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Exploring logistics actions enabling environmentally sustainable freight transport

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Exploring logistics actions enabling environmentally sustainable freight transport

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Abstract

To curb unsustainable freight transport trends; such as transport growth, larger dependency on road transport and generally an increased share of greenhouse gas emissions from the sector, actions needs to be taken among actors in the logistics system. The purpose of this thesis is to explore logistics actions that enable environmentally sustainable freight transport. This explorative research, based primarily on empirical data from interviews, focus groups, and a case study, adopts the perspectives of different actors in the logistics system: transport buyers, freight forwarders, transport operators, and authorities.

The thesis identifies a wide range of actions in the logistics system to potentially enable environmentally sustainable freight transport. The perception from actors regarding what actions are important to adopt indicate that more knowledge among actors regarding how transport and traffic work can be reduced and how different actions affect each other are needed; especially how transport buyers acting affect the transport operations performed by freight forwarders and transport operators. By exploring what hinders environmentally sustainable freight transport in the interface between transport buyers and providers, it can be concluded that closer co-operation can provide better internal conditions for actors and new business solutions. Open dialogue, information sharing, and proactivity among both transport buyers and transport providers are essential. Furthermore, in order to increase load factor in practice, actions can be taken by transport buyers in the area of packaging, loading, and booking efficiency. More flexible time requirements will potentially increase the load factor. Gaining positive environmental effects from these changes is dependent on the freight forwarder's actions in terms of consolidating with other transport buyers' goods, route planning, and the positioning of vehicles. Since improvements in one actor's system may not necessarily yield positive effects at a higher system level, it is important to also have a holistic view when aiming for environmentally sustainable freight transport.

This thesis contributes with knowledge about how logistics actors can work toward environmentally sustainable freight transportation by providing insight for managers of transport buying and transport providing companies by exemplifying the interactions between actors and actions and their potential effects.

Keywords: actions, actors' perspectives, co-operation, environment, freight transport, load factor, logistics, sustainability

List of appended papers

This thesis is based on the research presented in the following four papers, which are referred to by Roman numerals in text:

PAPER I: Santén, V. and M. Blinge (2010). *Actions for sustainable freight transport - comparing theory and practice.* An earlier version of this paper was published in Proceedings of WCTR Conference 2010. Lisbon.

PAPER II: Santén, V. and Arvidsson, N. (2011). *Road freight transport efficiency and less environmental impact - the perspectives of transport buyers and operators.* Published in Proceedings of NOFOMA conference, 2011 Harstad.

PAPER III: Santén, V. (2012). *Building a framework for increased load factor – mapping actions and effects from a transport buyer's perspective.* An earlier version of this paper was published in Proceedings of NOFOMA conference. Turku.

PAPER IV: Santén, V. (2012). *Increased load factor and sustainable logistics – interactions between a transport buyer's and freight forwarder's system*. Published in Proceedings of LRN conference. Cranfield.

Acknowledgments

My research journey started in February 2009 and a new world opened up for me. Research is so much more than what I expected; it is indeed a challenging trip towards a doctoral thesis including lots and lots of learning. Learning about research; the research area, planning process, how to perform studies, how to write papers and so on, but, also learning about myself. For me this process has similarities with doing a sports campaign. If successfully proceed towards the high academic goals, you need to go all in. To get published in high ranked journals is not made at first try. Training, training and further training is needed in order to learn the tools for research. Writing up this thesis made me realize – wow I learnt a lot – but also that there is so much more to learn. And that is a driving force for me!

Of course, this part of the journey has not been made by myself only. I am surrounded by several fantastic people believing in me, co-operating with me and helping me out with good advices and time for discussions. First of all, Magnus, you definitely have a large role in this thesis. From encouraging me to take this step into the academic world at the first place, you are a truly supportive supervisor, coaching me through this process by trust, knowledge and with a great ability to see holistically on the problems leading to rewarding discussions. I really enjoy working with you! Dan, you are the one that works the hardest I have ever seen. You have permanently a line of people waiting to get a talk to you or to get your last touch on a document to be finished between all your movements. But anyhow, you always, always have room for a few minutes of discussions and to give valuable and constructive feedback on my work. It is magic, and that is so valuable and helpful for me! Kent, my examiner, I am really grateful for that you gave me this chance. You are really giving me the freedom to explore the academic world, and are always there to help out when that's needed. To my colleagues, the days at work had not been as great without you. Sara, you are the very best roomie. We have been a true team when writing our theses next to each other. You are so inspiring for me and have always time for discussing issues regarding both research and social life in a really helping manner. Sönke, thanks for useful feedback on my first draft, and for always being there to help out. Martin, thanks for valuable discussions and laughs. My neighbor Kristina, you cheer the life up on our side of the corridor. To all other colleagues, you are all important for making me enjoy my work.

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Vendela Santén

Göteborg, January 2013

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1 Introduction

This chapter presents the background of the thesis. The main problems underlying the research are described followed by the purpose, research questions, and scope of the research. An overview of the outline of the thesis ends this chapter.

1.1 Background

This thesis contributes to the sustainable logistics research arena by exploring logistics actions enabling environmentally sustainable freight transport from different actors' perspectives. The thesis links the larger overall logistics system perspective with the company level in actors' logistics systems. Central concepts are environmentally sustainable transport and logistics actions.

1.1.1 Environmentally sustainable freight transport

Sustainability is commonly defined as combining ecological considerations with economic development and social responsibility, usually called the triple bottom line (Norman and MacDonald, 2004). This thesis has a focus on contributing to the ecological dimension, thus the main concern is the environment. The view of prioritizing ecological considerations within sustainability is based on the principles of sustainability as defined by Holmberg and Robért (2000). The main idea behind these principles is to strive towards having a balance in the flow of physical resources in society; thus, nature should not *systematically* be degraded by increasing concentrations of, e.g., emissions or harmful substances (Holmberg and Robért, 2000). By employing this thinking, companies should be able to find more sustainable business strategies benefitting economic development in the long term.

In logistics, one of the main goals is to improve companies' efficiency and economic performance. Therefore, the implementation of actions that contribute to changes in other societal goals, such as environmental and social responsibility, is problematic unless the short-term economic goals are not fulfilled simultaneously (Vachon and Klassen, 2008). However, research shows that there are several benefits when prioritizing environmental work in companies, e.g., lower costs as a result of resource savings, increased sales by greening the company image, and future preparation for governmental regulations that will also save costs (Hart, 1995; Dey et al., 2011).

Using the elements of the value chain as portrayed by Wu and Dunn (1995), negative environmental impacts arise from logistics activities in all stages, from raw materials acquisition to after sales service. However, the largest source of environmental impacts in the logistics system originate from operated freight transports (Wu and Dunn, 1995; World Economic Forum, 2009). Environmental impacts caused by freight transport activities are, for example, emissions (such as of CO_2, NO_x, SO_2, PM, and VOCs), noise, and landscape fragmentation (European Environmental Agency, 2012). Also, traffic congestion and accidents are negative impacts of a social nature caused by transport systems.

In addition to the negative impacts mentioned above, driven from primarily economic goals, recent trends within logistics systems have caused an increase in transport and traffic growth as well as a modal shift from rail to road;

consequently, an increased share of environmental impact from the freight transport sector can be seen.

1.1.2 Unsustainable transport trends

Freight transport is an operation involved in both inbound logistics and outbound logistics as well as after sales services. Also, other elements in the chain may affect the transport operations in different ways. In general, trends regarding the expansion of market areas, wider sourcing of suppliers, and consequently an increased length of haul have contributed to a higher dependence on transport operations and an increased transport work in terms of tonne-km (McKinnon, 2003; Golicic et al., 2010). Similarly, logistics strategies moving from decentralized to centralized distribution systems in companies' logistics set-up have also contributed an increased transport work in general (Kohn and Brodin, 2008).

Looking at freight transport statistics, a growing amount of total transport work is clearly visible. On a European level there has been an increase of approximately 36 % of tonne-km between 1995 and 2007 (European Commission, 2011a), even though there were a small decrease between 2007 and 2009 due to the economic downturn (European Commission, 2011a). In Sweden, the total amount of transport work had more than doubled between 1960 and 2011 (Trafikanalys, 2012). These changes are primarily due to the increase in the length of haul in transport operations, not an increase in transported tonne.

There has also been a shift to more freight transport occurring by road. Different transport modes do have different characteristics and limitations (see e.g., Kohn and Brodin (2008)), making the demands around the specific transport operation direct the choice of mode. Due to logistical trends like Just-In-Time, using less storage and more frequent deliveries have put more pressure on the transport market, which has been characterized by an increase in the importance of time, speed, and reliability on transport operations leading to a higher dependence on road transport (Golicic et al., 2010). Since road transport is contributing to the most environmental burden in terms of CO_2-emissions/tonne-km when comparing the major transport modes (i.e., road, rail, and sea; (Chapman, 2007), the growth of road freight transport in society is leading to an increase in the sector's environmental impact. As exemplified from Swedish statistics in Figure 1, road freight nearly doubled in terms of tonne-km between the early 1970s and 2011 (Trafikanalys, 2012). Sea transport, on the other hand, decreased slightly during the same period, and rail freight had a small increase in transported tonne-km. On a European level, road freight transportation increased by 35 % within Europe from 1995–2004 and is expected to increase by 50 % from 2000 to 2020 (European Commission, 2006).

Because of the trend towards a larger share of goods being transported by road, traffic work (vehicle-km) has also been impacted. In Sweden, the road freight traffic growth has increased faster than the amount of transport work; from 1997 to 2007, the vehicle-km doubled (Smidfelt Rosqvist and Dickinson, 2012). One reason for this development is the increased usage of distribution vehicles, as a larger share of smaller vehicles are now being used (Trafikverket, 2011). Also, the goods are now characterized by lower weight and higher volume, leading to

more vehicles distributing the same amount of goods in terms of tonne (Banverket et al., 2008).

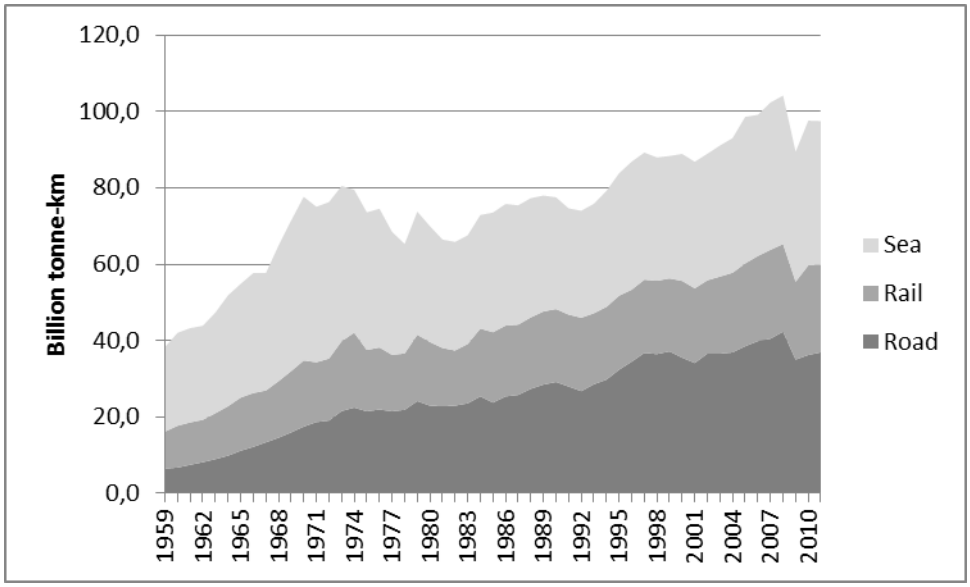

Figure 1 The development of freight transport work (billion tonne-km) in Sweden from 1960–2011 (Trafikanalys, 2012).

Concerning the environmental impact, in 2008, the European transport sector in total consumed 32 % of the total energy, mainly from diesel and oil (European Commission, 2011a). Within the sector, road transports accounted for 71 % of the total greenhouse gas emissions in 2008 as well (European Commission, 2011a). In Sweden in 2010, the transport sector accounted for 31 % of total greenhouse gas emissions, and within the sector there has been 7.5 % increase in greenhouse gas emissions from 1990 to 2010 (Swedish Environmental Protection Agency, 2012).

1.1.3 The gap between long-term political goals and transport trends

Transport is high on the political agenda not only due to its importance for society and for economic development, but also due to the large number of environmental consequences arising from the sector. This is seen by ambitious long-term political goals, both on the EU and national levels.

The EU's long-term targets for greenhouse gas emissions are a 20 % reduction by the year 2020 and an 80–95 % reduction by 2050 (European Commission, 2011b). In Sweden, the target is to reach a level of 10% renewable energy used within the transport sector by 2020. By 2030, the vehicle fleet should be independent from fossil fuel usage (Regeringskansliet, 2009). Moreover, the transport sector should contribute to the long-term vision for national environmental quality, which is to have a zero net output of greenhouse gases by 2050 (Trafikverket, 2012).

The Swedish transport administration identifies the need for the transport sector to contribute to the national climate change goals and conclude that policy measures that are decided upon today (concerning technical advances such as emission limits on vehicles) are not enough (Trafikverket, 2012) (see Figure 2).

Today, there is a large gap between macro-level goals and current trends in the transport sector.

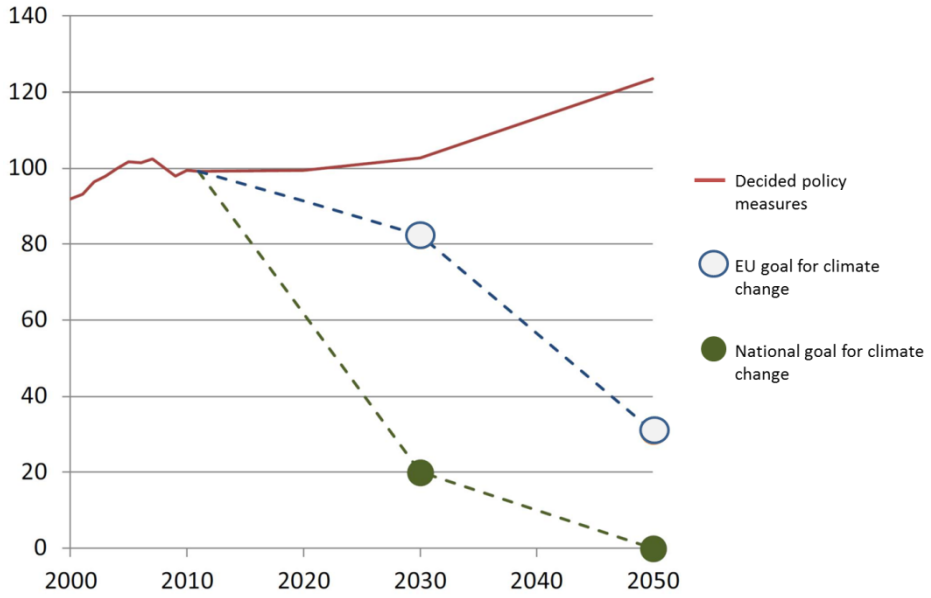

Figure 2 Scenario of road transports' impact on climate change in Sweden (index year 2004 = 100) compared to EU and national climate change goals (Trafikverket, 2012)

Other studies confirm the difficulties in reaching governmental targets and emphasize the necessity for developing a combination of different actions (Åkerman and Höjer, 2006; Miljörådet, 2008; Piecyk and McKinnon, 2010). Piecyk and McKinnon (2010) examined the likelihood of meeting an 80 % reduction of CO_2-emissions from road freight transport by 2050 when adapting business as usual in the UK. Their study shows a mid-range business as a typical scenario where a 10 % reduction in CO_2-emissions is reached by 2020, which is still far from reaching the long-term governmental targets. Åkerman and Höjer (2006) concluded that, *"It does not seem possible to reach the target level for sustainable greenhouse gas emissions… only by relying on technology. Improved technology in conjunction with renewable fuels is important, but transport volume growth also has to be curbed"* (Åkerman and Höjer, 2006, p. 1955).

Obviously, there is a need for significant changes in the transport sector to achieve these long-term targets. Technical advances have been mentioned as one strategy, but they will not be sufficient. There is a necessity for improved logistics in terms of cutting transport and traffic growth. In particular, road freight transport operations need to change in favor of more efficient logistics (transporting the same amount of goods using less vehicle-km) and a modal shift to other transport modes, such as rail and sea (Trafikverket, 2012).

1.1.4 Research linking logistics actions and environmentally sustainable freight transport

The above discussion highlights the fact that understanding how logistical activities affect freight transport operations and their environmental performance is of major importance. There is no doubt that sustainable logistics is a hot research field; however, it spans a wide range of areas. Several sources have highlighted the importance of conducting more research within areas

related to sustainability and logistics. Halldórsson and Kovács (2010) stressed the importance of sustainability and energy in the context of logistics and supply chain management and questioned the ongoing theories and solutions in logistics and supply chain management, indicating that a large transition may be needed. Similarly, Dey et al. (2011) argued for the importance of focusing on sustainability throughout firms' logistics operations. They further identified that "*there is very little work done to understand the role and importance of supply chain logistics operations towards this end*" (Dey et al., 2011, p. 1253).

Environment and freight transport-related issues are addressed in research in a number of ways, having varying areas of focus within the broad area of supply chain management. Abbasi (2012) recently summarized what research areas are covering sustainable supply chain activities in the literature, e.g., green/sustainable supply chain management, green/environmental logistics, green purchasing, green marketing, reverse logistics, energy efficiency, environmental assessment, sustainable procurement, sustainable mobility, and sustainable transport. From the above list of areas that are relevant for sustainable supply chains, freight transport issues with an emphasis on the environment are treated in varying levels of detail and with different emphases. In general, the "green" supply chain literature pays little attention to specific freight transport issues and the "green" logistics literature highlights the need for a better understanding about the impact of logistics on transport operations and environment (Drewes Nielsen et al., 2003; Dekker et al., 2012).

Several studies have linked logistical activities to freight transport operations and their environmental impact by proposing frameworks and models of cause and effect between logistics activities and the environmental impact of freight transport (Drewes Nielsen et al., 2003; Richardson, 2005; Aronsson and Huge Brodin, 2006; Piecyk and McKinnon, 2010). Logistics actions in these frameworks span from strategic and tactical to operational in companies (Aronsson and Huge Brodin, 2006; Piecyk and McKinnon, 2010), such as logistics structures, pattern of trading links, scheduling of product flow, management of transport resources (Drewes Nielsen et al., 2003), and political activities (Richardson, 2005; Piecyk and McKinnon, 2010). While Richardson (2005) and Piecyk and McKinnon (2010) have taken a macro perspective, Drewes Nielsen et al. (2003) have a product perspective and Aronsson and Huge Brodin (2006) a transport buying perspective. The hierarchical relationships between actions have been highlighted by Aronsson and Huge Brodin (2006) and Piecyk and McKinnon (2010), such that actions at a certain level create opportunities and at another level set limitations. Thus, several actors are involved in logistics activities, meaning that their separate actions can affect each other's work. However, this is not addressed in their descriptions of the frameworks. The macro-level frameworks are broad and lack detailed descriptions on how specific actors can act within a particular framework. Also, it is not clear from these frameworks how each action contributes to environmentally sustainable freight transport; environmental issues are treated either on a general level or specifically in terms of CO_2-emissions only. More research is needed at the company level to determine how actors can apply different sets of actions and how those actions affects environmentally sustainable freight transport.

1.1.5 The need for practical knowledge

To enable environmentally sustainable freight transport, the actors in the logistics system must be involved. Even though society's general awareness of environmental issues is growing, actors in the logistics system have little interest in making environmental improvements in freight transport operations: *"The transport customers do not display a great interest in an environmentally based change of transport demand and the transport companies only seem willing to supply new transport concepts if demand exists*" (Drewes Nielsen et al., 2003, p. 296). This is supported by other, more recent, studies with a focus on freight transport and the environment in either logistics or supply chain settings: "*Business needs to take a much more fundamental perspective on the challenge of climate change than could be observed*" (Wolf and Seuring, 2010, p. 99). "*Only 22 Fortune 500 companies have begun blunting their supply chain's impact on the environment*" (Golicic et al., 2010, p. 47), and "*operationalization of environmental areas are often met with reluctance"* (Abbasi, 2012, p. 55). Thus, research show that, from different angles, companies involved in logistics activities have a low interest in environmental issues.

Actions can be taken by several actors involved in logistical activities, e.g., transport buyers, freight forwarders, and transport operators and authorities, each of them having an opportunity to act and also to influence and impact each other. As indicated by the low interest in environmental issues among companies in the logistics system, the implementation of logistics actions that not only have a positive economic impact but that are also effective in reducing the environmental impact of freight transport is scarce (see, for example, the studies done by Léonardi and Baumgartner (2004), Golicic et al. (2010), and Perotti et al. (2012)).

The lack of interest in the environment and the low level of implementation of logistics actions enabling environmentally sustainable freight transport indicate a need for practically relevant research. In order to reach long-term goals and to contribute to environmentally sustainable freight transport, environmental issues must be given higher priority on the agenda among companies. There is a need to better understand how acting can take place, what actions can eliminate hindrances and which actions can have an important role for enabling environmentally sustainable freight transport. There is a need to gain an increased awareness of what can be achieved and also how this can be done in practice (Perotti et al., 2012). On the other hand, the issue of understanding each actor's role and impact on the system as a whole is complex. It is not sufficient to only view the system from one actor's perspective, since actions taken in one part of the system may affect surrounding actors. Therefore, linking a holistic view with company logistics is of importance to enable environmentally sustainable freight transport.

1.2 Purpose and Research Questions

The purpose of this thesis is to explore logistic actions enabling environmentally sustainable freight transport.

