and limits the transparency and comprehensiveness of such environmental assessments.

Despite its weaknesses, carbon footprint calculation remains one of the leading tools for assessing environmental impacts. Methodologies are being developed, supplemented, and procedures standardized, which means that in the future, it will become more reliable, and consequently, results will be more comparable. This will enable us to move towards climate-responsible practices.

Different greenhouse gases (GHGs) have different global warming potential (GWP) factors. GWP, or "Global Warming Potential," is defined based on their impact on atmospheric warming over a 100-year period compared to carbon dioxide (CO2), whose GWP factor is 1. These factors are used to convert emissions of various greenhouse gases into equivalent CO2 emissions for easier calculation of their impact and for comparing them. The most commonly used GWP factors for frequent GHGs are shown in Table 1.

Table 1: Most commonly used GWP factors of common GHGs

TGP	GWP	Note
Carbon dioxide (CO2)	1	This value is used as a reference point for comparison with other greenhouse gases.
Methane (CH4)	21	This means that its impact on atmospheric warming is 25 times stronger than that of CO2 over a 100-year period.
(Dinitrogen) oxide (N2O)	310	This means that its impact on atmospheric warming is 298 times stronger than that of CO2 over a 100-year period.
Sulfur hexafluoride (SF6)	23.900	Extremely high, 23,500 times stronger than CO2.
Chlorofluorocarbons (CFC)	Extremely high, ranging from 4,470 to 10,720.	CFCs are potent greenhouse gases that were commonly used in industry in the past.

Source: IPPC, 1995

4 Conclusion

Carbon footprint calculation is one of the tools for assessing environmental impacts, which includes the identification and quantification of all sources of greenhouse gases (GHGs) caused by an individual, organization, or process. These sources can include direct emissions, such as those from transportation and manufacturing facilities, as well as indirect emissions, such as those caused by the production of electricity. The primary purpose of calculating the carbon footprint is not just to display the impact but to allow for the evaluation of the current situation with potential scenarios and process improvements. Only by measuring and assessing the current and future environmental impacts that could result from implementing different scenarios can we determine which business decision is the most environmentally sound–just as we use economic calculations to determine which investment makes the most sense from an economic perspective. Carbon footprint is becoming one of the most important tools for assessing environmental impacts due to trends in international policies aimed at reducing greenhouse gas emissions. With the development of methodology and standardization, both the calculation process and emission factors are becoming increasingly comparable and reliable. However, it is important to recognize that, although it covers environmental impacts across the entire supply chain or lifecycle, its main limitation is that it is focused solely on emissions expressed in CO2 equivalent, while neglecting other equally important environmental impacts, such as water consumption, land use, radiation, human health impacts, biodiversity effects, and others.

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