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# Expanding knowledge on environmental impacts of transport processes for more sustainable supply chain decisions: A case study using life cycle assessment

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## ABSTRACT

With this study, we highlight the necessity to improve the environmental performance in supply chains and freight transportation systems to respond to the unbroken trend of increasing environmental impacts of transport. Based on a literature review, we first identify 19 environmentally relevant decision criteria which determine transport processes, such as delivery times, delivery frequency, or mode choice. We group these criteria depending on the time horizon and their influenceability by a company decision-maker and further apply them to empirically enquire in a life cycle assessment case study about the relationship between freight transport processes and the related environmental impacts. The case example of a resource intense and heavy-weight product represents a typical product system with long transport distances and economic as well as environmental relevance. By means of some robustness tests we further show how some criteria which are controllable and influenceable in the short and medium term trigger the indicator results. Finally, we develop a decision tree approach to prioritize actions and derive environmental transport strategies depending on the time horizon and the influenceability of the decision criteria. While the decision tree is from a manufacturing company's perspective, it has relevance also for other actors along the supply chain and in politics. With this literature review, case study, and decision-tree approach we contribute to transportation research and practice and thereby aim to incentivize decision-makers to systematically explore the sources of environmental impacts and continuously improve the environmental performance of freight activity.

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## 1. Introduction

Environmental impacts of transport processes have become a major issue of concern as transportation is the second most important contributor to overall greenhouse gas emissions in the United States and Europe: In the United States, transporta-

*Abbreviations:* CML, Centrum for Milieukunde; EPD, Environmental product declarations; EURO, European emission standards; IBU, Institut Bauen und Umwelt; ISO, International Organization for Standardization; LCA, Life cycle assessment; LSP, Logistics service provider; RER, Europe; tkm, Tonne kilometer; TRACI, Tool for reduction and assessment of chemicals and other environmental impacts. For environmental impact indicators, please refer to the abbreviations provided in Table 3.

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tion accounts for 27% of overall emissions (United States Environmental Protection Agency, 2013), while in Europe transportation generates 22% of total emissions (European Commission, 2011a; European Environment Agency, 2014). While the emissions of the most important contributors (industry in the United States, energy in Europe) are slowing down, transport emissions are continuously increasing (European Commission, 2011a; European Environment Agency, 2014; United States Environmental Protection Agency, 2013). Hence, a reduction of environmental impacts of transport processes can help to achieve the set environmental targets.

Meanwhile, researchers have noticed an upswing in demand from shippers for more sustainable logistics services (López-Navarro, 2014; Martinsen and Björklund, 2012). The World Resources Institute and World Business Council of Sustainable Development (2013) published an accounting and reporting standard to analyze emissions throughout the company value chain, i.e. scope 3, which also includes transportation and distribution.

Sustainable supply chain management has become popular as a means to enhance the sustainability performance over the whole supply chain (Browne et al., 2005; Jaegler and Gondran, 2013). The joint consideration of economic, environmental, and social impacts delivers a valuable contribution through more transparent decision-making for the long-term horizon. In order to tackle environmental impacts of transport processes, the integration of environmental measures into transport decisions is indispensable. Yet they are still rarely considered alongside cost and service (Eng-Larsson and Kohn, 2012; Guenther and Greschner Farkavcová, 2010; López-Navarro, 2014).

This may be explained by limited management attention (Simons, 1995) and potential target conflicts between performance measures such as time, cost, or environmental aspects (Nealer et al., 2012). Besides, environmental assessments require more detailed analysis efforts (Bergantino and Bolis, 2008; Feo et al., 2011) and decision-makers are uncertain about who is actually responsible as there are so many actors involved. For instance, transport decisions are taken inside a company by the company logistics department, but also by logistics service providers (LSPs) due to outsourcing (Facanha and Horvath, 2005) and by policy-makers due to the use of public infrastructure.

For these reasons, we aim to incentivize taking environmentally relevant decision criteria into consideration as decision variables alongside cost and service (López-Navarro, 2014) and differentiate them by the time horizon and their influenceability (López-Navarro, 2014; Pfohl, 2004; Cooper et al., 2008), which has been neglected in the scientific literature so far.

To address this research gap, in this paper we take a three-step procedure: First, we review existing life cycle assessment (LCA) case studies which include transportation to summarize environmentally relevant decision criteria determining transport processes and group them depending on the time horizon and their influenceability by a company decision-maker. Second, we use these criteria to empirically enquire in a LCA case study about the relationship between freight transport processes and the related environmental impacts for a resource intense and heavy-weight product. Third, we contribute to literature by developing a decision tree approach to prioritize actions and derive environmental transport strategies depending on the time horizon and the influenceability of the decision criteria. On this basis decision-makers within legal entities and along the supply chain, as well as in politics, can prioritize strategies supporting the continuous improvement of the environmental performance of freight activity.

This paper is organized as follows: After a review of the environmentally relevant decision criteria determining transport processes in Section 2, we explain the applied LCA approach in Section 3. In Section 4, we present and discuss our case study results as well as suggest a decision-tree approach to guide action. Finally, we present our conclusions in Section 5.

## 2. Review of environmentally relevant decision criteria determining transport processes

In this study we aim to enhance the knowledge of how environmentally relevant decision criteria which determine transport processes can be considered as decision variables alongside cost and service for improving the overall performance in logistics and transportation as postulated by López-Navarro (2014). If these criteria are neglected in overall decision-making, this might lead to distorted results and counteract sustainability efforts by other decision-makers inside the legal entity, along the supply chain, and in politics. Cooper et al. (2008), López-Navarro (2014), and Pfohl (2004) call for a differentiation of such criteria by their influenceability depending on who the decision-maker actually is. Furthermore, some criteria can be influenced either in the short or medium term, while others can only be changed in the long term. However, to the best of our knowledge, current literature does not provide a comprehensive overview of such criteria.

So, building on this, we follow a systematic, three-step procedure. First, we review existing LCA case studies which include freight transportation to summarize environmentally relevant transport decision criteria which determine transport processes. We further classify the criteria depending on the time horizon and their influenceability by the actual decision-maker (in this case a company decision-maker) as called for by Cooper et al. (2008), López-Navarro (2014), and Pfohl (2004). Second, we apply them to empirically enquire in a LCA case study about the relationship between transport processes and the related environmental impacts for a resource intense and heavy-weight product and show with some robustness tests how some influenceable criteria trigger the indicator results. Third, we conceptualize our findings in a decision-tree to prioritize actions depending on the time horizon and the influenceability of environmentally relevant decision criteria. While the decision tree is from a manufacturing company's perspective, it also has relevance for other actors along the supply chain (e.g. raw material suppliers, LSPs) and in politics because decisions made at one entity can affect the supply chains' environmental impacts and may require changes elsewhere.

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