To further explain the purpose, Figure 3 shows the main areas that are explored in the studied system. The overarching aim of the present research is to contribute to environmentally sustainable freight transport by gaining an increased understanding of how actors can act in that direction. This is explored from various actors' perspectives. Specifically, descriptions of their perspectives and overviews of patterns and structures of actions within actors' systems as well as between actors will contribute to the results. The first step is to identify what logistics actions can possibly play an important role when aiming for environmentally sustainable freight transport. In order to encourage action among actors in the logistics system, it is important to explore current reasons for actors' non-activity; this includes primarily hindrances to taking action. Hindrances can be of internal (such as managements priorities) or external character (such as poor supplier commitment). Hindrances can affect actors acting in general and vice versa; actors' acting can generate hindrances, consequently hindrances also influence the adaption of actions enabling environmentally sustainable freight transport in practice. The third step is to give examples of how actions can be taken in practice, i.e., in actors' context. How actions in practice affect environmentally sustainable freight transport as well as other actors' possibilities to act are then also of importance.

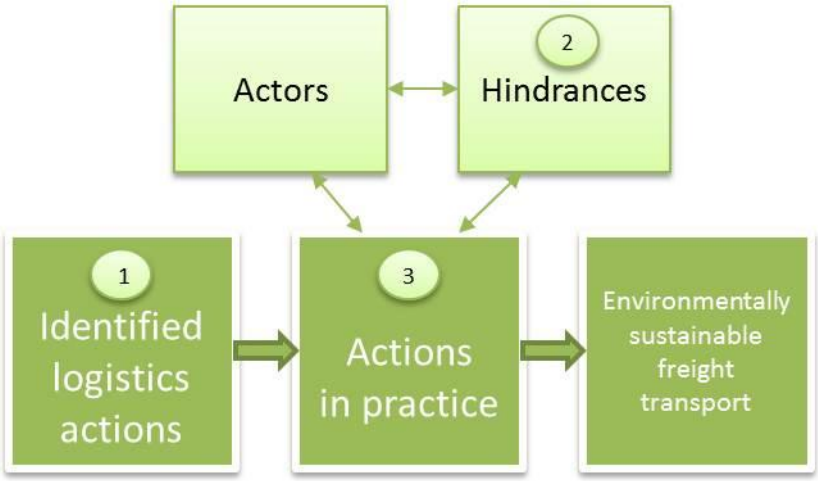

Figure 3 The explored areas in the studied system.

Figure 4 shows the perspectives taken in the three explored areas; identification of actions, hindrances and actions in practice, and relates the research questions to each area. The perspectives are connected to three system levels: logistic, dyadic, and company system levels. These three levels are inspired by a framework presented by (Björklund, 2005), structuring research within the field of environmental logistics. By taking different perspectives in each research question, the research can contribute to generating knowledge that can be

practically applicable in actors' systems, thus achieving change while also having a holistic view. Therefore, this research will contribute to linking the larger logistics systems perspective with the company level among actors in the logistics system. The research questions have been developed based on the overall purpose of the study, and each step has motivated the next one. Thus, the research questions have emerged during the research process. Each of the three research questions takes a different actor's perspective. RQ 1 takes a logistics system standpoint in which authorities, transport buyers, freight forwarders, and transport operators are the main focus. These actors have different roles in the logistics system, and the combination of their actions results in the overall environmental sustainability of freight transport. It is important to adopt a holistic perspective when identifying actions taking place within the logistics system to get an overview of how such actions affect each other and what role each action can play in relation to the others. In RQ 2, a dyadic system is studied, and the interface between transport buyers and transport providers is the central focus. The dyadic system view is of special importance to study due to the impact transport buyers have on transport operations performed by a third party—a freight forwarder or transport operator. RQ 3 looks at a company system from the perspective of a transport buyer and a freight forwarder. This system level is important to study to gain knowledge about how actions can operate in practice and to get examples of the possible effects actors can have on their surrounding systems. Each research question is presented and further described below.

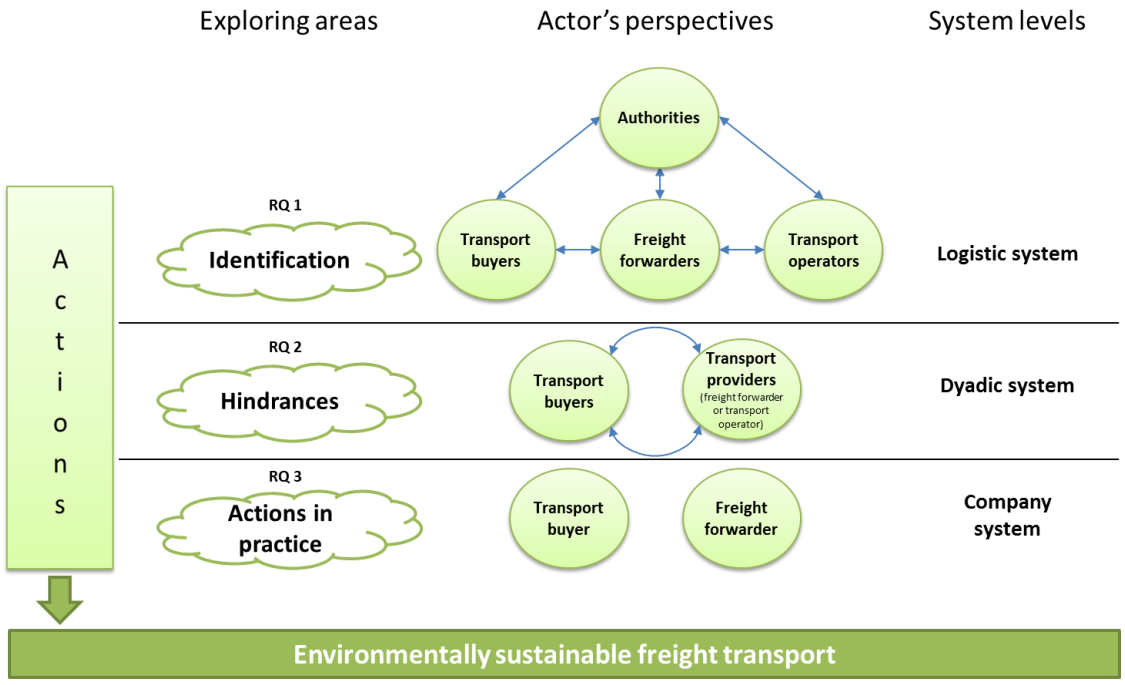

Figure 4 The perspectives taken in each explored research area.

RQ 1:

What actions enabling environmentally sustainable freight transport are perceived as important within the transport community?

The first research question aims at identifying logistics actions that can enable environmentally sustainable freight transport. It takes a holistic view in that sense that it identifies a wide range of actions in the logistics system that the main actors can implement, namely, transport buyers, freight forwarders, and transport operators and authorities. The logistic actions within a company range from tactical and operational to strategic. Technical, organizational, and political actions are also included. The perception of what actions are important among the main actors will be compared with up-to-date research to identify possible between-group differences. Thus, the transport community includes both the main actors in the logistics system as well as the academic community. This research will contribute to understanding actors' view on actions enabling environmentally sustainable freight transport, identify varying views between actor groups and possible knowledge gaps between practitioners and theorists. Moreover, the overview of potential logistics actions enabling environmentally sustainable freight transport makes it possible to view actions not as isolated activities, but rather as a part of the logistics system as a whole. This is important to see how actions in different parts of the logistics system may affect each other as well as what role they can play in relation to each other when enabling environmentally sustainable freight transport.

RQ 2:

What hinders environmentally sustainable freight transport in the interface between transport buyers and transport providers?

The second research question aims at increasing the understanding about why so little action is being taken among actors in the logistics system. In order to actually improve the implementation level of such actions, it is important to understand the actors' view on the difficulties in applying actions in practice.

Since there are several actors involved in logistics activities, the relationship between them is the key to understanding how changes may affect transport operations. Of special interest is the interface between the transport buying actor and the transport providing one. Today, outsourcing of transport activities to a third part is common. Lammgård (2007) reported, from a Swedish perspective, that over 95 % of manufacturing companies have their transports organized by transport providers. The actions taken by one actor, e.g., the transport buyer, can have an effect on the transport provider due to limitations or opportunities that are set on the transport operations from the transport buyer's acting. As an example, Aronsson and Huge Brodin (2006) presented a general hierarchical model illustrating how logistics decisions at one level create opportunities and set limitations for other levels; e.g., choices concerning planning and management create opportunities and limitations for the operative work. Also, Drewes Nielsen et al. (2003) discussed, in general terms, how changes in logistical organization, e.g., scheduling of product flow, have an effect on transport. Different sources report on difficulties in the relation between

transport buyers and transport providers that impact the environmental performance of transport operations and motivate the need for, e.g., improved co-operation, trust, and information exchange between actors (Wolf and Seuring, 2010).

Due to the few initiatives in research that have looked at the linkage between transport buyers and transport providers, their interface is of special interest. Thus, the second research question takes a dyadic perspective, including transport buyers and transport providers. Transport providers represent both freight forwarders and transport operators.

RQ 3:

How can an increased load factor in road freight operations be achieved by transport buyers and freight forwarders?

The aim with the third research question is to give examples of how actors can enable environmentally sustainable freight transport. To increase load factor has been identified as one central action area for reducing the environmental impact of freight transport, therefore the third research question study how to increase load factor specifically. For example, Piecyk and McKinnon (2010) identified the load factor as a key variable to consider when reducing the total environmental impact of road freight transport systems. Load factor is about how efficient a transport is in terms of level of goods load in the vehicle and an increased load factor possibly has an influence on reducing traffic work (vehicle-km). The first study in this research shows that the actors themselves are strongly interested in increasing the load factor. This can be explained by its potential combined effect of lowering the environmental impact and saving costs, which also has been demonstrated in earlier studies (Wu and Dunn, 1995; Blinge, 2005; Kohn and Brodin, 2008). However, in what way different logistical actions affect the load factor has scarcely been analyzed in the literature. The importance of load factor has mainly been discussed in general terms, as one action among others, leading to a limited focus on the load factor concept alone. Also common for earlier research is the lack of detailed descriptions of how actions relate to each other and in what way they affect the load factor in specific contexts. Due to the limitations and opportunities that are set on transport operations from logistics decisions on higher levels (such as by transport buyers) (Aronsson and Huge Brodin, 2006), there is of special interest to study how transport buyers can work towards increased load factor. Also, central to the actual transport operation is the freight forwarder which makes their specific influence of importance. This research question takes a company perspective, studying how an increased load factor can be achieved by actions taken in both a transport buyers' and freight forwarders' system.

1.3 Scope and delimitations

This study explores logistics actions enabling environmentally sustainable freight transport. Environmentally sustainable freight transport does not violate the four sustainability principles (Holmberg, 2000); including actions reducing emissions from each transport mode (e.g., CO_2, NO_x, SO_2, PM, and VOCs), using an environmentally better transport mode, and/or diminishing the need for

transports in terms of reducing transport and traffic work. Potential actions concern logistical changes at strategic, tactical, and operational levels within a company to be taken by the central actors in the logistics system: transport buyers, freight forwarders, and transport operators and authorities. Technical, organizational, and political actions are also included. The actors, in turn, get influenced by policies and regulations, called action pre-conditions.

The study does focus on logistics actions affecting freight transport operations, but it is not limited to a specific part of the transport chain. However, road freight transportation is one area of focus, including its interface with other transport modes.

The scope of the empirical data collection is a national Swedish perspective, involving companies having their base in Sweden.

1.4 Project outlook

This research is part of a collaborative project called "Integrated logistics development for sustainability and competitiveness," involving five PhD students at both Chalmers University of Technology and the University of Gothenburg. The project's main funder is VINNOVA, in corporation with the Logistics and Transport Foundations (LTS), Volvo Logistics, DB Schenker, Stora Enso, Region Västra Götaland, the Public Transport Authority in Gothenburg, and the two involved universities. The project involves five focus areas, corresponding to each of the five PhD students' research, integrating operations efficiency and environmental sustainability within the logistics and transportation system.

1.5 Outline of the thesis

In *Chapter One* of the paper the reader is introduced to the problems that have led to the overall purpose of the thesis as well as the research questions. In *Chapter Two*, the frame of reference introduces the theoretical background for the main concepts used in the research. *Chapter Three* presents and discusses the methodological approaches adopted in the undertaken studies. A summary of the appended papers is presented in *Chapter Four*, while the overall results are analyzed in *Chapter Five*. *Chapter Six* discusses the results relation to sustainability, and finally, *Chapter Seven* ends with the conclusion and discussion of further research.

2 Frame of reference

This chapter presents the main concepts used in the research and clarifies the standpoints that are taken in relation to existing theories.

Figure 5 gives an overview of this chapter by connecting each subsection to relevant areas explored in the research.

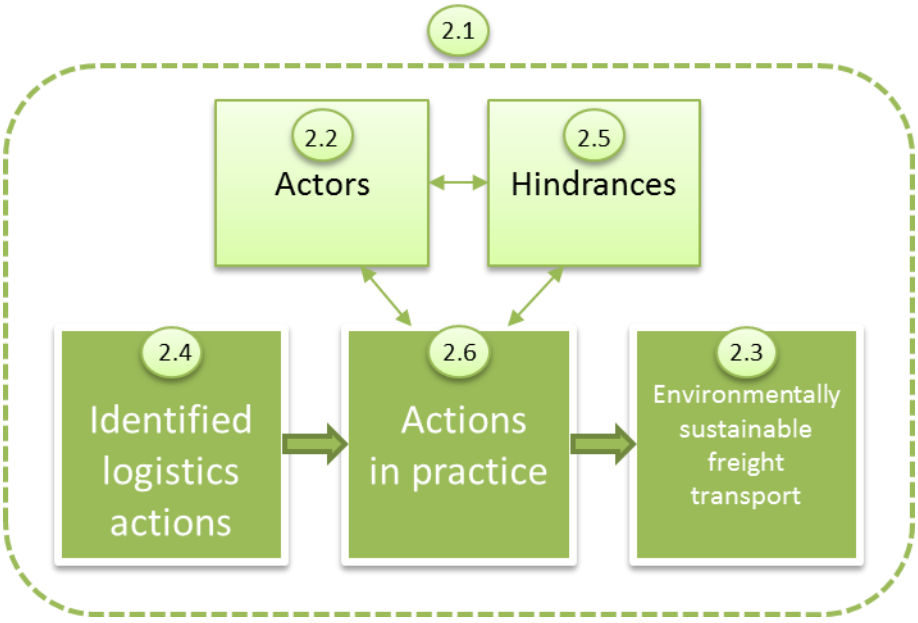

Figure 5 Relevance of each subsection to the areas explored in research

In Section 2.1, the theoretical view on the logistics system is described relevant to the research as a whole. In Section 2.2, the actors in the studied logistics system are described. In Section 2.3, views on sustainability are addressed, illustrating the importance of environmentally sustainable freight transport and the main issues violating sustainability principles. In section 2.4, the theoretical frameworks of sustainable logistics are reviewed, including potential important actions and their relationships to environmental impact. In Section 2.5, earlier research that has studied hindrances to environmental actions in supply chains is described. Finally, Section 2.6 gives an overview of ways to improve load factor. Section 2.7 contains a summary of the key issues from theory relevant to the purpose of this thesis.

2.1 Freight transport: part of the logistics system in a supply chain

While freight transport operations can be seen as one function in the logistics system, the logistics system can similarly be seen as one function of the supply chain (Mentzer et al., 2001). When the supply chain concept emerged, logistics and supply chain were sometimes used as synonyms (Cooper et al., 1997), but today it is important to distinguish between them.

The Council of Supply Chain Management Professionals (CSCMP) defines supply chain management as: "*Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes*

coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies" (CSCMP, 2012). As defined by Mentzer et al. (2001), the core in a supply chain is the "*set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances and/or information from a source to a customer*," and an ultimate supply chain involves all organizations from ultimate supplier to ultimate customer (Mentzer et al., 2001, p. 4).

Logistics management can be defined as: "*that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements*"(CSCMP, 2012). Logistics are also commonly related to the 7 Rs: that logistics are those activities that has to do with receiving the right commodity at the right place, in the right quantity, in the right quality, at the right price, in the right condition and at the right customer (Shapiro and Heskett, 1985). These two definitions of logistics include the core of the logistics definition; i.e. to meet the customers' requirements by having a high service level and a low price.

As interpreted from the definitions above, there is overlap between the concepts of supply chain and logistics management. However, supply chain management has a stronger focus on the chain of actors and the collaboration and coordination between them, while logistics focus more on effectiveness of the flow of goods in each part of the supply chain.

Taking a material flow perspective, in a supply chain the focus is on a **product** and the movement between the integrated chain of actors, from origin to the place of consumption; in a logistics chain the focus is on an **item,** as a part of an article or as an article to be consumed; and the transport chain focuses on the movement of a **consignment** (Ramstedt and Woxenius, 2006). See Figure 6 for an example of the scope of supply chains, logistics chains and transport chains.

As described by Jonsson (2008), logistics systems commonly have the company as a limit, including material supply from suppliers, production, and distribution to customers. Taking a higher level of analysis, the logistics system can also be seen as including the supply chain flow, i.e. including the entire material flow from raw material to end-users in the same system (Jonsson, 2008). In that case, the overall logistics system consists of several sub-systems each of which has the company as a limit.

In order to describe the goods flow in relation to the supply chain, logistics and transport system, Wandel et al. (1992) present a three-layer model (Figure 7). The top layer represents the nodes and links in the supply chain and the flow of material within them. The structure in this layer sets the demand for the transport market (middle layer). The transport flow supplies transport service in terms of load units on the transport market. The transport flow generates the vehicle flow, the traffic. The demand for vehicle flow gets supplied by the capacity of the infrastructure (lower layer). These layers describe the hierarchy

in terms of the transport market as a balance between demand, based on the activities in the material flow layer, and the supply from the transport flow. Similarly, the traffic market is the balance between the demand in terms of vehicle flow and what capacity the infrastructure can serve.

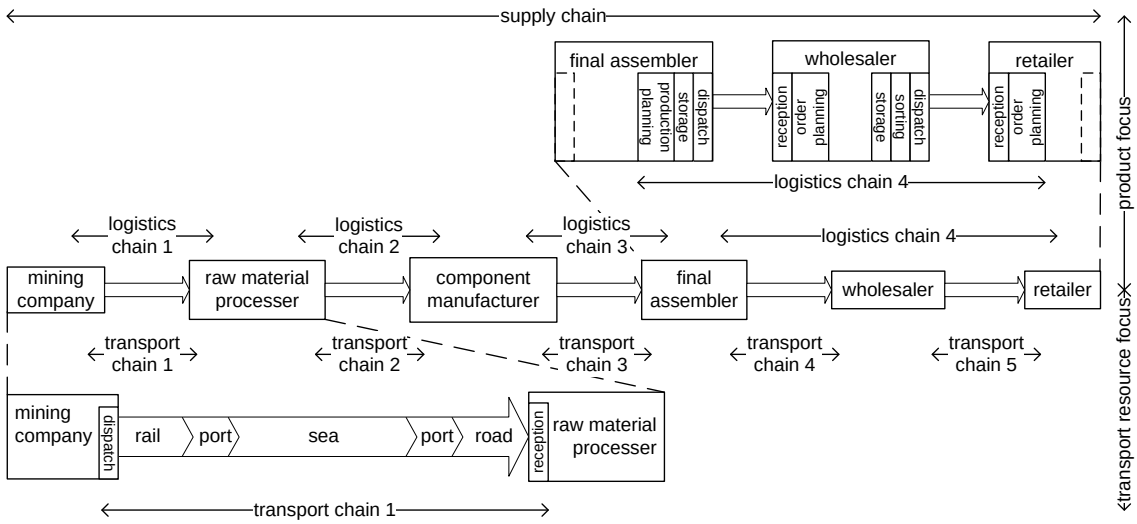

Figure 6 Examples of the scope of a supply chain, logistics chain, and transport chain (Ramstedt and Woxenius, 2006)

The research undertaken in this thesis focuses on the flow of goods and thus the freight transport operations within the logistics system. Freight transport operations as part of logistics are important to the issue of sustainability because transport is the major source of environmental impact in the logistics system (Wu and Dunn, 1995). Inspired by Wandel et al. (1992) and their three-layer model of logistics described above, the logistics system in this research primarily deals with the upper two layers: material flow and transport flow. The freight transport system is viewed as one central part in the logistics system supplying demands on the material flow layer. Material flow layer activities originate from the actions of single companies, suppliers, and/or customers in the larger supply chain environment. This analysis does not distinguish which type of logistics processes or actor functions are of special interest, rather the primary area of interest for analysis is the outcome in terms of sustainability performance when limiting environmental impact from freight transport operations. The critical issue is to identify actions in these two systems based on actor businesses and activities in general. To view the logistics system at these layers has the advantage of focusing on the performance of freight transport operations and especially on how material flow-layer decisions influence the demand for freight transport and these operations. Interaction between the two layers, forming the transport market, can be viewed as either the demand and supply from single actors, i.e. between one transport buyer and their operating freight forwarder, or as the aggregated demand from all customers and suppliers in supply chains on the national market to be supplied from the transport community.

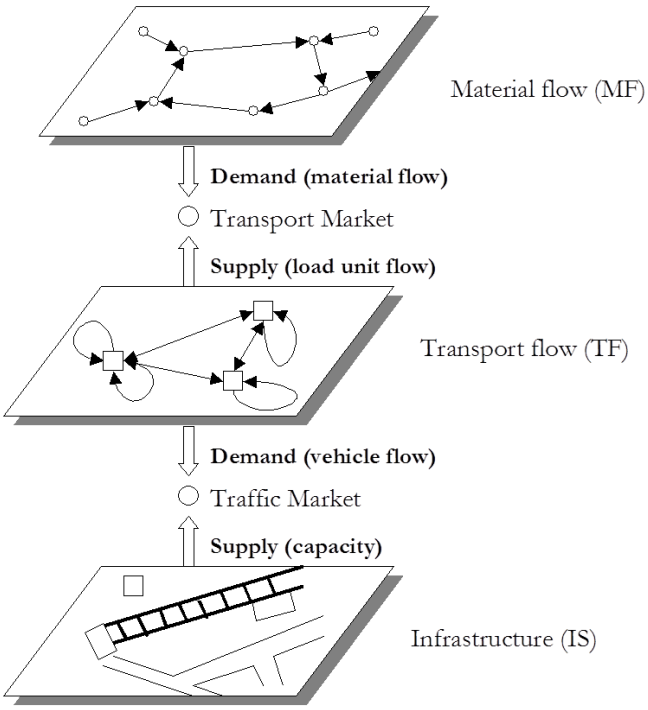

Figure 7 Three-layer model of logistics and its actors (Wandel et al., 1992)

2.2 Actors in the logistics system

In a logistics system there are a number of actors involved. As mentioned above, logistics systems commonly have a company as a limit, and the company, in turn, has suppliers and customers. The company can be any type of company that handles a flow of material, components, and/or products that are distributed to customers, either at the beginning, middle or end of the supply chain. The distribution part of the chain can involve several actors in transport operations. One way of describing these actors is as done by Behrends et al. (2008) (being adapted from Sjöstedt (1996)) and is shown in Figure 8. This model is organized around three functions in the transport system, goods, vehicles, and infrastructure. The shipper handles a product that will be transported in the system involving, for example, the forwarding industry and operator. Behrends et al. (2008) point out that there are several other actors involved in the transport system as well, and this model indicates all important actors and their basic interactions.

Flodén, (2007) sees the actors from a transport-channel perspective. Flodén differentiates between influencing actors (lobby groups and media), framework actors (government or local authorities), system actors (forwarders, terminal companies, and road haulers), and system output receivers (transport customers such as senders or receivers).

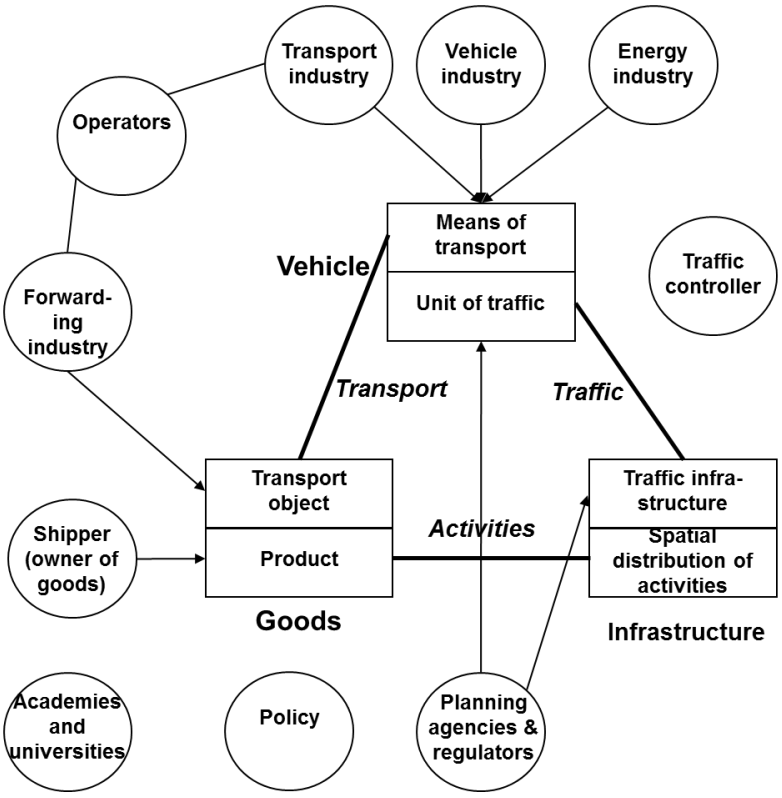

Figure 8 An actor-based model of a transport system (Behrends et al., 2008)

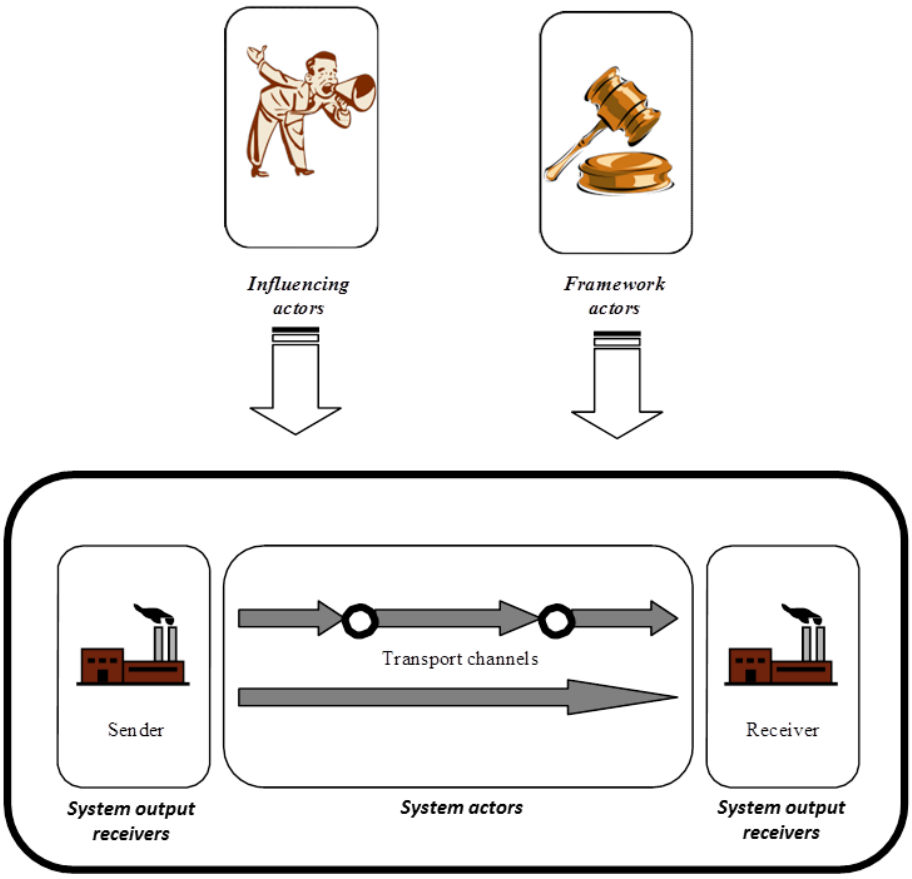

Figure 9 The actors in the transport system (Flodén, 2007)

In the literature, there are several names for the same type of actor. As exemplified in the figures above; the "shipper" (Figure 8) can be either a "sender" or "receiver" of goods (Figure 9), depending on perspective and specific context. Ramstedt and Woxenius (2006) collected commonly used actor names for different roles from the logistics system literature, presented in Table 1.

Table 1 Categories of transport chain actors (Ramstedt and Woxenius, 2006)

Abstract terms	Generic actor names	Roles	Practically used actor names
Source	Consignor	Send goods	(Product) Supplier
Sink	Consignee	Receive goods	(Product) Customer
Management	Transport co-ordinator	Co-ordinate transport services	Forwarder, Third party logistics provider, Agent
Link operator	Transport operator	Move goods	Road haulier, Rail operator, Shipping line, Airline
Node operator	Terminal operator	Tranship, consolidate or deconsolidate goods	Port, Airport, Intermodal terminal operator, Consolidation terminal operator

My research includes both framework actors and logistics and transport systems actors in the system studied. Based on the above presentation of how actors are viewed in the logistics and transport systems, I have categorized the four most relevant actors for my research: authorities, transport buyers, freight forwarders, and transport operators, shown in Figure 10. These actors are the ones most directly affecting activities in the logistics system.

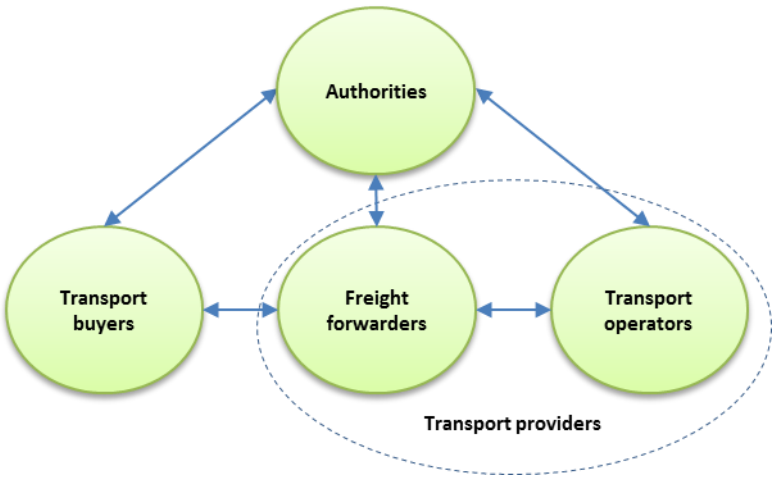

Figure 10 The actors of focus in the logistics system

Transport buyers can be either senders or receivers of goods, but what is important is that the transport buyer has the primary ability to make choices that influence transport operation in areas such as what mode to select and what the requirements are for how the transport should be operated. In addition, whether the transport buyer is the receiver or sender of goods, it must be a

company central to the logistics system, handling a certain flow of goods, which makes the strategies of that actor important to the issue of sustainable logistics.

A freight forwarder is a transport coordinator and has direct contact with the transport buyer. The transport operator is the one responsible for moving the goods and is contracted with by the freight forwarder. There are, of course, exceptions to this trio, such as some freight forwarders who act as transport operators, too, by owning vehicles themselves. For purposes of this research, without making distinctions between freight forwarders and transport operators, this actor group is called transport providers.

Authorities are those governmental agencies that have a central role in advocating for a sustainable logistics system, working toward long-term goals and using power to affect the system through policies, regulations, and infrastructure investments at the national or local levels. If their focus is not on vehicle technology, other actors who relate to the transport industry, such as vehicle manufacturer, etc., are not emphasized.

2.3 Sustainability

The term "sustainable development" is used frequently today, and there are several definitions of what sustainability comprises. The best-known one, from the Brundtland report, Our Common Future (Brundtland, 1987), define sustainable development as: "*a development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (Brundtland, 1987, p. 54). This definition gives the broad meaning of the concept without going into detail; it shows one of the critical characteristics of sustainability, the long-term perspective taken, connecting the present with future generations.

There are three aspects that are identified as important for our society and that are commonly related to the concept of sustainable development: **environmental** concern, **social** welfare, and **economic** development, often called the triple bottom line (Norman and MacDonald, 2004). Definitions of sustainability often include the importance of simultaneously striving toward all these three goals, such as Elkington's definition that involves to simultaneous pursuit economic prosperity, environmental quality and social equity (Elkington, 2002).

Within supply chain management, (Carter and Rogers) define sustainability as "*the strategic, transparent integration and achievement of an organization's social, environmental and economic goals in the systemic coordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its supply chains*" (Carter and Rogers, 2008, p. 368). This definition includes both the triple bottom line's goals as well as the focus on coordination between organizations in the supply chain and long-term business thinking.

Today, sustainability is of interest in the logistics literature, even if it is not well-defined. Most commonly, when sustainable logistics are implied, the environment is the focus, and then the more common term "green logistics" is used. Table 2 presents examples of definitions of green logistics.

Table 2 Examples of definitions of green logistics

Examples of definitions of green logistics	**Reference**
Green logistics is an environmentally friendly and efficient transport and distribution system.	Rodrigue et al. (2001)
The purpose of green logistics is to realize economic benefits of certain products, and at the same time to look after saving resources and protecting environment especially.	Ping (2009)
Green logistics is about achieving a more sustainable balance between economic, environmental and social objectives.	Green Logistics (2010)

Also, "reverse logistics" is a topic included in environmental discussions of logistics, covering how to handle product returns and the secondary market (Storhagen, 2003; Jonsson and Mattsson, 2005). Other logistics literature discusses sustainability in the areas of green supply chain management (Abukhader and Jönson, 2004), environmental logistics (Wu and Dunn, 1995), green purchasing (Björklund, 2005), green marketing (MacLean, 2010), energy efficiency (Halldórsson and Kovács, 2010) and sustainable transport (Gudmundsson and Höjer, 1996).

2.3.1 Challenges when adapting to sustainability

When analyzing the term "sustainability" in the literature, there are different meanings and understandings of what sustainability is, in general, and of what sustainable logistics are in particular (Carter and Rogers, 2008). In total, the concept of sustainability can be very vague to adapt to in a company environment. Norman and MacDonald (2004) critically review the concept of triple bottom lines, concluding that they turn out to be a "*good old-fashioned Single-bottom line plus vague commitment to social and environmental concerns.*" Many of the arguments raised by Norman and Mac Donald concern vagueness in the concept and difficulties in measuring, valuing, and comparing social responsibility issues as well as environmental concern within and across companies and sectors (Norman and MacDonald, 2004). Instead, clear and meaningful principles can serve firms that are bound to form serious strategies for corporate sustainability (Norman and MacDonald, 2004).

Traditionally, from a company perspective, logistics is driven by profit maximization, a high service level and low costs. In the logistics literature, tradeoffs between different goals are a well-known problem. (Jonsson, 2008) exemplifies how goals within the functions of purchasing, production, marketing, and finance can conflict. Therefore, it is important to strive for the best overall performance, not increasing one variable at the expense of others (Jonsson, 2008). Vachon and Klassen (2006) discuss the greening of supply chains and mention that social, environmental and economic goals can harmonize (Vachon and Klassen, 2006), but there can also be conflict among them (as shown by the unsustainable trends in the transport sector). However, environment and social issues not are as highly prioritized in companies. Vachon and Klassen state that "*it is unlikely that environment-related goals and objectives take precedence over primary operational performance criteria such as cost, quality and delivery*" (Vachon and Klassen, 2006, p. 801). In line with this, Rodrigue et al. (2001)

identifies the paradoxes of green logistics in five dimensions: costs, time/flexibility, network, reliability, and warehousing. When seeing the consequences of efficient and cost-effective goals in logistics, they conclude that logistics is a long way from being green (Rodrigue et al., 2001).

Comparing the single-company (micro) perspective with a macro perspective, the latter has a longer-term focus on welfare maximization in the society as a whole and thus also includes sustainability as an important goal. Of course, the whole logistics sector contributes to social welfare because of the services it assists (e.g. the availability of a wide range of products in society) and its contribution to economic development. Still, the economic forces in the micro-environment are prevalent. One reason for not prioritizing environmental and social sustainability goals over short-term economic goals in a micro-environment is that there are no costs directly related to negative environmental and social effects. These costs often are referred to as external costs (for different methods on how to value and calculate external costs for the transport sector, see Belhaj and Fridell (2008) or Fridell et al. (2011)). From a macro perspective, it will be important to internalize external costs to a larger extent in future, such as by increasing fuel taxes. In Figure 11, three levels of analysis and their respective primary goals are described.

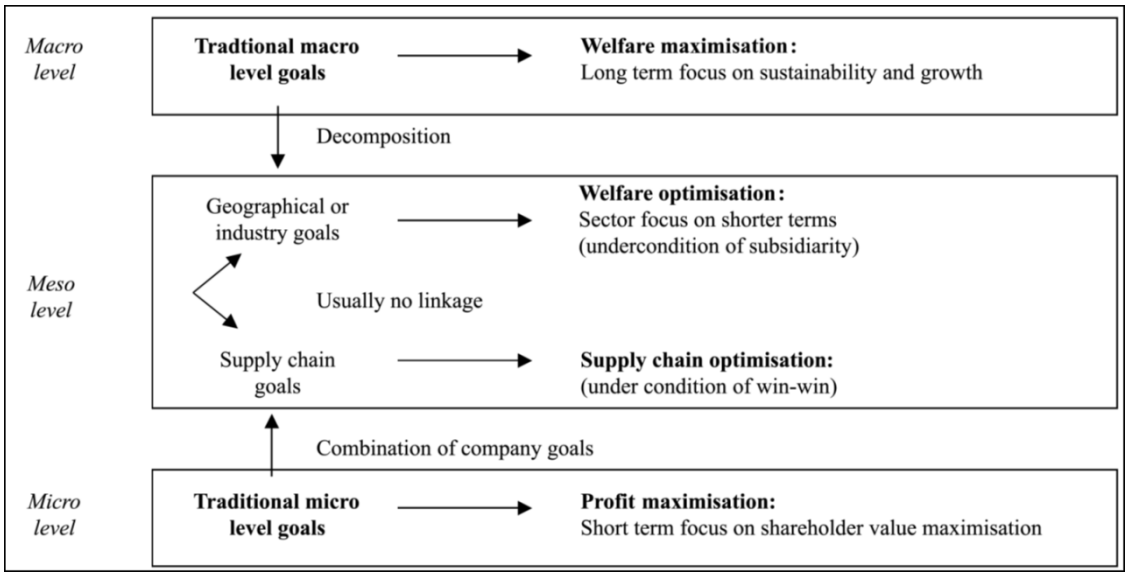

Figure 11 Macro, meso, and micro levels and their respective primary goals

Complex interactions between different aspects of the sustainability concept makes it complicated to describe in detail its definitions and application. Definitions of sustainability are often so broad that they are difficult to understand in a company environment (Venkataraman, 2009) as well as to apply in practice (Bowen et al., 2001). Since logistics management focuses on economic variables, there is no need to focus on economics specifically when discussing the sustainability concept in relation to sustainable logistics. Since the literature also show the lack of focus on environmental and social issues in logistics, as well as the large environmental impact, it is even more important to highlight these issues when looking at sustainability within the sector.

For future business competitiveness, it will be important for firms to have a longer-term perspective (as opposed to focusing on short-term economic gains), to prioritize ecological and social aspects more highly and thus take a higher level of systems thinking (Holmberg and Robért, 2000). This is due, for example, to higher environmental and social concerns from customers (Wolf and Seuring, 2010), stricter policies and regulations (Dey et al., 2011), higher costs of freight transportation (Dey et al., 2011). On a global level, societal development is making radical changes to conditions in the complex ecosystem, shown by changed climate, decreased number of species in nature, over-harvesting, over-fertilization, and health effects from pollution. For it to be possible for the expected population of 9 billion people to live with a reasonable quality of life on this planet, the limited resources the earth provides us need to be used in a much more efficient way. With respect for the prerequisites of the natural environment as a basis for decision-making, it should be possible to find sustainable, new business opportunities among companies. This kind of reasoning is in line with strong sustainability: imposing that stronger environmental control is a higher priority than economic and social consequences. This thinking may be more widely applied in order to curb environmental problems in terms of, for example, climate change (McKinnon, 2010b).

In the next section, a number of definitions that place a higher priority on environmental and social issues and are more concrete in sustainability applications are reviewed.

2.3.2 Sustainability with focus on natural resources

In the area of sustainable transport, several definitions take the view of balance between usage and conservation of resources and their distribution. The OECD uses the concept of Environmentally Sustainable Transport (EST) and defines EST as: "*Transport does not endanger public health or ecosystems and meets needs for access consistent with a) use of renewable resources below their rates of regeneration and b) use of non-renewable resources below the rates of development of renewable substitutes*." (OECD, 2002, p. 42). Moreover, (Gudmundsson and Höjer) conclude that the following principles for sustainable development are applicable in a transport context:

1. *To safeguard a natural resource base within critical loads, levels, and usage patterns*
2. *To maintain the option value of a productive capital base for future generations*
3. *To improve the quality of life for individuals*
4. *To secure an equitable distribution of life quality* (Gudmundsson and Höjer, 1996, p. 280)

Also, Behrends identifies principles for sustainable freight transport, in which he negates upstream sources of unsustainability. "*A sustainable freight transport system:*

1. *Does not impair an undisrupted goods supply at reasonable cost*

2. *Does not impair the accessibility of peripheral regions versus central regions*
3. *Does not use fossil resources or renewable resources over their rates of generation*
4. *Does not emit air pollutants*
5. *Does not generate traffic and infrastructure in sensitive urban areas and ecosystems."* (Behrends, 2011, p. 70-71)

Holmberg and Robért (2000) developed principles for sustainability to be used in a framework for strategic planning in organizations. Generally, it is referred to as the framework for strategic sustainable development (Robèrt, 2000; Robèrt et al., 2002). The framework has been used in strategic planning activities in earlier research in various research and organizational environments for method development, such as by Ny et al. (2006), policy making, such as by Szpala (2008), and business strategies, such as by Hallstedt et al. (2010). Use of these principles as a guideline for actions guiding sustainability in logistics has not been seen in earlier research, although they seem promising in their application in a company environment, and they do focus on resource use and social concern, which other definitions have failed to do concretely. The principles for sustainability are about striving toward having a balance between the resources used in society and nature, meaning that the activities in society should not systematically degrade biodiversity, change the ecological system, and delimit its resources. The first three of the four principles developed by Holmberg and Robért are described as follows: *"In a sustainable society, nature is not… :*

1) *subject to systematically increasing concentrations of substances extracted from the earth's crust*
2) *subject to systematically increasing concentrations of substances produced by society*
3) *impoverished by over-harvesting or other forms of ecosystem manipulation." (Holmberg and Robért, 2000, p. 301)*

These three principles focus on ecological sustainability; the fourth principle deals with the societal dimension. *"In a sustainable society…*

4) "*… resources are used fairly and efficiently in order to meet basic human needs worldwide." (Holmberg and Robért, 2000, p. 301)*

These four sustainability principles are used as an overarching definition for sustainability. To apply sustainability for freight transportation according to these principles requires that environmental concern be the focus. Figure 12 shows an overview of the main issues in the freight transport system that violate these sustainability principles. Violating Principle 1 is depleting fossil fuel resources. Violating Principles 2 and 3 is emitting pollutants and using too much land for infrastructure. Violating Principle 4 is transporting inefficiently and causing social damage. An environmentally sustainable freight transport system does not violate these sustainability principles. Logistics actions that have the

potential to limit any of the above-mention violations have the potential to enable environmentally sustainable freight transport.

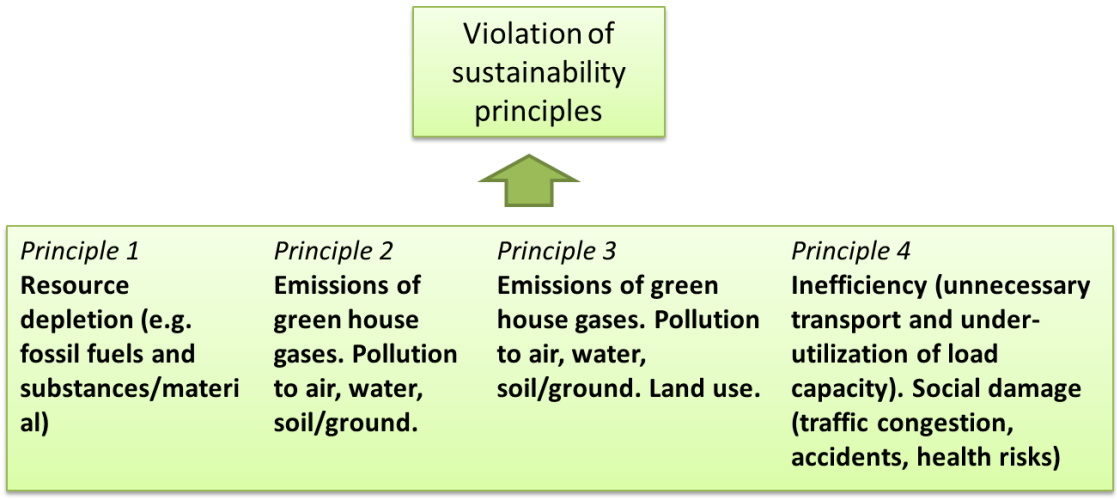

Figure 12 Summary of how freight transport activities violate the sustainability principles

2.4 Logistic actions bridging the gap

In order to bridge the gap between today's unsustainable freight transport pattern and an environmentally sustainable freight transport system, change is needed. It is crucial to identify what logistics actions can play an important role in this change.

In this thesis, a logistic action is one that implies a change. Other expressions that are used in this sense in the green logistics literature are practice, measure, choice, and decision. The use of the term action indicates that this activity has potential to lead toward change in the logistics system. Logistic actions of interest in this research include actions to be taken in tactical, operational and strategic level in companies and can be taken by the main actors in the logistics system: transport buyers, freight forwarders, transport operators, and authorities. Technical and organizational actions also are included. The actors, in turn, are influenced by policies and regulations, so-called action pre-conditions.

A number of analytical frameworks have been identified in the literature that study cause-and-effect between logistical activities and environmental impact. Relationships between various factors and their effects show the complexity in the logistics system and the many ways to choose and combine variables to illustrate relationships. The main theories influencing the current research are presented below.

McKinnon (McKinnon and Woodburn, 1996; McKinnon, 2003); Piecyk and McKinnon (2010) has, through a number of studies, developed an analytical framework to map inter-dependence between logistical variables, determinants, and environmental impact in terms of CO_2-emissions. The variables include:

1. **Structural factors** related to number, location and capacity of factories, warehouses, shops and terminals in the logistics system.

2. **Commercial factors** related to a company's sourcing and distribution of products (the pattern of trading links between the company and its suppliers, distributors and customers)
3. **Operational factors** related to scheduling of product flow.
4. **Functional factors** related to management of the transport resources.
5. **Product-related factors** related to the nature of transport operations.
6. **External factors** such as government regulations, macro-economic trends, market dynamics, and advances in technology.

McKinnon has influenced other researchers (such as Drewes Nielsen et al. and Aronsson and Brodin) in their way of structuring logistics decisions. Drewes Nielsen et al. present a "*chain perspective on transport, where transport is to be understood as an integrated part of the logistical systems*" (Drewes Nielsen et al., 2003, p. 304). The analytical approach presented includes how changes affect four levels of decision-making within logistics (based on McKinnon (1998)), how this is revealed in transport logistics indicators, its effect on transport indicators, and, finally, its environmental and societal impacts (Drewes Nielsen et al., 2003). While Piecyk and McKinnon (2010) focus on CO_2-emissions only, Drewes Nielsen et al. takes a wider perspective regarding environment and societal impact, including also pollution, noise, accidents, and congestion, even though she does not further link each decision or indicator to specific impacts.

Inspired by McKinnon, Aronsson and Brodin (2006) propose a framework model illustrating how logistics decisions at one level create opportunities and set limitations for decisions made on another level, as shown in Figure 13. Their first three levels are operational, tactical, and strategic, whereas the fourth level concerns product design. Also, they have linked the four levels to the system levels concerned. However, environmental consequences are dealt with only in general terms.

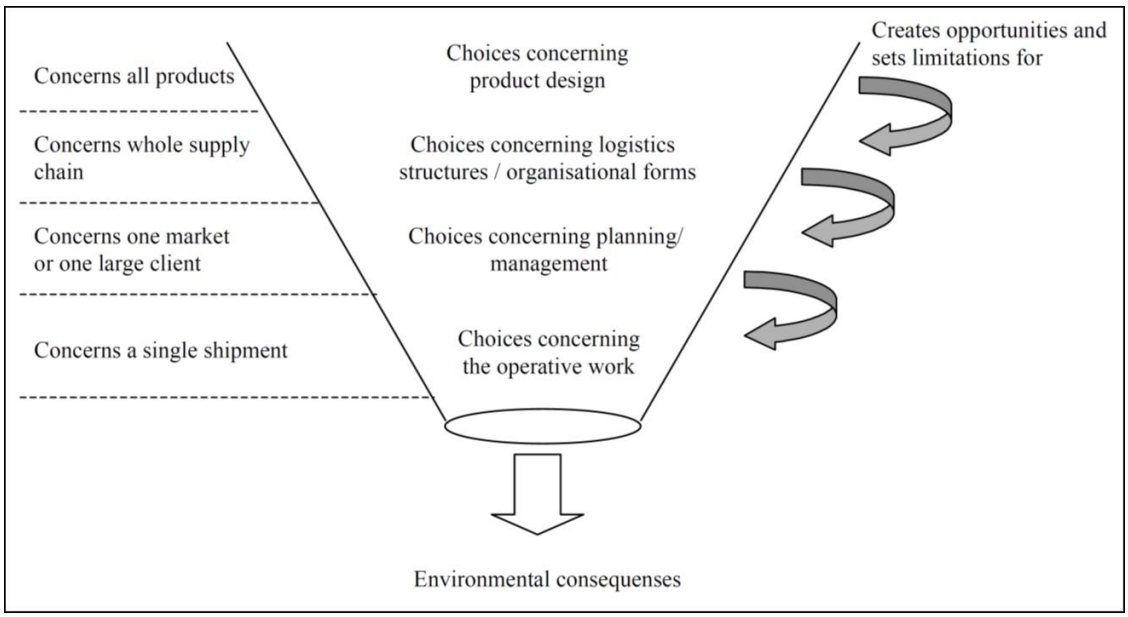

Figure 13 Framework model describing different logistics decision levels and their funnel-like relationship (Aronsson and Huge Brodin, 2006)

In order to be more concrete than earlier research into the environmental consequences of logistics strategies, the starting point for the current research is to divide logistics actions into three categories, based on three approaches for reducing environmental impact of freight transportation, based on Björklund (2005) and Lammgård (2007):

1. Reduce the environmental impact for each transport mode
2. Use environmentally better transport modes; or
3. Diminish the need for transport

These three approaches of reducing the environmental impact of freight transport form a general characterization and are related to each other in several ways. To reduce the environmental impact of each transport mode relates to technical advances at the vehicle level. To use environmentally better transport modes concerns modal shift and the use of intermodal transport. To diminish the need for transport is about reducing transport on one hand (tonne-km) and traffic on the other (vehicle-km). For example, this can be about reducing transport by logistical and organizational changes so that increased load factor can be obtained in the vehicles, leading to fewer vehicles in traffic because of better coordinated transport flow. It is also about localization of industries and choice of suppliers so that an effective transport flow can be obtained. Understanding what factors drive increased demand for freight transport is important to knowing how to enable environmentally sustainable freight transport. The need for transport and goods movement in itself are constructed around many external and internal factors in a company, such as: availability of resources, location of markets, number of suppliers and production facilities, available techniques in the market, and customer demand. These factors influence in different ways the possibilities for improvements on the other two levels, increasing use of environmentally better modes of transport and reducing environmental impact of each transport mode.

2.5 Hindrance of actions

The literature discusses several arguments for establishing sustainability in firms. Possible competitive advantages to acting to reduce environmental impact are to lower costs, pre-empt competitors, and take an industry-leading position (Hart, 1995). Carter et al. (2000) have indicated that environmental purchasing among firms actually can be positively related to a firm's performance. Further, competition, legitimation, and environmental responsibility motivate companies to adopt environmental management strategies (Bansal and Roth, 2000). From a third-party logistics firm's perspective, Lieb and Lieb (2010) point out the following reasons: desire to do the right thing, pressure from customers, desire to enhance company image, desire to attract green customers, and competitive pressure. Further, Dey et al. (2011) identify a number of motivations complementing those above: a green company image can increase product sales; an efficient use of resources saves costs; and, similarly, acting ahead of government intervention may also save costs.

Even though there are plenty of arguments for acting in a more sustainable way, the literature shows a poor implementation level of environmental practices (Léonardi and Baumgartner, 2004; Perotti et al., 2012). The reasons for acting or

not acting are scarcely dealt with in earlier research. Walker (2008) has explored drivers and barriers to green supply chain management. Drivers include, internally, organizational factors, and externally, regulation, customers, competition, and society. In addition, barriers include, internally, costs and lack of legitimacy, and, externally, regulation, poor supplier commitment, and industry-specific barriers. Björklund (2011) investigated what factors can influence the purchase of environmental transportation services in terms of both driving forces and hindrances. For the management of the firm, drivers are top/middle management awareness, priorities, environmental management, and characteristics of management. In addition, the firm's reputation and the image of the firm and its products are also great driving forces. Hindrances include customers' non-environmental demands, while carriers' knowledge, ambitions, equipment, and the relationship with the carrier have great positive influence on the environmental purchasing. Finally, influence from government, such as judicial means of control, taxes, and subventions are drivers as well.

To improve the actual implementation level of actions, it is important to understand the perspectives of the actors themselves. Today, outsourcing transport activities to a third party is common. Lammgård (2007) reports, from a Swedish perspective, that more than 95% of manufacturing companies have their transport organized by transport providers. Also, as mentioned earlier, changes in one actor's system may have effects on another, especially between the material and transport flow layers, see 2.1. This means that the relation between a transport-buying company and a transport-providing one is crucial. Few research initiatives have looked at the linkage between transport buyers and transport providers; thus, their interaction is of special interest in this research.

2.6 Importance of load factor

Road transportation has become an increasingly dominant choice for transport buyers; therefore, diminishing the need for those operations is important. More specifically, using vehicles efficiently, in terms of load-factor level, has been shown to be critical to total environmental impact in road freight transport systems (Piecyk and McKinnon, 2010). In addition, studies show that an increased load factor causes less environmental impact and saves transport costs (Wu and Dunn, 1995; Blinge, 2005; Kohn and Brodin, 2008) and are therefore of high interest to the main actors in logistics systems.

Several ways of improving load factor are discussed in the environmental/green logistics literature, ranging from strategic and tactical decisions within firms to operational practices and regulatory activities. Table 3 shows ways to improve load factor in vehicles, based on the environmental/green logistics literature.

Table 3 Overview of ways to improve load factor in vehicles

Type of logistical action	**Examples**	**References**
Strategic decisions in firms	• Size of warehouse • Centralize distribution • Reduce number of warehouses • Change location of warehouses	Wu and Dunn (1995), Aronsson and Huge Brodin (2006), Kohn and Brodin (2008)
Tactic operations in firms	• Vehicle routing • Change storage strategies • Minimize number of deliveries	Aronsson and Huge Brodin (2006)
Order and delivery	• Order lead time • Order and delivery timetable • Frequency of deliveries to shops • Variability of order size	McKinnon (2000), Piecyk and McKinnon (2010)
Packaging	• Reduce weight and volume in packaging material • Package more efficiently on one loading unit	Wu and Dunn (1995), A.T. Kearney (1997), Gustafsson et al. (2004), Blinge and Svensson (2005)
Loading	• Choosing appropriate loading method and load unit • Possibility to stack on height	McKinnon (2000)
IT	• Implementing IT-based scheduling systems e.g., positioning and navigation of vehicles • Computer programs assisting packaging operations	Wu and Dunn (1995), Léonardi and Baumgartner (2004)
Consolidation	• Consolidation between transport buyers • Consolidation by third-party logistics providers • Coordinated distribution in city logistics	Wu and Dunn (1995), McKinnon (2000), Ljungberg and Gebresenbet (2004), Blinge and Svensson (2005), Kohn and Brodin (2008)
Backloading	• Increased return loading in companies' transport systems	McKinnon (2000)
Empty running	• Reduce empty running by trucks	McKinnon and Ge (2006)
Regulations	• Raising limits on vehicle carrying capacity	McKinnon (2000)

2.7 Relevant theory to purpose

The above-described earlier research and theories in the area of sustainable logistics motivates the researcher's view on the logistics system and on the main areas to be explored in the current research. In Figure 14, the outcome of each

subsection is summarized in terms of key issues related to areas explored in the research.

In this research the focus in the logistics system is on actors acting in the material flow and transport flow layers. The interactions between those two layers are creating the transport market where actions taken on one layer creates opportunities and set limitations for the acting on the other layer. The main actors in focus acting within these two layers are transport buyers, freight forwarders and transport operators. Also, of interest in this research are the authorities, setting the framework conditions for the actors' activities. The theoretical frameworks of sustainable logistics were reviewed, concluding that possible logistics actions can be taken at strategic, tactical and operational level in companies taken by the above mentioned actors. This includes also technical and organizational actions as well as policies and regulations relevant for enabling environmentally sustainable freight transport. Actions can be categorized according to three approaches reducing environmental impact from freight transportation (Björklund, 2006; Lammgård 2007). Based on the review on definitions on sustainability, this research describes environmentally sustainable freight transport as not violating the four sustainability principles (Holmberg and Robért, 2000), thus the identified actions should aim at contributing to fulfilling these principles. New insights about why so little action is taken among logistics actors can be received by studying hindrances in the interface between transport buyers and transport providers. Possible hindrances for acting can be of both external and internal character. In order to gain knowledge about how to apply actions in practice, increasing load factor is found to be an important action area and there are several logistics actions that can potentially increase load factor level in vehicles.

The explored research areas are broad in the sense that they handle a wide range of issues, linking a holistic logistics system view with the practical work of companies. However, earlier research has shown the need for specifically linking those views, providing better understanding of interaction between activities in different parts of the system and their contributions to sustainable freight transport, while also providing knowledge that will be applicable in practice. The above summary of relevant theory to the purpose of this thesis provides the basis for the undertaken research.

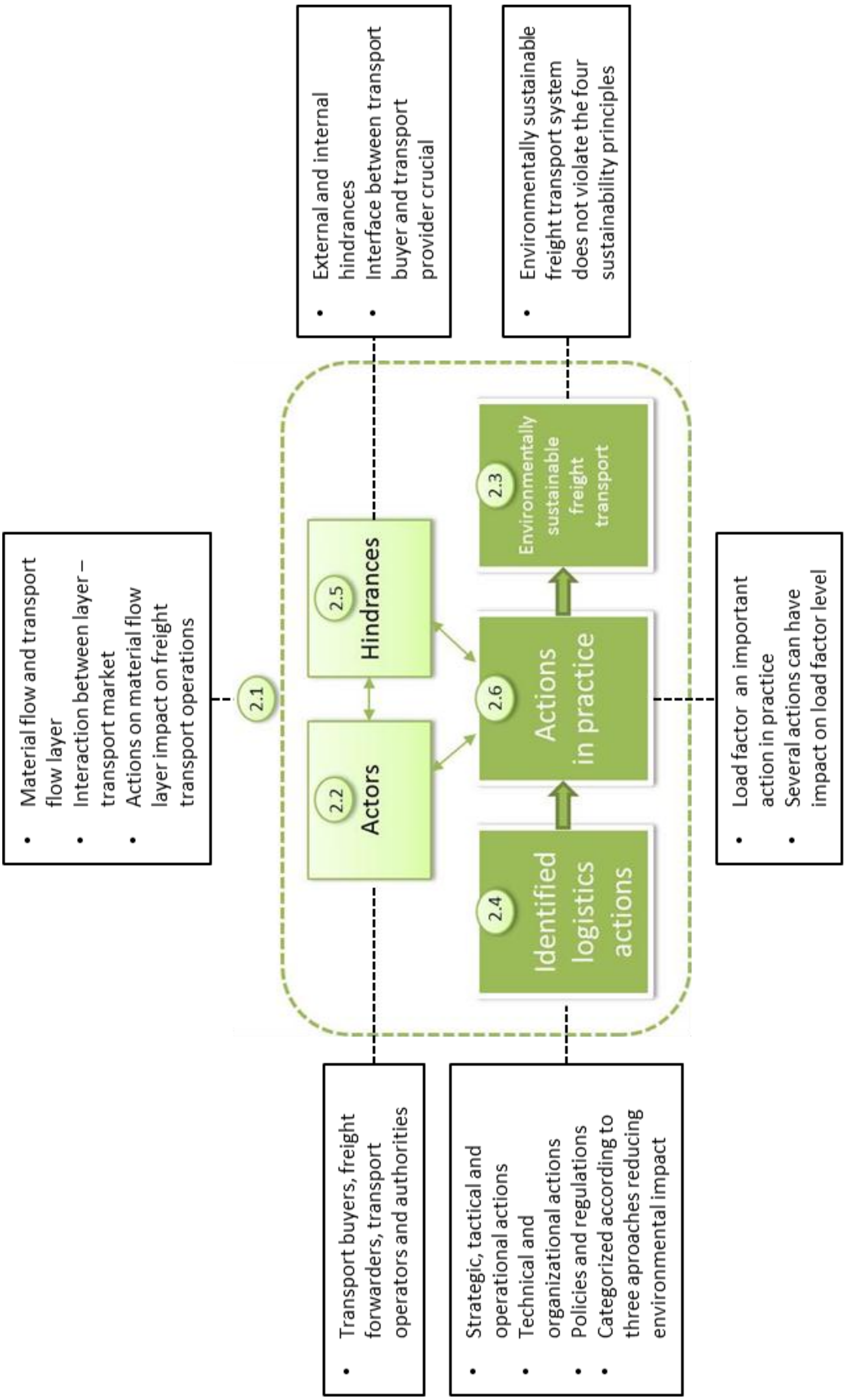

Figure 14 Relevant theory to the explored research areas

3 Methodology

This chapter presents the research approach taken in order to answer the proposed research questions and describes the methodological choices regarding research design and methods for data collection and analysis. In addition, the quality of the research is discussed.

3.1 Research process

According to Croom, the process of research is a very individual one and "*very few research projects or doctoral projects follow a neat, linear project plan*." (Croom, 2009, p. 43). However, authors do mention the importance of having an idea of the structure of the main elements in a research project. Such a plan can include several steps, which in reality most often becomes an iterative process that greatly depends on the actual situation in the specific project and the responsible researchers. As an example, Bryman (1988), specifies a simplified overview of the research process: 1. Identify a broad area of study; 2. Select the research topic; 3. Decide the approach; 4. Formulate the plan; 5. Collect the data or information; 6. Analyze and interpret the data; 7. Present the findings.

The research undertaken in this thesis involves several sub-studies. However, in line with the above-mentioned research process, the first step was to identify a broad area of study and select the research topic. Having a background from studies in industrial ecology and practical work in the area of logistics and environment, the main interest was in the area of sustainable logistics. In order to familiarize with earlier research, the literature was first overviewed and reviewed in the broad area of sustainable logistics and related matters, such as environmental/green issues in transport, logistics, and supply chain. The challenges in this first part of the research were to get an overview of the research topic that was defined within the project as a starting point in the research and to delimit the research into manageable studies. Within the project, the aim with this part of the research was to contribute to have a holistic view on the logistics system analyzing how to proceed towards sustainability. Based on the literature review, the focus was chosen as logistics actions and how these can enable environmentally sustainable freight transport. Still, there was a need for knowing more about how the actors in the logistics system work in order to get a better view of practical implications. From this starting point, the first study (presented in Paper I) was designed, focusing on identifying actions that reduce environmental impact from freight transport, based on the literature on one hand and on practitioners' perceptions on the other. Based on the findings of the first study, the coming studies were designed. The second study (presented in Paper II) focused on identify what hinders environmentally sustainable freight transport in the interface between transport buyers and transport providers. The third study dealt more specifically with studying one of the actions identified as important, namely how to increase load factor. Hence, the overarching purpose of this thesis was formed from the primary literature review, and the research questions were continuously adjusted during an iterative research process during which each study was motivated by previous ones. Along with the research process, the literature was constantly reviewed and formed the input for each

study as well. The research process and research methods are described in Figure 15.

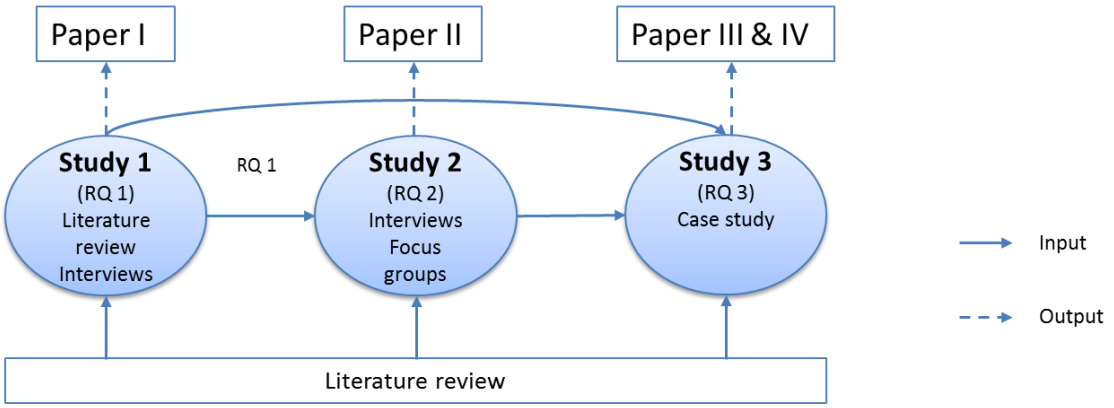

Figure 15 Overview of the research process undertaken and the main research methods

3.2 Systems view

The research approach undertaken in this thesis can be classified according to the systems view. Following is a discussion of different interpretations of systems views in logistics research and thereafter is a concretization of the systems view undertaken in this thesis.

3.2.1 Systems view in logistics research

"*The general tenet of the systems concept is that we do not focus on individual variables but on how they interact as a whole. The objective is to operate the whole system effectively, not just the individual parts*" (Coyle et al., 2003).

Logistics research traditionally has a systems approach, as mentioned by a number of authors (e.g. Stock and Lambert (2001), Bowersox et al, (2002), and Coyle et al. (2003)). The traditional components in a logistics system are functions (Bowersox et al, 2002) or activities (Stock and Lambert, 2001) such as transportation, warehousing, inventory, order inventory, materials handling, packaging, and facility network design (Bowersox et al, 2002). The systems approach is shown by "*a synergistic interrelationship between functions in pursuit of higher overall achievement*," where in "*logistical systems, synergistic performance is targeted customer service levels at the lowest possible total cost.*" (Bowersox et al, 2002).

When using a systems perspective in logistics research, different notions are used almost synonymously, such as systems theory, systems approach, and systems thinking (Gammelgaard, 1997). Checkland (1993) uses systems thinking as a main notion, defining it as making "*conscious use of the particular concept of wholeness captured in the word 'system', to order our thoughts*." This thinking implies to "initiate and guide actions we take in the world." Lindskog (2008) argues the importance of distinguishing between systems approach and systems thinking, the latter not being seen as much in logistics research. Systems thinking is argued by Lindskog to be different from systems approach because it takes into account the actors thinking within the system and engaging in the social context. This view seems to be close to the "soft systems" approach as described

by Checkland, which focuses on the human activity system managing "soft" problems in social systems and which is also used in action research. Another similar approach, but one differentiated from systems view, is explained by Arbnor and Bjerke (2009): the actors view.

3.2.2 System view in this thesis

As the above quotation by Coyle et al. (2003) indicates, central to this thesis is the view of that the sum of the parts are more than each individual variable. The goal when studying the system in this thesis is directly linked to the purpose of this thesis, that is, to explore logistic actions enabling environmentally sustainable freight transport. This is explored by taking the perspective of different actors within three system levels.

Therefore, viewing the system as including several subsystems, and their individual parts are central. The system used in the undertaken research is represented by actions within three system levels: logistics system, dyadic system, and company system, where each system level represents the perspective of different actors. The system levels are presented in Figure 16. Further, the focus is on interactions between subsystems as well as interactions between parts in each subsystem. This is due to the importance of understanding direct and indirect relations between actions among the main actors in the logistics system.

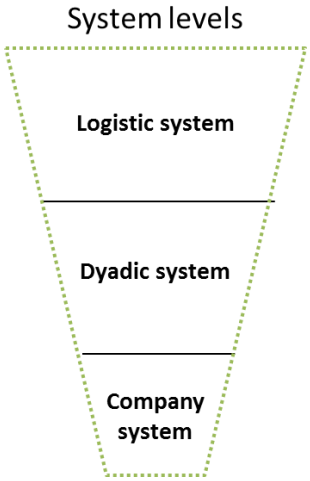

Figure 16 The system levels that are included in the current research

As in soft systems methodology (Checkland, 1993), not only is the technical system included, but also the individuals. This means focusing not only on technical advances that enable environmentally sustainable freight transport, but also including how logistics actions can affect transport operations and diminish the need for freight transport in general. In order to reach a good enough understanding of the system, it is important to see it from a more holistic view (Arbnor and Bjerke, 2009). By looking at the system from the first system level, the logistics system, the most holistic view of the system is achieved. This is especially important due to the possible effects that actions in each actor's system can have on other system levels. It is important to be aware of sub-optimizations, creating a new problem from limiting an existing one. Looking at only one actor's system, such as at the company level, is not enough. An improvement on the higher system level must be reached as well.

As has been discussed by Sandén and Harvey (2008), it is difficult to relate the problem to one specific system level because lower level studies can miss the effect on the higher level. On the contrary, higher system levels may lack detail, leading to over-simplification. Looking at logistics actions from the three system levels makes it possible to both receive knowledge about the details and also map these effects on a higher system level, which is of special importance when aiming for environmentally sustainable freight transport.

3.3 Qualitative research

There are "*two distinct clusters of research strategies*," quantitative and qualitative (Bryman and Bell, 2007). The general distinction between them concerns how the relationship between theory and research are viewed and what epistemological and ontological orientations are taken in the respective research strategies. The differences between qualitative and quantitative research strategies are described in Table 4.

Table 4 Comparison between quantitative and qualitative research (Bryman and Bell, 2007)

Research strategy	**Relationship between theory and research**	**Epistemological orientation**	**Ontological orientation**
Quantitative	Deductive research - theory guides research	Natural science model, in particular positivism	Objectivism
Qualitative	Inductive research - theory is an outcome of research	Interpretivism	Constructivism

The distinctions between the two research strategies, as described in Table 4 above, is not as straightforward as it may look (Bryman and Bell, 2007). Quantitative research has a history of being underpinned by a natural science model in which mathematical and statistical tools are used to analyze numerical data (Bryman, 1988). However, qualitative research has emerged due to the need of formulating "*subject- and situation-related statements, which are empirically well founded*" (Flick, 2009). One reason for that is that rapid social change has made researchers face new contexts and perspectives (Flick, 2009). Also, there has been a growing need for inductive research because in the new world makes it unsuitable to use earlier theories and form hypothesis and research questions from them (Flick, 2009). Therefore, qualitative research has received increased attention during the last decades (Flick, 2009).

The above differentiations can be seen as the extreme sides of each strategy, while in reality, a mixture and combination of different research strategies can be used; "*it is plausible, and indeed common, that researchers having a qualitative approach may adopt either a positivist or phenomenological stance*" (Croom, 2009, p. 67). Thus, qualitative research can also test rather than generate theories (Bryman and Bell, 2007). Also, the two research approaches can complement each other. Two ways that qualitative research can facilitate

quantitative is by providing hypothesis or aiding measurement (Bryman and Bell, 2007).Further, using mixed data collection methods and analytical tools are common in qualitative research. Nevertheless, it is important to choose the most appropriate one for the undertaken purpose and research question (Croom, 2009).

The research undertaken in this thesis is qualitative in nature. Because the area of sustainable logistics is rather new to study and is rapidly emerging, existing theories are lacking. Furthermore, the need for application of actions in practice makes it important to understand the context and perspectives of the actors in the system. Therefore, this research is inductive, taking as its base empirical data. This research contributes to developing hypotheses and theory rather than being guided by existing ones.

3.4 Research design

"*Research deign is a plan for collecting and analyzing evidence that will make it possible for the investigator to answer whatever question he or she has posed. The design of an investigation touches almost all aspects of the research, from the minute details of data collection to the selection of the techniques of data analysis*" (Ragin, 1994, p. 191).

Based on the purpose and questions that are posed in this research, the research design is chosen; what type of data needs to be collected and how to analyze the collected data.

The purpose of this thesis is to explore logistic actions enabling environmentally sustainable freight transport from actors' perspectives. The purpose makes it apparent that the research is exploratory and takes different actors' perspectives. Key points for exploration are descriptions of their perspectives and overviews of patterns and structures of logistics actions within actors' systems as well as between actors. The unit of analysis is logistics actions enabling environmentally sustainable freight transport.

To explore is historically one of the main purposes of qualitative researchers (Marshall and Rossman, 2006). Two other major purposes in qualitative research are to describe and to explain. Exploratory research can be described as investigating little-understood phenomena, identifying or discovering important categories of meaning and generating hypotheses for further research (Marshall and Rossman, 2006).

The current research is divided into three research questions, which were presented in 0. While the overall purpose is rather open in its formulation, the three research questions are step-by-step narrowing the scope and perspective of its formulation. As mentioned in 3.1, these three questions have not been posed at the very beginning of research; rather the results from each study have provided input into the next ones (see Figure 15).

RQ 1, **What actions enabling environmentally sustainable freight transport are identified as important within the transport community?,** is of a descriptive character, thus it aims at documenting and describing logistics actions that enable environmentally sustainable freight transport. Literature review and

interviews are chosen as appropriate data collection methods. RQ 2, **What factors hinder environmentally sustainable freight transport in the interface between transport buyers and transport providers?**, is of an exploratory nature in that it aims at identifying factors that can be important for enabling environmentally sustainable freight transport. Interviews and focus groups are used to collect data. RQ 3, **How can an increased load factor in road freight operations be achieved?,** explores linkages between actions and an increased load factor. This research question takes the company system perspective, thus it is suitable to perform a case study as the main approach. Interviews, archival sources, and visual observations are used as data collection methods. Table 5 summarizes the type of research performed and the methods used to answer each question.

Table 5 Summary of research questions, type of research and research methods used

Research question	**Study**	**Type of research**	**Methods used**
RQ 1: What actions enabling environmentally sustainable freight transport is identified as important within the transport community?	Study 1	Descriptive	Literature review Interviews
RQ 2: What factors hinder environmentally sustainable freight transport in the interface between transport buyers and transport providers?	Study 2	Explorative	Interviews Focus groups
RQ 3: How can an increased load factor in road freight operations be achieved?	Study 3	Explorative	Case study approach including: Interviews Archival sources Visual observations

3.4.1 Methods of data collection

From the summary in Table 5, it is apparent that a number of different methods have been used to answer each research question. As seen in Table 5, methods include literature reviews, interviews, focus groups, archival sources, and visual observations. Below, the choice of each method is further motivated. The methods used to answer the first two research questions are handled separately, while the case study approach is described in a separate section.

Literature review

As mentioned in Section 3.1, the literature has constantly been reviewed during the research process in order to provide input to the studies. However, as a main research method, review has been used in order to answer the first research question. The literature review was used to identify what actions discussed in research would enable environmentally sustainable freight transport. The literature review included scientific articles, policy documents, and reports. Policy documents were searched for on national and European governmental

websites. From the literature, a list of actions was made, categorized by certain action aims: reduction of environmental impact for each transport mode, usage of environmentally better transport modes, and diminished need for transport. The action list was used in the interviews in the second part of the study, which is further described below.

Interviews

Interviews were used as one type of research method to answer RQ 1 and 2. The aim of the interviews was to explore practitioners' work in the field of logistics actions that enable environmentally sustainable freight transport. The interviews were semi-structured, combining open-ended questions with more specific ones. Also, respondents were allowed to discuss issues related to the subject more closely if there was need for more detailed explanation in order to give a better picture of their situation. Therefore, follow-up questions depended on the situation. This is in line with the characteristics of a semi-structured interview, which allows the researcher to be flexible about the order of questions and to include questions of interest depending on the specific respondent (Bryman and Bell, 2007). The interviews consisted of two parts: the main section with questions and the final section, with an evaluation of actions. An interview guide was used, with questions covering a number of areas of interest. The areas were related to the following issues: background of the company or organization, environmental goals, actions implemented today, actions in the future, and actor's responsibility. When discussing actions, reasons for acting and difficulties in realizing an action were discussed. The final part of the interviews included an evaluation of the action list developed from the literature. The purpose of the evaluation was to identify to what extent each action was important in order to reduce environmental impact of freight transport for each respondent's organization. These were seen as a complement to the discussions from the first part of the interviews.

The respondents were from four main practitioner groups in the Swedish logistics system: transport operators, freight forwarders, transport buyers, and authorities. The transport operators were medium-sized trucking terminals operating on a regional level, the freight forwarders were third-party logistics providers operating on an international level, and the transport buyers were large international companies with bases in Sweden. The authorities were acting both on national and municipal levels. Three interviews in each actor group were conducted, thus twelve in total.

Two researchers conducted the interviews, and they lasted 1 to 2 hours each. The interviews were recorded and thereafter transcribed.

Focus groups

Focus groups were used as a research method to answer RQ 2. This method was chosen because of its advantages for capturing the dynamics of viewpoints from several participants in the groups (Kvale and Brinkman, 2009). Also, focus groups are useful for orienting oneself in a new field, generating hypotheses based on informants' insights, and evaluating different study populations (Morgan, 1988). Because the research question specifically focuses on a dyadic system, the interface between transport buyers and transport providers, focus

groups were helpful in comparing viewpoints between the two actors. Interviews, described above, contributed to choosing subject areas that were discussed in the focus groups. These were challenges, goals, actor's perspectives, hindrances, and opportunities when aiming for environmentally sustainable freight transport. Two focus-group sessions were conducted, one including transport providers and one including transport buyers. Focus groups consisted of 8 and 10 company representatives, respectively, which is in line with the suitable focus group size, between 7 and 10, suggested by Marshall and Rossman (2006). The focus groups discussions were organized in cooperation with a related research project involving the vehicle industry. Thus, researchers and representatives from both industries were moderating the focus group discussions. The aim was to create informality in the discussions in order to get all members to speak openly while at the same time keeping the discussion on the subject areas. Notes were taken continuously during the focus groups. The notes were thereafter summarized and sent out to the participants for their comments.

Case study

In order to answer RQ 3, a single case study was conducted. RQ 3 is the most specific of the three questions and focuses on how an increased load factor in transport operations can be achieved. The literature expresses a need for more research into how actions can be taken in practice, which is in the hands of the actors. Since case studies are suitable when there is a need for "understanding the dynamics present within single settings" (Eisenhardt, 1989, p.534), case research was chosen to answer RQ 3. The case studied how an increased load factor can be facilitated in outgoing goods flow from a transport buyer's central warehouse. This involved studying actions of one transport buyer and its collaborative freight forwarder. The reason for choosing this particular case was to look specifically at a company that had recently implemented a number of actions aimed at improving load factor.

The data collection in the case was done in a number of steps that evolved over time. The main data collection methods were interviews and searches in the archives of the studied companies. In addition, visual observations of the vehicles leaving Wholesale Alpha's central warehouse were organized in the form of a self-assessment survey to be filled in by the loading staff.

Interviews were performed with employees from both the transport buying and the freight forwarding company. The respondents were chosen based on their position and potential knowledge about the companies' strategic, tactical, and operational logistical work. An interview guide was used in the interviews, divided into a number of themes, with all themes more or less deeply covered, depending on the respondents' knowledge about the theme. The first aim was to get an overview of each company's logistical work as well as about their collaboration. Second, more detailed information was gradually searched for in the areas of their ambitions, implemented actions, reasons for acting, effects, environmental work, customer requirements, and future work. The interviews lasted between one and two hours, and notes were taken during them. Directly after the interviews, a protocol was written based on the notes. Some of the

respondents were contacted more than once in order to confirm findings as well as add further questions that evolved over time.

Archival sources included transport data from both Wholesale Alpha's and Freight Beta's systems. The data included information about Wholesale Alpha's purchased transport to each district in Sweden in terms of ordered load meter, extra booked vehicles, and sent order rows during 2010 and 2011.

The visual observations were performed using a survey to be filled in by the loading staff before the vehicles departed from the central warehouse. Departures of vehicles to three districts during one week were studied, including 15 departures in total.

3.4.2 Analyzing qualitative data

Analysis of qualitative data typically falls into seven stages (Marshall and Rossman, 2006):

1. Organizing the data
2. Immersion of the data
3. Generating categories and themes
4. Coding the data
5. Offering interpretations through analytic memos
6. Searching for alternative understandings
7. Writing the report or other format for presenting the study

These seven steps have been used as a model for the data analysis. The main focus has been on organizing, categorizing, and coding data, and further interpretation of that data. These steps have similarities with Strauss' and Corbin's approach to coding, which is "*representing the operations by which data are broken down, conceptualized, and put back together in new ways*" (Strauss and Corbin, 1990).

Interviews

The data from the interviews were organized according to what actor group the respondent belonged to and further organized into different categories. These categories concerned identification of actions that had been realized historically, today, and what was planned to be applied in the future. Further, hindrances and incentives were connected to each action when possible. The actions were then matched to the results from the literature review in order to identify which actions belonged to identified action operations and action preconditions. In this step "new" actions could be identified.

Focus groups

The data from the focus groups were first organized according to each actor and number of subject areas that were included in the discussion in the focus groups. Secondly, in order to find the common factors, data regarding hindrances and incentives to enable environmentally sustainable freight transport were identified and grouped. This last step required a number of iterative steps in which adjustments were made. Then all data was processed and analyzed until a good match between all data and the factors were found. Also relationships

between these factors were found from this process, which resulted in a model in which the factors are connected to each perspective and its influence on the actors.

Single case study
Similar to the analysis of data from the interviews and focus groups, the data from the interviews in the single case study were analyzed using the seven stages. The collected data were first organized by entering collected data in an Excel sheet. The focus was on identifying actions that had been either implemented, been under discussion, or were ideas for future work, and actions were grouped according to these three aspects. Each action was then further linked to incentives and effects in those cases for which information had been received. The resulting display of actions, incentives, and effects were used to find relations between actions and to see in what way load factor level could be affected. From this analysis, actions were categorized into three areas that were clearly linked to load factor indicators. This categorization of actions is based on the above analysis and originates from interpretation of the interviews. In addition, based on indirect relationships with load factor indicators, a number of logistics variables were found to affect the load factor indicators. Categorization of actions and identification of logistics variables then formed the basis for the framework on how to increase load factor at a transport-buying company.

3.5 Trustworthiness of research

The following criteria have been selected to evaluate the undertaken research in terms of trustworthiness, credibility, transferability, dependability, and confirmability (Marshall and Rossman, 2006; Bryman and Bell, 2007). These criteria have been selected in favor of more commonly used criteria (e.g. validity and reliability) due to the motivations raised by Bryman and Bell (2007), that the criteria developed for qualitative research (and not primarily for quantitative research) may be more suitable for evaluating qualitative research.

Credibility is about ensuring that the research is following good practice and that the members taking part in the study have had the possibility to confirm that the researcher understood the social world correctly (Bryman and Bell, 2007). It can also be explained as being equivalent to internal validity, which refers to the extent to which the conclusions regarding cause and effect between factors are supportable (Croom, 2009). To verify that the research is credible, respondent validation, or triangulation, can be used (Bryman and Bell, 2007).

Respondent validation has been used in two of the studies. The protocols from the focus group discussions, underlying the data collection in the second paper, were sent out to all participants in order to allow them to comment on the content. Furthermore, the case study that resulted in the third and fourth paper included several interviews. A large number of these interviews were followed up with a second contact, by mail, phone, or in person, during which results from the first interview round were discussed and clarifications could be made.

Two useful triangulation methods are mentioned by Croom (2009): methods triangulation and data triangulation. Methods triangulation has been used in the first two studies, which resulted in Paper I and II. The first study uses both

literature review and interviews as data collection methods. The second study uses both interviews and focus group discussions when collecting data. Data triangulation has been used in the case study, resulting in Paper III and IV. Different data sources were used in order to support the findings: interviews, archival sources, and visual observations.

Transferability refers to the degree to which the findings can be generalized across social settings (Bryman and Bell, 2007), or in other words, to what extent the findings can be useful for others in a similar situation or with a similar research question (Marshall and Rossman, 2006). To generalize findings from qualitative research is mostly seen as difficult due to its nature of having small samples and depth rather than breadth. However, there can be some part of the findings or from the approach taken that can be possible to generalize. Possible generalizations can then concern the theoretical parameters of research (Marshall and Rossman, 2006). All studies undertaken in this thesis provide some kind of theoretical contribution (in terms of categorizations, models, or frameworks) that could have value for others. For example, the Paper I contributes an overview of logistics actions categorized according to three approaches of reducing environmental impact that can be valuable in giving a better understanding of actions related to environmentally sustainable freight transport. In general, the detailed descriptions about the empirical data provided in the papers make it possible for others to judge to what extent the results are transferable to other contexts (Bryman and Bell, 2007).

Dependability is about how changes in conditions in the phenomena under study are handled by the researcher (Marshall and Rossman, 2006). The criterion parallel to dependability, used in quantitative research, is reliability, which is about to what extent a study can be replicated, or how members of the research team agree about what they see (Bryman and Bell, 2007). To replicate a qualitative study is difficult due to the assumption of continuous change in a social setting. However, it will be possible to replicate the methodological choices and the role of the researcher. To ensure that there was inter-observer consistency (Bryman and Bell, 2007) at the stages in the research where two researchers were involved, both researchers carefully reviewed all notes from interviews, and when performing analyses, both researchers met to discuss their judgments of the data.

Confirmability refers to the objectivity of the research, or more concretely, that the researcher did not allow personal values to influence research (Bryman and Bell, 2007). One way of dealing with this is to confirm the research with others to see whether it makes sense (Marshall and Rossman, 2006). The steps taken to make sure that the undertaken research has been confirmed are that a constant dialogue around the research design, analysis, and results have been undertaken with the research colleagues and supervisors. Furthermore, until now, results from the studies in this research have resulted in four conference papers, each of which was discussed at a session of the conference. Thus, other researchers got the opportunities to question the studies. In addition, three of the four conference papers were reviewed prior acceptance at the conferences.

4 Summary of appended papers

This chapter summarizes the four appended papers; their purpose, methodological approach and main findings.

4.1 Paper I: Actions for more sustainable freight transport – a comparison between theory and practice

This first paper takes a holistic view of the logistics system, presenting actions found in literature review that reduces environmental impact of road freight transport. These actions are compared by degree of implementation as well as by their importance among practitioners. The actions are further analyzed against sustainability principles. This paper contributes to answering the first research question.

4.1.1 Purpose

The purpose of this paper is to compare theory and practice in the field of future sustainable actions in the logistics system from a holistic view in order to identify actions for more sustainable freight transport.

4.1.2 Method

The identification of actions was made by reviewing the literature and conducting interviews with the main actors in the logistics system: transport buyers, freight forwarders, transport operators, and authorities.

In order to analyze the actions' contributions to sustainability, actions were mapped according to the four socio-ecological sustainability principles.

4.1.3 Results and contribution

The main findings in this article are identified logistics actions that are important to reducing environmental impact from freight transport. Findings were arrived at by identifying a wide range of actions that can be implemented by the main logistics actors. These actions were grouped into three categories regarding whether they contribute to reducing environmental impact for each transport mode, contribute to use of an environmentally better transport mode, or diminish the need for transport. From the identified list of actions, the level of implementation was discussed with the actors interviewed, along with the actors' views on what actions are of most importance for a sustainable future. Further, how these actions contribute to sustainability was analyzed by discussing how the actions identified as most important from the actors' viewpoints contribute to the four socio-ecological sustainability principles.

The article concludes that there is a gap of awareness and a difference in opinion among practitioners and between practitioners and academia on how important and relevant the suggested actions are for reducing environmental impact. Further, the analyses show the importance of having a holistic view on logistics and sustainability and illustrate the need for combining different actions in order to contribute to all four sustainability principles.

4.2 Paper II: Road freight transport efficiency and less environmental impact – the perspective of transport buyers and operators

The second paper studies transport buyers' and providers' perspectives regarding what factors are important when working to reduce environmental impact of freight transport activities. This paper contributes to the second research question, thus identifying hindrances to environmentally sustainable freight transport.

4.2.1 Purpose

The purpose of this paper is to describe and compare the transport buyers' and providers' perspectives about what factors affect the ability to reduce environmental impact of freight transport.

4.2.2 Method

Data collection was based on interviews and two focus group discussions. The interviews were semi-structured and performed with five transport providers and three transport buying companies. The interviews contributed to identifying the subject areas that would be discussed in the focus groups. The focus groups consisted of eight and ten company representatives, and each focus group discussion involved participants from one actor group only.

4.2.3 Results and contribution

Based on the perspectives of those in the two actor groups, six factors were identified as most important to improving transport efficiency and reducing environmental impact of freight transport. These were **competence and resources**, **knowledge and information**, **demands**, **priority of transport**, **service and offers,** and **follow-up environmental goals**. Both similarities and differences were identified among the views of the two actor groups on how to work to reduce environmental impact of freight transport and be more efficient in transport operations. The transport providers raised the challenge of finding enough competence within their organizations regarding environmental issues. They also said economical resources for investments, such as in new technology, were scarce, which had an impact on the ability to act. The transport buyers, on the other hand, felt a lack of knowledge and information about their transport flow on a detailed level. Both sets of actors are dependent on each other's co-operation and increased dialogue to provide better internal conditions. Key issues were how to have an open discussion about how to prioritize among certain demands and how to prioritize transport higher among transport buyers. From the transport providers perspective, transport buyers' demands concerning fast transport time and low price of transport were highlighted as affecting the ability to act more efficiently and environmentally. On the other hand, the transport providers were identified as taking a passive role today. A more proactive attitude regarding offering environmentally preferable services and providing increased information about effects of changes and possibilities to follow up environmental goals would benefit co-operation with the transport buyers. This paper concluded that in both actor's systems it is a necessity to generate better understanding of each other's' systems, have an open dialogue, increase information sharing, and be proactive.

4.3 Paper III: Building a framework for increased load factor – mapping actions and effects from a transport buyer's perspective

The third paper takes the perspective of a transport buying company, a more narrow perspective compared to the first two articles. Earlier studies have described the importance of increasing load factor as one strategy toward sustainable logistics. Since there is also a lack of research on the load factor concept itself, this paper makes a contribution in that area. This paper contributes to RQ 3 by identifying actions that affect load factor as well as studying how these interact.

4.3.1 Purpose

The purpose of this article is to explore the load factor concept in the context of a transport buyer by identifying actions that affect load factor and more specifically study in what way these actions affect load factor and how these effects can be measured. The empirical findings resulted in a framework that describes how load factor can be improved in a transport buying company.

4.3.2 Method

The results presented in this paper are based on a case study. A transport buying company's goods flow from the central warehouse was studied, involving both activities at the transport buying company as well as its contracted freight forwarder. The reason for choosing this particular case was that this company recently implemented a number of actions aimed at improving load factor.

Data collection was based on interviews with employees at the transport buying company and the freight forwarder, searches in archival sources, and visual observations of vehicles leaving the central warehouse.

4.3.3 Results and contribution

Actions taken by both the transport buying company as well as the freight forwarder in the areas of packaging, loading, and booking showed an increase of order rows/used load meters of approximately 7% (on average) between 2010 and 2011. Visual observations showed a volumetric load factor ranging between 62% and 74% load factor, leaving room for further improvements.

The presented framework describes how to increase load factor at a transport buyer's system by identifying load factor indicators at three levels, packaging, loading, and booking, and linking them together. Further, logistics variables have been identified that affect the indicators. These are product characteristics, order variation, and lead time. A higher flexibility regarding lead time has been identified as having the potential to increase load factor further.

The framework is unique in that it focuses not on single actions, but provides an increased understanding of load factor due to the larger picture of linking the three load factor indicators together.

4.4 Paper IV: Increased load factor and sustainable logistics – interactions between a transport buyer's and freight forwarder's system

The fourth paper is based on the same case as the previous paper, but instead focuses on how actions taken to increase load factor in the transport buyer's system affect the load factor in the vehicle as a whole. Thus, this paper contributes to answering RQ 3.

4.4.1 Purpose

The purpose of this paper is to study how actions improving load factor at a transport buyer's system affect the load factor in the freight forwarder's system. Based on empirical data, a framework describes how load factor can be increased in the freight forwarder's system, including interaction with the transport buyer.

4.4.2 Method

The results presented in this paper are based on a case study. A transport buying company's goods flow from the central warehouse was studied, which involved both activities at the transport buying company and its contracted freight forwarder. The reason for choosing this particular case was that this company recently implemented a number of actions aimed at improving load factor.

Data collection was based on interviews with employees at the transport buying company and the freight forwarder, searches in archival sources, and visual observation of vehicles leaving the central warehouse.

4.4.3 Results and contribution

Actions implemented in the areas of packaging, loading, and booking have shown positive effects on load factor in the transport buyer's share of the vehicle. The increased number of LTL bookings by the transport buyer creates greater possibilities for the freight forwarder to consolidate with other customers' goods. Visual observations show a volumetric load factor ranging from a few percent to approximately 50% in the freight forwarder's remaining share of the vehicle, while the volumetric load factor in the whole vehicle ranged between 66% and 69% to the destinations studied.

Other effects of the actions implemented concern more transport work due to the need for relocating load units, but also time savings, less damages to goods, and better working environment.

The suggested framework describes how to increase load factor at three levels: packaging, loading, and vehicle, and how to connect these to interacting variables, changes in the transport buyer´s system and level of consolidation with other transport buyers. The framework provides better understanding of how to increase the load factor in vehicles by highlighting how the indicators are related and how those relationships interact with the transport buyer's system. Thus, a higher level of systems thinking can be achieved.

4.5 Summary

Table 6 summarizes the papers described above, their purpose, methods, and main findings. In addition, the papers' contributions to each research question are included. It can be seen that Paper I contributes to RQ 1, Paper II contributes to RQ 2, and Paper III and IV contributes to RQ 3.

Table 6 Summary of appended papers and their contribution to the research questions

Paper	**Purpose**	**Method**	**Main findings**	**Contributes to answering RQ**
Paper I: Actions for more sustainable freight transport – a comparison between theory and practice	To compare theory and practice in the field of future sustainable actions in the logistics system.	Literature review and interviews with practitioners.	* Identification and categorization of actions. * Actions' importance among practitioners. * Describes the importance of a holistic view on logistics and sustainability.	RQ 1
Paper II: Road freight transport efficiency and less environmental impact – the perspective of transport buyers and operators	To describe and compare the transport buyers' and providers' perspectives on what factors affect the ability to reduce environmental impact of freight transport.	Interviews and focus group discussions with transport buyers and providers.	* Identified six factors of importance. * Discussed the relation between factors and described the importance of co-operation between actors.	RQ 2
Paper III: Building a framework for increased load factor – mapping actions and effects from a transport buyer's perspective	To explore the load factor concept in the context of a transport buyer by identifying actions that affect load factor.	Case study	* Development of a load factor framework, including indicators, measures, and logistics variables affecting the indicators.	RQ 3
Paper IV: Increased load factor and sustainable logistics – interactions between a transport buyer's and freight forwarder's system	To study how actions improving load factor at a transport buyer's system affect the load factor in the freight forwarder's system.	Case study	* Development of a load factor framework, including indicators, measures, and interacting variables affecting the indicators.	RQ 3

5 Analysis

In this chapter, the overall results based on the posed research questions are summarized and analyzed.

The previous chapter shortly summarized the appended papers and pointed out to which research question each paper contributed. In this chapter, the answers to each research question are described based on the results from each paper and analyzed according to the limitations in the present research and relations to other research. In Figure 17, each research question is connected to the explored research areas.

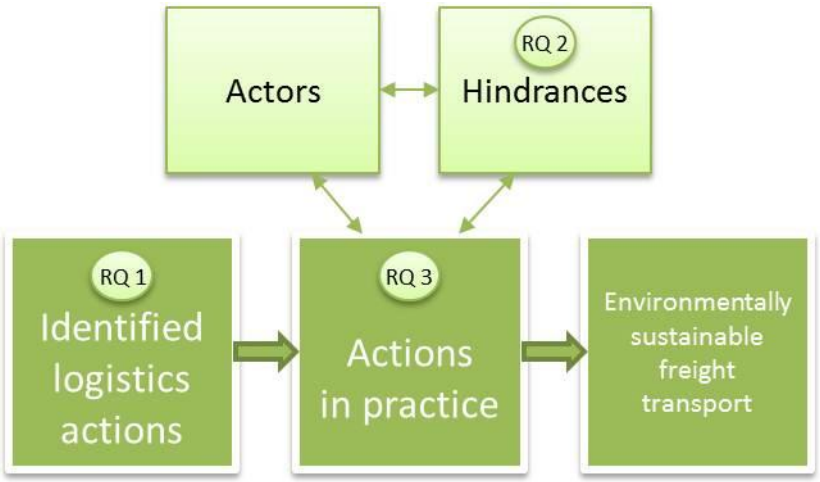

Figure 17 Research questions' connection to explored research areas

5.1 What actions enabling environmentally sustainable freight transport are perceived as important within the transport community?

The first research question focuses on identifying what actions are perceived as important when enabling environmentally sustainable freight transport according to the perspective of actors within the transport community; actors in the logistics system as well as academia in terms of earlier research.

This means that both actors' viewpoints and the results from earlier research have been bases for identifying these actions. Even if the number of respondents taking part in this study is limited (12 in total), it gives an indication of the attitudes among practitioners (transport buyers, freight forwarders, transport operators and authorities) and can guide and form hypotheses for further research.

5.1.1 Identified actions

Identified actions, or action areas, have been grouped according to action aims, i.e., three approaches to reducing environmental impact (based on Björklund, 2005 and Lammgård, 2007). Action pre-conditions were also identified based on policies and regulations that spanned over all three action aims. In Figure 18, action aims, preconditions, and areas are summarized. The identification of these actions is primarily based on findings in the literature.

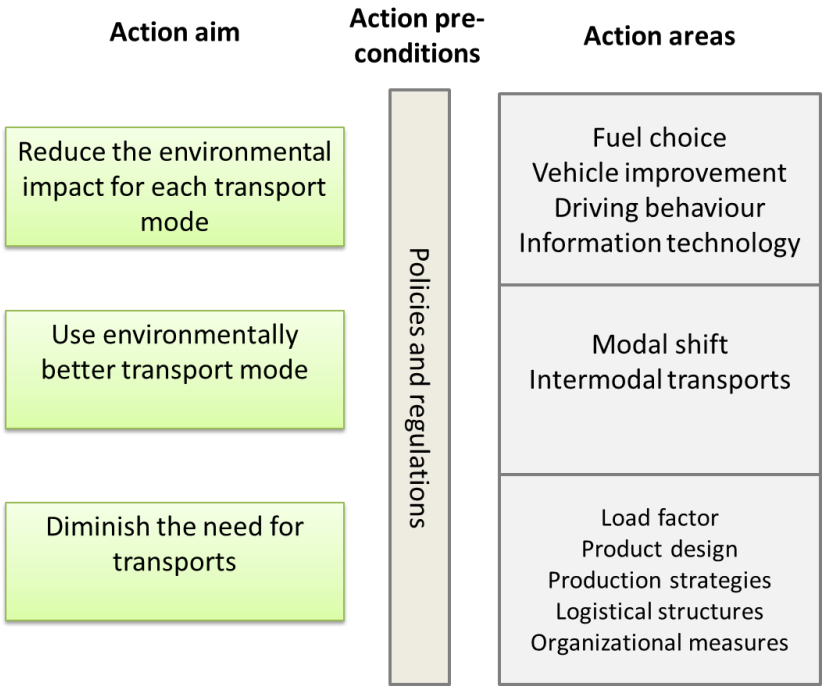

Figure 18 Types of actions that are identified and categorized according to action aims

Each transport mode can reduce its environmental impact through technical advances, such as by improving vehicles (in terms of, e.g., design or engine development) or by choosing fuel that is better for the environment. Behavioral changes in terms of driving patterns will also affect the environmental impact of specific transport modes. Information technology can play a vital role in supporting, e.g., efficient driving behavior. Reductions in the environmental impact of each transport mode can be measured in terms of emissions/vehicle-km. The use of environmentally better transport modes (reducing emissions/ tonne-km) entails a modal shift and the use of intermodal transports. Diminish the need for transports reducing traffic (vehicle-km) and transport (tonne-km) levels by logistical advances in the area of increasing load factor, improved product design, as well as working with production strategies, logistics structures, and organizational matters. Within each of the above mentioned action area, more specific actions are identified. In Table 7, identified actions within each of the action area are summarized.

Table 7 Summary of identified actions within each action area (those perceived as most important by the actors are underlined).

Action area	**Identified actions**
Fuel choice	Alternative fuels
Vehicle improvement	Truck hybrids More efficient engines Better aerodynamic designs for the vehicles
Driving behavior	Eco-driving
Information technology	Route optimization Support system for better planning and visualization of transports
Modal shift	Shift to more sea transports Shift to more rail transports
Intermodal transports	More intermodal transports at a general level Better technique for shifting loading units between transport modes
Load factor	Increase the load factor at a general level Consolidate with other operators/companies' goods Reduce empty running
Product design	Reduce the material used in products Packaging adapted for efficient logistics
Production strategies	Reduce the use of JIT strategies Reduce frequency and combine larger quantities into one order Have more flexible time restrictions for pick up/delivery of goods
Logistical structures	Reduce the number of nodes and links in the supply chain Centralized distribution system Decentralized distribution system Choosing more regional suppliers
Organizational measures	Increased quality of the environmental work within the organization Increased co-operation between organizations Increased focus on demands upon suppliers, contract design, and conditions for delivery etc.

The action pre-conditions include policies and regulations in the areas of economic and administrative measures as well as investments. In Table 8, a more detailed summary of the action pre-conditions are shown.

Table 8 Summary of identified actions within action pre-conditions (those perceived as most important by the actors are underlined).

Action pre-condition	**Identified action**
Economic measures	Road charges – city
	Road charges – highway
	Taxes on fossil fuels
	<u>Incentives schemes for renewable fuels</u>
Administrative measures	Increase the amount of night deliveries – less restrictions
	Lower speed restrictions
	<u>Allowance of longer/heavier vehicles</u>
Investments	Infrastructure investments – rail
	Infrastructure investments – road

5.1.2 Actions of importance

From the above list of actions, six action areas and two policies and regulations from the action pre-conditions were perceived as most important among the actors enabling environmentally sustainable freight transport. These actions are underlined in Table 7 and Table 8 above.

Alternative fuels were perceived as very important, in particular among transport operators and freight forwarders. In addition, the implementation of incentives schemes for alternative fuels was valued as important. Today alternative fuels are not used to a great extent, although there have been tests performed among the interviewed practitioners. However, studies show that only a small share of today's usage of fossil fuels can realistically be substituted with alternative sources of fuel, such as biofuels (VIEWLS, 2005).

Eco-driving was generally seen as an important action. This action is, to some extent, implemented among the transport operators and freight forwarders, and drivers are now being educated. Eco-driving is a typical example of an action that brings about cost savings quickly by saving fuel.

Increasing the load factor, in particular by consolidating with other operators or companies' goods was an action that all practitioners perceived as important. Other actions on the list relate to increasing the load factor. Packaging adapted for efficient logistics was a focus among transport buyers in the study and can positively affect the load factor. More flexible time restrictions for pick-up and delivery can allow transport operators and freight forwarders to plan their transport operations more efficiently and have the potential to increase the load factor as well. This action was perceived as more important by the transport operators and freight forwarders and was of less concern for transport buyers. Co-operation between organizations is a typical example of an important action that can bridge the knowledge gap between actors and increase the understanding of each other's systems. In particular it seems to be a need for a

better co-operation between transport buyers and freight forwarders/transport operators. It can lead to actions facilitating an increased load factor, but also to those initiating other actions. The practitioners showed great interest in collaborative activities, and they are currently participating to a large extent in collaborative forums.

There were a few surprising results among the previously discussed actions identified as most important. For example, the issue of a modal shift from road to rail and intermodal transportation has received increased attention among governments and researchers as an important strategy towards reducing the environmental impact from road freight transport, e.g., European Union (2011) and Chapman (2007), but these actions were not discussed as the most important actions among the practitioners included in this study. One transport buying company had already purchased the majority of their transports by rail and sea, which could be one reason why changing modes of transport was not that company's priority. The overall results could depend on the type of companies included in the study as well, and there is a possibility that other companies could prioritize differently. The results could also be an indication that there is a strong focus on road freight transport operations and practitioners are resistant towards shifting to other transport modes or combining modes. Another issue that has recently received increased attention in literature, e.g. Aronsson and Huge Brodin (2006) and Piecyk and McKinnon (2010), but not among the practitioners themselves in this study, is actions included in the area of logistical structures (reduce the number of nodes and links in the supply chain, centralized distribution system, decentralized distribution system and choosing more regional suppliers). One reason for not including them among the most important actions can be that it is difficult to estimate the total environmental effect resulting from these types of actions, which is exemplified by the differences in opinions amongst researchers in various studies, e.g., if centralization is positive or negative (McKinnon, 2003; Kohn and Brodin, 2008). Another reason is that there are substantial economic incentives for changing logistical structures; e.g., global markets, longer distances between facilities, centralization, and outsourcing to a larger extent, which may conflict with environmental goals. That a difference in opinions between the actors were seen regarding more flexible time restrictions for pick-up and delivery, can be explained by that freight forwarders and transport operators more directly see the effects from these demands in the efficiency of their transport operations. These effects are not as obvious from the transport buyers themselves. Other actions within the area of production strategies, such as reducing frequency and larger quantities in one order) were not identified as highly important among the actors even if research highlighted these issues as influencing environmental impact to a large extent, e.g., by Drewes Nielsen et al. (2003) and Piecyk and McKinnon (2010). One reason for not valuing those actions high among freight forwarders and transport operators can be due to the strong focus in offering as high service level as possible. Also it may not be obvious how these actions are affecting environment negatively. For the transport buyers themselves, the economic incentives have been driven trends counteracting actions in the area of production strategies, and there seem to be necessary for transport buyers to better understand the effects from these actions. Among the expected results

were the perceptions of the importance of cost-efficient actions such as eco-driving and to increase the load factor in vehicles. From these activities there is a clear connection to the potential savings of transport costs. Also, connected to the increase in load factor was the packaging adapted for efficient logistics that was of high importance for the transport buyers especially.

5.1.3 Connecting actions to their environmental impact and actors' involvement

The above discussion points out the actors' perceptions on what actions are of importance. A further analysis is made below, regarding how the actors' perceptions correspond to their actual influence of that action, i.e., what actor has most influence of acting in that area. Also, a further clarification of the actions relation to environmental impact in terms of emissions/vehicle-km, emissions/tonne-km, tonne-km and vehicle-km is made. In Figure 19, the identified actions are linked to each actor and to their environmental impacts. The development of Figure 19 below is based on the identification of actions categorized into the three approaches to reducing the environmental impact resulting from freight transport shown in Figure 18 (reducing the environmental impact for each transport mode (emissions/vehicle-km), using an environmentally better transport mode (emissions/tonne-km), and diminishing the need for transports (tonne-km and vehicle-km); it is also based on the model of actors involved in the undertaken research (see Figure 10).

The actions in Figure 19 have been restructured somewhat differently than in Figure 18. Two of the action areas are rather broad in their descriptions, and they could be used to reduce the environmental impact of transport in diverse ways. Those cross-cutting actions areas are information technology and organizational measures. For example, route optimization programs do affect traffic in terms of saving vehicle-km, and information technology is needed to follow up on the effects of driving behavior improvements. Organizational measures, such as increased co-operation between organizations can lead to initiatives taken in all areas of action areas. Another development is that the actions in the aforementioned area of load factor are renamed to management of goods flow. This improves the logic in how the actions areas are named implying that management of goods flow including actions affecting load factor level; increase the fill rate at a general level, consolidate with other operators'/companies' goods, and reduce empty running. In addition, the importance of route planning when increasing the load factor (highlighted by, e.g., Baumgartner et al. (2008)) should be included in the management of goods flow area as well.

Although the identified actions described in this thesis are those most frequently discussed among actors and in the literature, it should not be seen as a complete list of actions. This merely shows one way of structuring some of the most discussed actions enabling environmentally sustainable freight transport. Other actions mentioned in the literature concern, for example, home-delivery (World Economic Forum, 2009) and online retailing (Edwards et al., 2010). Further, another action that has recently gained attention is increasing the horizontal and vertical collaboration among companies (Ballot and Fontane, 2010; Holguin-Veras et al., 2011). Apart from the action preconditions, policies and regulation,

identified in this research, a recent study also highlighted the importance of knowledge-based measures such as information, guidance, and environmental labeling (Stelling, 2011).

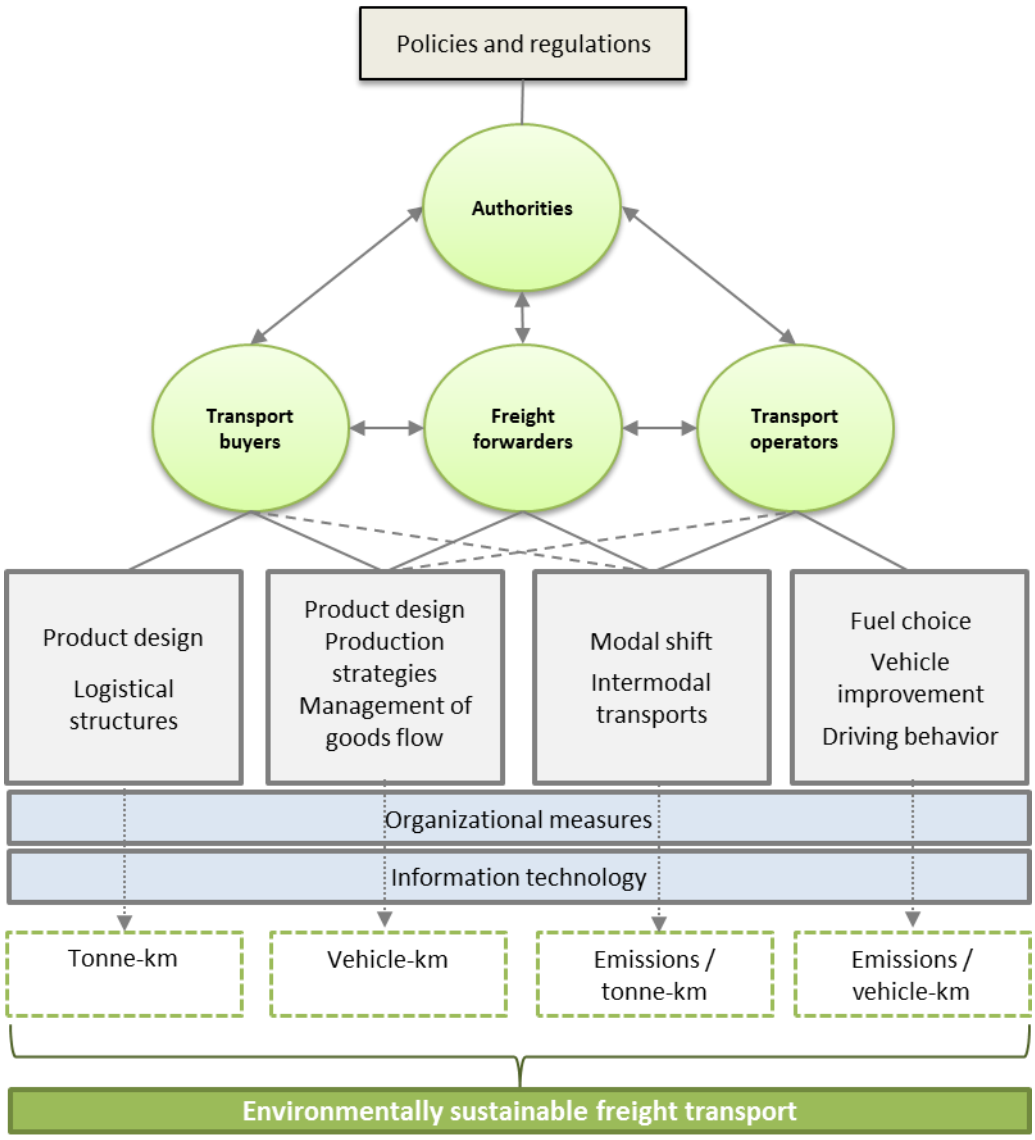

Figure 19 Identified actions' connection to the logistics actors and environmentally sustainable freight transport.

The categorization of actions into approaches that reduce environmental impact concretely suggests in what way the environmental impact is reduced by each action. In Figure 19, four ways of reducing environmental impact is distinguished, making the difference between transport and traffic work clearer. Acting in the areas of product design and logistical structures has an impact on transport work (tonne-km). Product design issues also affect traffic work (vehicle-km), as do production strategies and the management of goods flow. Working in the area of modal shift and intermodal transports reduces emissions/tonne-km. Finally, fuel choice, vehicle improvement, and driving behavior have an effect on emissions/vehicle-km. How policies and regulations affect environmental impact is not specifically handled. Policies and regulation do establish the basic conditions for the market on which the other actors can

act as well as informing and influencing acting in different directions; therefore, all action areas can be influenced.

The actors have different possibilities to act within each action area. A transport buyer sets the prerequisites for the transport operations in terms of stating where, when, and what to send while the freight forwarder and transport operator are performing and offering the service. The authorities are responsible for the external premises in terms of laws and regulations for conducting businesses but can also have administrative influence. The focus in this study has been on the major actor groups in the logistics system: transport buyers, freight forwarders, transport operators, and authorities. Still, there are others influencing the system that can be of importance in the future, e.g., vehicle manufacturers and the fuel/energy industry have a significant responsibility when it comes to technical solutions available on the market.

Figure 19 highlights which specific actors can primarily take actions in the identified action areas. Naturally, policies and regulations are the responsibility of the authorities. However, how the other actors in the logistics system can take responsibility and act in the different areas is not that straightforward, although this analysis is somewhat simplified. This is due to the diverse roles the actors can have in different situations; for example, a freight forwarder can act more or less as a transport operator, or being more or less involved in activities in the transport buyer's system. However, transport buyers do have the most significant influence on transport work in terms of tonne-km, by working with product design and logistical structures. Transport buyers also affect traffic by their actions in the area of product design and production strategies. Freight forwarders also affect traffic in terms of their management of the flow of goods. All logistics actors (transport buyers, freight forwarders, and transport operators) have an influence on modal shift and intermodal transports. Transport buyers can require a particular type of transport mode in the transport buying process, but freight forwarders are responsible for making arrangements with the operators who perform the actual transports. The transport operators, in turn, do have most influence on the choice of alternative fuels, vehicle improvements, and their undertaken driving behavior. All actors can take organizational measures and use information technology. Furthermore, actions can have influence on each other. As an example, setting demands on suppliers (transport buyers on freight forwarders and freight forwarders on transport operators) in determining what technology to use in vehicles impacts on the implementation of that.

In order to achieve environmentally sustainable freight transport, all action areas need to be taken into account and acted upon. Naturally, different actions are perceived as important among the various actor groups, which reflects the challenges they face and their roles in the logistics system. From the actors' perspective, they are most interested in technical solutions such as alternative fuels. Modal shift and intermodal transport was not perceived as highly important, while cost-efficient actions such as goods flow management in terms of increasing the load factor, were actions that all practitioners thought were of importance for the future. Action areas that the transport buyers' would be able to influence most, such as logistical structures and production strategies, were

not perceived as most important among themselves. As an example, it was interesting to note that production strategies (more concretely "flexible time restrictions for pick-up and delivery") were perceived as very important among freight forwarders but not among transport buyers. Comparing the information available in literature and among the practitioners taking part in this study, there seems to be a knowledge gap. The knowledge available in the literature does not fully match the perception of the practitioners, indicating that practitioners must obtain a clearer understanding of how actions can contribute to environmentally sustainable freight transport. Transport buyers need to take more responsibility for transport and traffic demand issues, while transport operators need to focus on how to best perform their operations. Freight forwarders have a central role in the logistics system. Collaborative actions seem to serve an important role for increasing actors' understanding of actions' effects.

5.2 What hindrances environmentally sustainable freight transport in the interface between transport buyers and transport providers?

The first research question identifies a wide range of actions enabling environmentally sustainable freight transportation. However, few of them have been implemented to a large extent among actors. The second research question focuses on what factors hinder environmentally sustainable freight transport in the interface between transport buyers and transport providers. The interface between transport buyers and transport providers is of special interest due to the fact that actions taken in the transport buyers' system may affect transport providers, and vice versa, which has further consequences on the environment. The results of this study are based on empirical data—interviews and focus groups discussions. Other researchers have studied drivers and hindrances in the context of, e.g., green supply chain management (Walker, 2008), purchasing transport services (Björklund, 2011), and logistics service providers (Isaksson, 2012). However, regarding the interface between transport buyers and transport providers, no studies have been found that look specifically into what factors impact on the implementation of actions enabling environmentally sustainable freight transport.

5.2.1 Identified hindrances

Six factors have been identified that negatively influence the transport buyers' and transport providers' environmental work. These hindrances had varying levels of attention and influence in the two actor groups; one factor could be highlighted among, e.g., transport buyers, but not mentioned to the same extent among the transport providers and vice versa. Thus, several differences can be seen when comparing their perspectives. In Table 9, the six factors and the actors' views are summarized.

Table 9 Identified factors that hinder environmentally sustainable freight transportation based on the perspectives of transport buyers and transport providers.

Identified hindrances	**Perspective of transport buyers**	**Perspective of transport providers**
Lack of ***competence and resources***	Knowledge and information were discussed rather than competence and resources.	Lack of competence and resources to work with environmental issues within the organization.
Lack of ***knowledge and information***	Lack of knowledge about all of their transport operations and their environmental impact.	Competence and resources were discussed rather than knowledge and information
Limiting ***demands*** from transport buyers	To keep the time, i.e. JIT, and robustness in deliveries is a prerequisite.	Demands, like cost and time, can sometimes be viewed as a limiting factor. Greater time windows at delivery are needed and more flexible solutions.
Lack of proactive ***service and offers***	Would like the operators to offer more environmental services and to be more proactive.	Would like the buyers to be more open in their discussions about possible solutions.
Low ***priority of transports*** among transport buyers	Low priority of transports in transport buying companies. There is a low willingness to pay for more environmentally friendly solutions.	Notice the low willingness from the transport buyers to pay extra for more environmental friendly solutions.
Difficult to ***follow up*** on environmental goals	Raises many challenges in the area of measuring environmental impact: difficult to measure in detail. More information from the transport provider is needed.	Raises the need for measuring goal fulfillment.

Transport providers highlighted a *lack of competence and resources* as affecting their internal environmental work. Competence issues that were raised were, e.g., that employees do not have enough knowledge about environmental issues and that it is difficult to hire competent personnel in the transport sector. Lack of resources was mentioned as a hindrance that also influences employees' competence; i.e., there may not be sufficient economic resources to hire specialists in all areas, or there are limited possibilities to invest in technical improvements.

Lack of knowledge and information were mainly concerns for the transport buyers due to their experience of not having full control of their transport flows

internally on the one hand and their lack of detailed information about the environmental impact of their freight transports on the other hand.

Limiting demands from transport buyers mainly concerned cost and time demands. Even though transport buyers saw cost as an important factor in the choice of suppliers, strict lead time, and in particular Just-In-Time, seemed to be even more crucial. One reason for valuing time so highly was due to the importance of robustness in the transport chain; incidents and delays could lead to high unexpected costs, e.g. from purchasing express transport solutions. Transport providers paid attention to the importance of focusing on time to stay competitive. However, they did see the strict time requirements as sometimes being a factor that limited their ability to operate their transports efficient, and to some extent they doubted the necessity of these. E.g., they experienced the demands as sometimes being phrased based on historical habits, without detailed knowledge being provided about a transport buying company's actual operations. When starting a dialogue about these demands, the transport providers experienced that it was not always the demands from the transport buyers needed to be stressed as hard as firstly perceived.

Lack of proactive service and offers were identified as one important factor from both actor groups. The transport buyers viewed the transport providers as being too passive regarding their offerings of environmentally preferable solutions while the transport providers perceived the buyers as dictating, to a large extent, the demands, what service level should be maintained, and indirectly, the conditions in the offer as well.

Transport buyers argued that the *priority of transports* was too low. This was identified as an important factor from both actor groups' perspectives. The low priority of transports results consequently in less willingness to pay more for more environmentally friendly solutions in the freight transport operations even though the price of freight transport services is generally very low today.

The difficulties to follow up on environmental goals were of more concern for the transport buyers than the transport providers. This was due to the fact that many transport buyers did not have a clear picture of their transport flows' emissions. Rough estimations underlie the calculations and there is a lack of detailed data. Transport buyers pointed out that more data about the performed transports are needed.

Comparing the identified factors with other research, a comparison can be made with Björklund (2011), who studied drivers and hindrances when purchasing green transport services, thus taking the transport buyers' perspective, and Isaksson (2012), who studied drivers and barriers when adopting green initiatives from a logistics service providers' perspective. Björklund (2011) highlighted a number of factors that significantly influence the purchasing of green transport services in the areas of management, image, customers, carriers, and means of control. Looking into the area of carriers, their knowledge, ambitions, equipment, and the relationships with the company purchasing the services are identified as important driving forces in the purchasing process. Isaksson (2012) found that the largest internal barriers for adopting green initiatives among logistics service providers are high investment costs and

uncertain payback periods followed by a lack of organizational/human resources. When it comes to external barriers, a lack of economic incentives was found to be highest, followed by a lack of customer interest, customer support, and clear regulations. These factors also support the view from this research that the lack of competence and resources among transport providers and the low priority transport buyers give to transports is hindering the environmental work among transport providers.

5.2.2 Overcoming hindrances by increased co-operation

An analysis of the interactions between the above factors indicates each factor's importance in the larger setting, what actors are most likely to overcome the identified hindrances, and how these activities can influence the other actors in a positive way for environmentally sustainable freight transport. Figure 20 summarizes the identified interactions between the factors; which actors get affected and which actors influence each factor most are indicated by grey (transport buyers' influence) and black (transport providers' influence) arrows.

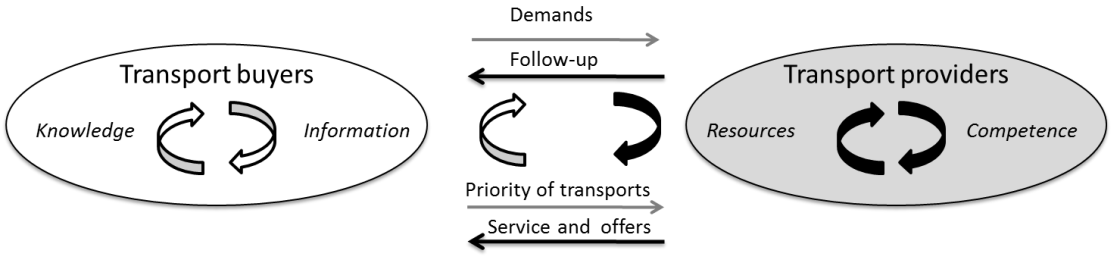

Figure 20 Illustration of how an increased dialogue and information exchange may help to overcome the identified hindrances.

Figure 20 shows that an increased dialogue and information ex-change between a transport buyer and a transport provider is essential for each to gain a better understanding of the other's systems and also to find ways to overcome the identified hindrances. The internal conditions in both actors' settings, a lack of knowledge and information among transport buyers, and a lack of resources and competence among transport providers will be positively affected by an increased dialogue and information exchange between them. Increasing transport buyers' knowledge about freight transport operations requires necessary information from the transport provider so that it is possible to, e.g., follow up on environmental goals or motivate the purchasing of environmentally preferable services. On the other hand, increasing transport providers' resources and competence requires placing a higher priority on transports and having an open discussion around the demands for transport operations. That would encourage a better atmosphere for providing profitable business in line with new services and offers that reduce environmental effects from freight transport operations.

In general, increased co-operation between transport buyers and transport providers is essential to generate environmentally sustainable changes in freight transportation. The notion that co-operation between actors can be crucial for implementing environmentally sustainable freight transport has been recognized by other researchers as well, e.g., Wolf and Seuring (2010), although they found that these types of collaborations are infrequent today. Key factors to overcome

the identified hindrances is to have a discussion around effects of transport buyers' various demands on transport operations and to find services that reduce the environmental impact. This means that being pro-active and open and sharing information are essential among both transport buyers and transport providers when co-operating in their efforts to ensure environmentally sustainable freight transport.

5.3 How can an increased load factor in road freight operations be achieved by transport buyers and freight forwarders?

Increasing the load factor has been argued as essential for reducing the environmental impact of freight transport, both from a theoretical and a practical view. The load factor refers to how efficient a transport is in terms of the level of goods loaded in the vehicle. Common ways to measure the load factor are by the occupied floor space, weight load, or volume. The results from the first study (RQ 1) show that the main actors value to increase the load factor as a very important action for the future. One reason for that is that it potentially saves transportation costs while simultaneously reducing the environmental impact in terms of vehicle-km. However, few studies exist that focus only on the load factor. Due to transport buyers' potential influence on transport operations, it is of particular interest to explore how the load factor can be increased from their perspective. First, the results for how an increased load factor can be achieved in the context of a transport buyer are presented. Second, there is a discussion of how increasing the load factor in transport buying company may affect environmentally sustainable freight transportation in the freight forwarders' system.

5.3.1 How to increase the load factor in the context of a transport buyer

Ways in which the load factor could be increased were explored in the context of a transport buying company; the focus was on outgoing road transports, from the central warehouse to the district terminals in the freight forwarder's network (the transports were operated by a freight forwarder). From studying that specific case, actions that impact load factor could be identified and further categorized according to three load factor indicators. These indicators were further found to interact with logistics variables. The empirical findings resulted in a framework describing how a transport buyer can increase the load factor (see Figure 21). The developed framework clarifies possible ways to increase the load factor, linking three levels of detailed load factor indicators together. The three load factor indicators are packaging, loading, and booking efficiency. Packaging efficiency is about maximizing the utilization of each loading unit, e.g. by matching products with an appropriate load unit. Loading efficiency is about maximizing the utilization of each load meter by combining load units effectively. Booking efficiency is about maximizing the utilization of the total booked load meters in each vehicle. This last indicator is of crucial importance when vehicle space is booked from a freight forwarder beforehand and when the actual usage is not certain until shipping.

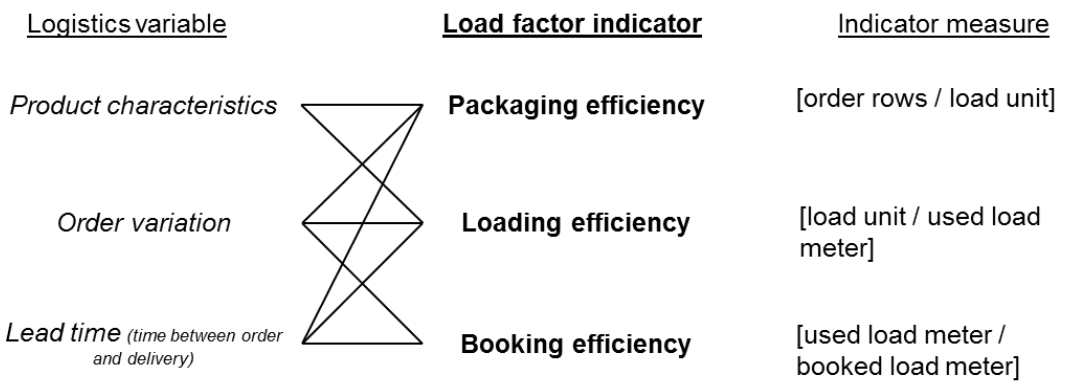

Figure 21 Framework describing how a transport buyer can increase the load factor

The logistics variables in the framework are variables that can be seen as setting the boundaries or limitations for acting within the framework. Product characteristics affect packaging and loading efficiency; different products do not have the same possibilities to be packed in every load unit and to be combined with other load units. As a result, the packaging and loading efficiency varies depending on the specific product characteristics. Also, the risks for damages are of concern for how to pack and load consolidated products. Order variation involves the daily variation of orders; a large variation of orders makes packaging and loading efficiency look different from day to day, which also affects the packaging and loading efficiency in terms of how different types of products can be combined in specific load units in an efficient manner. Booking efficiency is also affected due to the difficulty in matching the booked load meters with the actual need. Lead time concerns service level; in this case it is the time from when a transport buyer's customer places an order to when it is delivered to the customer's site or to the pick-up point. It is argued that lead time affects all three load factor indicators: packaging and loading efficiency since it may be more time-intensive to pack and load efficiently, and depending on when the final order income is known, booking efficiency can be affected as well. This is due to the limited possibilities of planning the specific transport operations if there is a short lead time and vice versa. As a potential action for the future, increased flexibility regarding lead time has the potential to increase the load factor further.

Examples of actions taken by the transport buyer in the area of *packaging efficiency* were the introduction of new loading units (e.g., a plastic box that could be stacked with a pallet on top, parcel cages that could be used for lighter, longer, and unevenly sized goods, and steel racks that were used for longer goods and that also could be stacked on top of each other). Due to the substantial variation in products and their characteristics in the studied transport flow, it was found to be of crucial importance to match the products with an appropriate loading unit. In the area of *loading efficiency,* the transport buyer collaborated with the freight forwarder; the freight forwarder provided the transport buyer with four extra employees who preloaded load units in certain load areas before loading them onto the vehicles. In the area of *booking efficiency,* the transport buyer worked to change the booking pattern. The number of load meters booked each day to each destination was changed so that it better matched the weekly demand fluctuations. An example of a change was

the transition from full-truckloads on all weekdays to only booking full-truckloads during the first half of the week and less-than-full-truckload at the end of the week. Still, planning was difficult since the booking of transport operations was done in advance, and the transport buying company did not know its order income until just before the vehicles left the central warehouse.

In the suggested framework, three levels of load factor indicators were suggested, based on packaging (load unit level), loading (load meter level), and booking (booking level). It would be possible to distinguish these three levels into even more detailed levels, such as also including a "parcel level" and a "product level." Packaging efficiency measures load factor at load unit level, where each load unit can take various forms. In the case included in this study, a load unit most often includes a number of different parcels and products. In order to highlight the potential areas of improvement within this load unit, each parcel need to be efficiently packed and each product and its wrapping needs to be designed so that it can be efficiently packed in each parcel. More detailed load factor indicators would make it even clearer to determine how to the load factor can be increased in even more ways. However, this framework's usefulness varies depending on the companies' combination of products and transport patterns. It may be valuable in a company with a larger variety of products comprised of rather small components, as there are actually several levels of consolidation taking place. A more detailed level will neither be useful for large-sized products nor when one product takes up an entire loading unit, e.g., a dishwasher on one pallet. Furthermore, a higher level of detail will increase complexity, which may limit the ease of obtaining a holistic view.

The load factor of the transport buyer's outgoing transports in this specific case is said to depend on the formula in Figure 22 below; the total load factor is based on the three load factor indicators in the suggested framework.

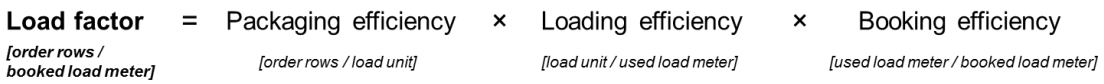

Figure 22 Load factor as a product of three load factor indicators

Thus, order rows/booked load meters should be used to measure load factor in this specific case. It is possible to follow up on the changes made at each level while simultaneously seeing the relations between these and the total effect. However, it is not sufficient to only measure the load factor according to this indicator based on order rows. It is important to complement this with volumetric and weight-based load factors to determine how order rows/booked load meters is related to possible maximum load, as well as to have possibilities to calculate the environmental impact.

By comparing the overall load factors between 2010 (when the above actions got introduced) and 2011, the order rows/booked load meters are almost 7 % greater in 2011 than in 2010. However, the performed visual observations in the case study from 2011, show that there is still potential to increase the load factor since neither booked load meters nor height are fully used at all observed destinations, and thus there is still potential for further improvements. It may be very difficult to reach a 100 % volumetric load factor, due to the challenges in

combining a large order with different products that have specific characteristics. In order to better estimate and forecast the possible effects of further changes, improved data about the products' characteristics and stack ability are needed, such as weight and volume-based data in the internal systems.

5.3.2 How to increase load factor in the context of a freight forwarder

In order to understand how actions contribute to environmental improvements when taking a larger systems perspective, it is important to not only include the transport buyers' system, but also that of the freight forwarder.

The effects on the whole vehicle from actions taken to increase load factor in a transport buyer's share of the vehicle (when less-than-full-truckload booking is made) to a large extent depends on a freight forwarder's ability to consolidate with other transport buyers' goods. Thus, when analyzing the effects on the freight forwarder's system, the whole vehicle needs to be taken into account. An increase of load factor in the transport buyer's share of the vehicle needs to be followed by an improvement in a higher consolidation level in the vehicle as a whole to get an effect in terms of reduction of vehicles-km in the transport provider's system. A suggested framework for increasing the load factor in the freight forwarder's system is shown in Figure 23, slightly adjusted from the one presented in the previous section from the transport buyer's perspective.

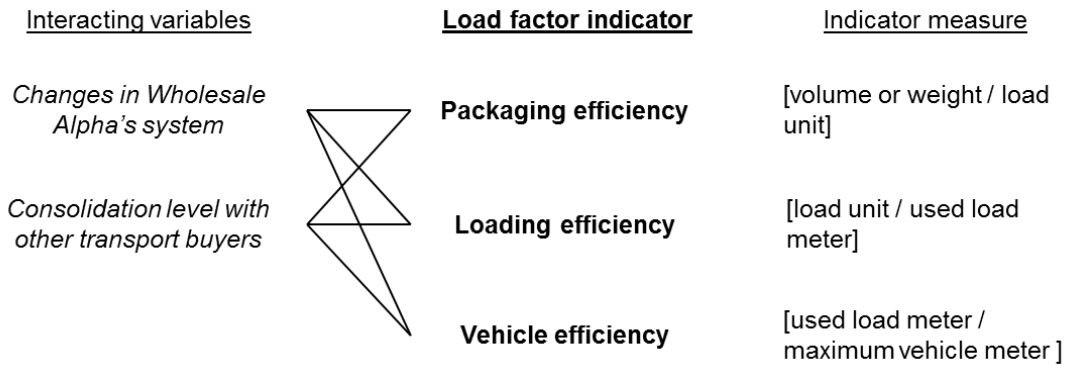

Figure 23 Framework for increasing the load factor in a freight forwarder's system

The framework follows the same logic as the one focusing on a transport buyer's system, although this system is based on the whole vehicle rather than just a share of the vehicle. The interacting variables are including the transport buyer's changes and how the freight forwarder can combine different transport buyers' goods, i.e., their level of consolidation with others. The load factor indicator that is suggested after studying a specific transport buyer's system is based on order rows/booked load meters. This is not applicable in a freight forwarder's system due to the need for a measure that can be used for all consolidated goods. A volume- or weight-based measure may instead be suitable. If the limiting factor is volume, which is likely if there are a variety of products, it will be of more importance than weight to follow up.

One example of an effect resulting from actions taken in the transport buyer's system was side effects due to the introduction of new loading units. The new loading units needed to be relocated back to the central warehouse, which

resulted in more transports. However, one exception was the introduction of parcel cages that was owned by the freight forwarder; in that case the transport buyer's network was used to relocate these load units back to the different district terminals in the freight forwarder's network—a typical win-win situation. Other positive effects that were found concerned time savings, fewer reported damages, and easier handling of the loading units; therefore, a better working environment was achieved.

Even though the performed visual observations in the studied case showed that consolidation was accomplished to some extent, the overall load factors on vehicles when less-than-full-truckloads were booked were lower than in the transport buyer's share. The transport buyer's share reached a volumetric load factor of 74 % – 78 % while the load factor in the vehicle as a whole reached 66 % – 69 %. The consolidation level (the volumetric load factor in the freight forwarder's remaining share) varied between 1 % and 50 %. Consequently, it would have been possible to increase the consolidation level even more.

5.3.3 Challenges in measuring the load factor

The suggested load factor indicators measure the load factor when a vehicle is at its maximum load. In reality, the load factor can vary during a particular trip due to off- and on-loading goods at different origins and destinations in a freight forwarder's network.

Therefore, in order to contribute to a more environmentally sustainable freight transport system, fewer transport resources should be used to meet the same level of transport demand, and a reduced traffic level should be achieved as well from the actions taken to increase load factor. Then, vehicles' routing and positioning need to be taken into account to determine whether, e.g., a longer distance must be driven to reach a higher level of consolidation. This means that it is not sufficient to only measure the load factor when a vehicle is at its highest possible load; the average load factor of the whole route (including possible positioning) needs to be taken into account. In addition, the highest average load factor is not necessarily the most preferable from an environmental point of view. Driving the heaviest goods via the shortest route leads to less fuel consumption than when the heaviest goods are routed via other pick-up or delivery points. Therefore, it is a tradeoff between kms driven and the maximum load factor when picking up and deliver goods on a route. It has not been possible to quantitatively investigate to what extent picking up more goods has resulted in extra driven kms or more empty running in the undertaken research, but in order to evaluate the total effects, detailed data about the whole route are needed.

McKinnon (2010a) has suggested several ways to measure the load factor, one of which takes trip variations into account. In that case, the load factor can be measured as the ratio between the actual tonne-km moved and the maximum tonne-km that could have been moved. Another way is to separate the load factor and empty running as two separate measures, as done by Piecyk and McKinnon (2010). In any case, one crucial issue seems to be finding accurate data that can be used to follow up on the chosen indicators. On a company level, several actors may be involved in the operation, which makes it even more

challenging to obtain data to follow up on specific changes. The transport buying company described here, have information regarding their goods and booking, while receiving information regarding consolidation level and routing from the operated transport is a challenge; this may be due to the different responsibilities of a transport buyer, freight forwarder and their in turn contracted transport operators. Detailed data on each route can be quite difficult to obtain from freight forwarders, since the transport operators generally have that information.

5.3.4 The relevance of the framework for increasing the load factor

Even though the suggested frameworks are based on one case, the principles of the framework, to analyze and expand a single aggregated load factor measure to relevant indicators affecting the load factor, can be further developed and used for other companies as well.

Other researchers have discussed the issue of packaging (Wu and Dunn, 1995; A.T. Kearney, 1997; Gustafsson et al., 2004), loading (McKinnon, 2000) and vehicles (McKinnon, 2000) independently as related to the load factor, but not in a combined way. Booking efficiency has not been addressed in earlier research at all. Indicator measures have been related to each other in a combined formula in logistics research by, e.g., Eng-Larsson et al. (2012) and Samuelsson and Tilanus (1997). Samuelsson and Tilanus (1997) presented a framework efficiency model for goods transportation including four dimensions: time, distance, speed, and capacity. Capacity is the dimension that deals with the load factor, and it is further divided into seven partial volume efficiencies: capacity floor, floor occupancy, height utilization, pallet load factor, net product factor, and actual loading execution efficiency. The overall efficiency is a product of the four dimensions. Eng-Larsson et al. (2012) separated freight transport CO_2-emissions into six factors, and the load factor was handled as a part of a larger value density measure.

The above presented frameworks are unique in the sense that they both clearly identify load factor indicators as well as their relations from a certain actor's perspective, which makes them useful in specific actors' environments. The number of load factor indicators can be adjusted to the specific company, and the measures may differ between contexts and the availability of data. However, the main principle of the frameworks—to expand a single load factor measure into detailed indicators—are important in order to raise the awareness among practitioners of how the load factor can be increased and how possible actions are linked together.

6 Discussion

In this chapter, the results are discussed in relation to overall sustainability principles.

A wide range of actions have been identified in the undertaken research as important for enabling environmentally sustainable freight transport. One type of action will be insufficient; a combination of actions will be necessary to contribute to environmentally sustainable freight transportation. Companies need to take action at different levels, including all actors in the logistics system, each having their own specific contribution.

The four sustainability principles presented in 2.3.2 are used as an overarching definition for sustainability in this thesis. The principles for sustainability involve striving to maintain a balance between the natural resources and those used in society, meaning that societal activities should not systematically degrade biodiversity, change ecological systems, and delimit environmental resources. The first three of the four principles developed by Holmberg and Robért are described as follows: *"In a sustainable society, nature is not… :*

5) *subject to systematically increasing concentrations of substances extracted from the earth's crust*
6) *subject to systematically increasing concentrations of substances produced by society*
7) *impoverished by over-harvesting or other forms of ecosystem manipulation." (Holmberg and Robért, 2000, p. 301)*

These three principles focus on ecological sustainability; the fourth principle deals with the societal dimension. *"In a sustainable society…*

8) "*… resources are used fairly and efficiently in order to meet basic human needs worldwide." (Holmberg and Robért, 2000, p. 301)*

Generally, actions that reduce the environmental impact of each transport mode contribute to the first three principles in terms of reducing certain types of emissions and pollutions. Indirectly, principle 4 can be affected as well, e.g., reduced health risks as a result of less local pollution in city environments (such as NO_x, SO_x, and particles). Action areas identified in this category are fuel choice, vehicle improvements, driving behavior, and information technology. In addition, land use issues that violate principle 3 are of concern when discussing alternative fuels (e.g., bio fuels from crops).

Moreover, actions that lead to the usage of a more environmentally efficient mode of transport also primarily contribute to the first three principles, but principle 4 can be addressed as well (e.g., less traffic congestion and accidents if moving from heavily congested roads to rail). Action areas identified in this category concern modal shifts and intermodal transports.

The third approach, when reducing the environmental impact of freight transport, is about diminishing the need for transports. Action areas identified

within this category concern the load factor, product design, production strategies, logistical structures, and organizational measures. These types of actions generally have an indirect contribution to the principles, primarily principle 4 in terms of increasing efficiency in the transport system and thus also limiting its negative impact on society. Consequently, improved efficiency due to reduced vehicle-km or tonne-km usage has an impact on the first three principles as well (less emissions from freight transports overall). To indirectly affect the principles means that it is not certain that the action itself contributes to a positive effect; it is dependent on other actions as well. For example, regarding the issue of the load factor, which has been analyzed more closely in the third research question, merely consolidating more goods does not guarantee improvements when the issue is studied from a larger perspective. The positive effects resulting from saving vehicle-km (which is the main effect of increasing the load factor by consolidation) are also dependent on whether the consolidation itself requires route changes, thus increasing the total distance driven, or if vehicles need to be repositioned to increase empty running. Another example of an indirect effect stems from working with packaging adapted for efficient logistics, which can positively affect the load factor in vehicles due to opportunities to load more products from the same area in the vehicle. Still, the improvement potential depends on the availability of a larger flow of goods with which to consolidate. The discussion about possible routing changes and empty running is then of relevance in this example as well.

From this discussion, it is clear that it is important to combine a number of different action areas to contribute to all four of the sustainability principles and to develop a more efficient freight transport system. There are several linkages between different action areas, such as between actions in a transport buyer's and a freight forwarder's system, which was further discussed in RQ 2. It is important to have a holistic view of sustainability, to link a specific action to its potential contribution in the system as a whole, and at the same time to remain aware of possible negative consequences.

7 Conclusions and further research

This chapter concludes the major findings, summarizes the theoretical and practical contributions, and pinpoints a number of possible research areas that are of interest for the future based on the present study.

7.1 Conclusions

Actions have been categorized into three approaches enabling environmentally sustainable freight transport: reductions in the environmental impact of each transport mode, the use of more environmentally efficient transport modes, and diminishing the need for transports. In order to achieve environmentally sustainable freight transport action within all these approaches are needed to act upon. The practitioners' viewpoints on these actions were examined, and certain actions were perceived as being more important than others while also some differences among the views could be seen comparing the actor groups. Among the shared views, there was a high belief in technical solutions, such as the use of alternative fuels. Moreover, cost-efficient actions dealing with increasing load factor and adopting eco-driving were of high importance. Also, to increase co-operation were also perceived as important among the actors. Modal shift and intermodal transport was not perceived among the highly important ones, neither was logistical structures. Differences were observed among the actors in terms of how important they felt it was to "have more flexible time restrictions for pickup and delivery of goods"; the transport operators and freight forwarders were most interested in this rather than the transport buyers, who actually influence this particular action most. Research has demonstrated the necessity for actions that diminish the need for transport in terms of reducing transport work (tonne-km) and traffic (vehicle-km), while it seems like practitioners need to raise their focus on actions affecting these. More knowledge on how each actor can contribute to environmentally sustainable freight transport and how their actions impact other areas is needed. In particular, since transport buyers' have a large influence on transport and traffic work, how they can act is of special interest.

Co-operation between actors is central to initiate actions that enable environmentally sustainable freight transport. In the interface between transport buyers and transport providers (including both freight forwarders and transport operators), identified hindrances can be overcome by closer levels of co-operation; increased dialogue and information exchange is argued to provide better internal conditions for both actors. Then, having a higher openness regarding what demands to be placed on the transport operations and introducing a higher priority on transport issues is important initiatives to be taken by the transport buyers. For transport providers, necessary information for motivating new solutions and follow-up changes can help to establish new services enabling environmentally sustainable freight transport. Thus, open dialogue, information sharing, and proactivity are essential.

To increase the load factor is identified as an important area enabling environmentally sustainable freight transport by potentially reducing vehicle-km. Increasing load factor can involve transport buyers, freight forwarders, and possibly transport operators, thus co-operation among the actors can facilitate

specific actions to be implemented. Taking the transport buyers' perspective, a number of actions that affect the load factor have been identified in the areas of packaging, loading, and booking efficiency. It is important to be aware of each action's contributing effects and in what way these actions relate to each other and to suggested load factor indicators. Logistics variables concerning lead time from order to delivery in the transport buyers' system, and from pick up to delivery in the transport providers' system, have also been found to affect the efficiency of transport operations. Specifically, strict time requirements and short lead time may hinder planning and, consequently, may also reduce vehicles' load factor. Thus, a more flexible approach regarding time requirements could lead to a more efficient use of transport resources. However, in order to follow up on these types of changes, more detailed data on transport operations are needed, such as volume, weight, and transport routes, including changes in the freight forwarder's system as well. A reduction of the total vehicle-km depends on the ability to consolidate goods in vehicles and also possible routing changes, including positioning (empty running).

In this research it is argued that when aiming for environmentally sustainable freight transport, it is important for the transport community to have a holistic view of the logistics system. Merely assessing one action or within one actor's system is not enough. An improvement in one actor's system may not necessarily lead to an improvement in a system at a higher level. The effects from actors' acting needs to be assessed not only from one company's perspective, broadening the view on how other actors may get affected can play a vital role for, e.g., identifying sub-optimizations and the overall effects on environmentally sustainable freight transport. It is therefore crucial to have a holistic view and being aware of what effects can be expected in different parts of the logistics system.

7.2 Contributions

This thesis contributes by increasing the understanding of how logistics actors can work towards achieving environmentally sustainable freight transportation. Theoretically, the undertaken research contributes to the green logistics research literature. Practically, this research provides insights for managers at strategic, tactical, and operational levels in transport buying and transport providing companies.

Earlier researchers called for more research about the potential roles logistics system could play in reducing environmental impact of freight transport (Aronsson and Huge Brodin, 2006). On the logistics system level, this research contributes by providing an overview of a wide range of actions that can be adopted by companies and organizations to enable environmentally sustainable freight transportation. This overview of logistics actions increases the understanding of the possible strategic choices for managers and offers a more holistic view of the logistics system and actors' roles when aiming for environmentally sustainable freight transportation. By grouping the actions into three approaches to reducing the environmental impact of freight transport, an increased understanding of their potential effects has been achieved. This has resulted in a clearer and broader view than what has been seen in earlier research about the impact of specific actions on the environment in terms of

tonne-km, vehicle-km, emissions/tonne-km and emissions/vehicle-km. The main actors' views regarding what actions are of most importance for the future have been discussed which increases the understanding about the focus among actors as well as their different views.

By identifying hindrances to environmentally sustainable freight transport in the interface between transport buyers and transport providers, the importance of co-operation and increased information exchanges between those actors has been confirmed. In addition, a better understanding of how co-operation can improve internal conditions as well as business relations between actors has been achieved. These insights can facilitate more dialogue between actors and give us a better understanding of how actors influence each other and what initiatives can be taken.

On a company level, this study provides examples of how transport buying companies can practically work with increasing load factor. Earlier research showed a lack of implementation of actions intended to reduce the environmental impact of freight transport (Léonardi and Baumgartner, 2004; Perotti et al., 2012). The interest in increasing the load factor as an important action has been especially high among practitioners. Moreover, the literature supports the importance of the load factor in reducing the environmental impact of freight transport on a general level (Wu and Dunn, 1995; Piecyk and McKinnon, 2010). However, previous researchers have not explored ways to practically accomplish this in companies. Two frameworks were developed on how to increase the load factor from a transport buyer's and a freight forwarder's perspective, respectively. They linked three load factor indicators together and further related them to a number of logistical and interacting variables. This knowledge would give managers a better understanding of what effects can be expected from different sets of actions as well as how these are related. The interdependencies of these actions were also discussed, showing the possible influence of transport buyer's acting on the freight forwarder as well as the necessity of the freight forwarder to act in order to actually get benefits from the undertaken actions in the transport buyer's system.

Still, the findings of this study highlight the need for more research on the cause and effect relationship between logistics actions and environmentally sustainable freight transport.

7.3 Further research

This thesis has contributed to theory and practice by providing both an overview of the important actions enabling environmentally sustainable freight transportation and more detailed knowledge about how actions in different actors' systems affect each other and environmentally sustainable freight transport operations.

The undertaken studies have taken an explorative approach in which the results are underpinned by mainly qualitative data: interviews, focus groups, and a case study. On the one hand, more detailed knowledge from other company settings or other types of actions would be valuable; on the other hand, future research is suggested to test these results in larger settings.

Based on the findings of this thesis it can be concluded that softening the high service level among transport buyers as well as the connected strict time demands on pick-up and delivery that are set on the transport providers could be a potentially important action enabling environmentally sustainable freight transportation. Expanding the knowledge about the effects of these types of changes would be a significant contribution to the green logistics literature. It is important to find cases where detailed transport data are available and where it is possible to quantitatively calculate possible changes in both the transport buying companies as well as in the freight forwarders' systems with regard to service level and then to estimate their effects. Another issue of importance is the need to further explore how the end customers value a high service level and the interest for having the possibility to choose between degrees of different service levels.

It would be valuable to use the results from the performed studies to generate hypotheses to be tested in larger settings, as this would allow more general conclusions to be drawn. Empirically strengthening the data collection in Paper I, e.g., through the use of a quantitative survey, would make it possible to generalize the findings and get a better view of the implementation level of actions among actors in the logistics system as well as their perceptions of various actions' importance.

A third area for further research is to study other actions in actors' environments (similarly to the case study of the load factor) to exemplify the effects as well as the interactions between activities in different parts of the system. For example, horizontal and vertical collaboration among companies has gained increasing attention among researchers recently, e.g., Ballot and Fontane (2010) and Holguin-Veras et al. (2011). How this could affect the load factor and generally improve the environmental sustainability of freight transport is one interesting issue. Another issue of interest is how the pre-conditions of various actions could affect practitioners' adaptation to environmentally sustainable freight transport.

The above suggested research areas are based on the outcome of this thesis. On the other hand, looking at the project's development over time, this thesis has been taking a somewhat narrower path than what was initially intended. Therefore, the thoughts go back to how the undertaken research in this thesis can contribute to the initial research aims. To give an overview, the alternative research paths can be summarized as follows:

- The development of a method or process map for how to evaluate what actions enable environmentally sustainable freight transport.
- The development of a framework or model for how logistics actions affect each other and environmentally sustainable freight transport. That framework could also be linked to actors' influence.
- The definition of environmentally sustainable freight transport; how can the concept be defined and how can actors more concretely measure environmentally sustainable freight transport?

- System borders—broadening the view to include sustainability as a whole, not only environmental sustainability, thus involving trade-offs between, e.g. economic and environmental effects.
- Include the sustainability principles and their framework to a larger extent, i.e., the backcasting technique.
- Co-operation with other projects—e.g., include usage of the "TrEx-Tool" developed in the project "Analysis tool for calculating environmental impact and efficiency of transport systems" (CPM, 2013) to evaluate environmentally sustainable freight transport solutions.

At this stage, it is important to be aware of what is required for fulfilling a doctoral degree and what studies are manageable to perform in practice. Of course, what research gap needs to be filled and how this matches with the interests of the researcher him/herself must play a vital role as well. Those aspects will be of importance when choosing the coming research path that will form the basis of the future doctoral thesis.

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