THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

Towards environmentally sustainable freight transport

Shippers' logistics actions to improve load factor performance

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Abstract

The purpose of this thesis is to explain how shippers' logistics actions contribute to environmentally sustainable freight transport, by clarifying the link between logistics activities and the resulting load factor performance. Five studies have been undertaken, which have given rise to six papers. The research applies a systems approach, comprising explanatory, descriptive and explorative research. An initial study, a literature study and case studies are performed, focusing on shippers' outgoing goods flows. New theoretical concepts are developed, based on empirical data.

This thesis provides an overview of actions that can contribute to environmentally sustainable freight transport and links them to actors' perceptions of their importance and to shippers' logistics activities. It concludes that, for shippers, reducing the amount of traffic by improving the load factor is of relevance to improve their environmental performance in transport.

It is suggested that shippers' load factor performance, defined as the ratio of the load carried (required capacity) and the maximum load that could be carried (available capacity), should be evaluated overall, as well as on each individual level (packaging and shipping). Load factor performance is a result of logistics activities related to *logistics structures*, *order and delivery*, *transport operations* and *packaging and loading*, which influence required and available capacity by creating conditions from one activity to another and for each other. To manage imbalances between required and available capacity, several logistics actions may be needed, on strategic, tactical and operational levels.

Shippers can take action in terms of changing logistics activities so that new conditions are created to support an improved load factor performance that reduces/increases or reallocates required and/or available capacity. New conditions can be created by changing *which* activities are performed, as well as *how, when*, and *by whom*. Shippers must collaborate both internally and externally to realise such actions, considering also influences on other parts of the system.

The results of this thesis will help shippers to determine how to improve their load factor performance, hence contributing to environmentally sustainable freight transport, specifically by 1) evaluating their current load factor performance, 2) identifying the causes of any imbalances, 3) identifying relevant actions, 4) implementing these actions, and 5) evaluating the improvements after changes have been made. This research will support logistics managers in their decision making, and add to existing green logistics research by providing details about how to evaluate the load factor, how logistics activities influence the load factor and what logistics actions a shipper can take to improve the load factor.

Keywords: actions, environmentally sustainable freight transport, links, load factor, logistics activities, performance, shipper, systems approach

List of appended papers

This thesis is based on the research reported in the following six papers:

PAPER 1: Santén, V., Blinge, M., 2013. Actions for sustainable freight transport: comparing theory and practice.

Published in Licentiate thesis, 2013, Exploring logistics actions enabling environmentally sustainable freight transport. Department of Technology Management and Economics, Chalmers University of Technology, Gothenburg. An earlier version of this paper was published in *Proceedings of WCTR Conference 2010, Lisbon*.

PAPER 2: Santén, V., Andersson, D., Fridell, E., 2016. Measuring the environmental performance of shippers' transport activities: the impact of uncertainty in input data.

Submitted to an international transport journal in September 2016.

PAPER 3: Santén, V., Rogerson S., 2016. Achieving transport efficiency through increased load factor: a literature review of measurement and influencing factors.

Submitted to an international transport journal in February 2016. An earlier version of this paper was published in *Proceedings of LRN Conference 2014, Huddersfield*.

PAPER 4: Santén, V., 2015. Toward more efficient logistics: increasing load factor in a shipper's road transport.

Accepted for publication in *International Journal of Logistics Management* (December 2015).

PAPER 5: Santén, V., Rogerson, S., 2016. Shippers' transport efficiency: a model for measuring load factor.

Submitted to an international logistics journal in September 2016. An earlier version of this paper was published in *Proceedings of LRN conference 2015, Derby*.

PAPER 6: Rogerson S., Santén, V., 2015. Shippers' opportunities to increase the load factor: managing imbalances between required and available capacity.

Submitted to an international logistics journal in December 2015.

Contribution in each paper

Paper 1. Vendela Santén is the main author of this paper and was responsible for the design of the study, collecting data, analysing the data and writing the paper. Magnus Blinge was involved in discussions on the design of the study, the results and the structure of the paper, and contributed in a minor way to writing the paper.

Paper 2. Vendela Santén was the main author of this paper, collected the data and conducted the evaluation of external costs. Erik Fridell was responsible for conducting the sensitivity analysis of the impact of uncertainty in the input data on the evaluation result. All co-authors were involved in analysing and discussing the results. Vendela Santén had the main responsibility for writing the paper, with assistance from Dan Andersson. Erik Fridell had a minor involvement in writing the paper.

Paper 3. Vendela Santén was the main author of the paper. Vendela Santén and Sara Rogerson were involved in designing the study and collecting the data. Vendela Santén had the main responsibility for analysing the data and writing the paper.

Paper 4. Vendela Santén was the sole author of the paper and had sole responsibility for designing the study and collecting and analysing the data.

Paper 5. In this paper, the work was shared between Vendela Santén and Sara Rogerson, and both were equally involved at all stages: designing the study, collecting data, analysing the data and writing the paper.

Paper 6. In this paper, the work was shared between Vendela Santén and Sara Rogerson, and both were equally involved in designing the study, analysing the data and writing the paper. Vendela Santén and Sara Rogerson were also equally involved in collecting data in two of the cases, while Vendela Santén had sole responsibility for data collection in the third case (Fast Response).

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Last but not least, to my family and friends, thank you for being there. Peter, this wouldn't have been possible without your never ending support and love. You have 'run the family wheel' while I have been working 'non-office hours', and you always encouraged me to believe I could make it. Joar and Teodor, my loving kids—you remind me of what is most important in life every day. Now the book is finally ready, and YES we will celebrate—with the biggest and nicest chocolate cake covered with all the red and black berries we can find!

Vendela Santén

Göteborg, October 2016

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1 Introduction

This chapter provides an overview of the problems underlying the research and proposes the purpose of the research and the research questions.

This thesis takes its starting point in the challenges of mitigating the environmentally unsustainable freight transport trends. The focus is on how shippers can contribute to environmentally sustainable freight transport by taking logistics actions, in particular by improving the load factor.

1.1 Background

Progress towards sustainability goals is an essential worldwide societal issue (United Nations, 2016), the challenge being to combine ecological considerations with economic development and social responsibility (Norman and MacDonald, 2004). Among ecological considerations, one major concern is greenhouse gas emissions (IPCC, 2014a).

Owing to its heavy dependence on fossil fuels, the transport sector is the second largest sector contributing to greenhouse gas emissions (after the energy sector), with 24.3% of the share within the European Union (EU) in 2012 (European Commission, 2016). In Sweden, the transport sector contributed 31% of total greenhouse gas emissions in 2010 (Swedish Environmental Protection Agency, 2012). Of these emissions, about 30% were derived from freight transport activities (Swedish Environmental Protection Agency, 2015).

In the light of these facts, societal long-term targets for the transport sector are ambitious. Within the EU, one such target is the reduction of greenhouse gases by 60% by 2050 compared to 1990 (European Commission, 2011b). Even more ambitious are Swedish national targets, which aim for the development of a vehicle fleet completely free of reliance on the use of fossil fuels by 2030 (Johansson, 2013). Global issues such as greenhouse gases are not the only concerns in the transport sector. Local and regional issues generate environmental targets as well, for example reducing nitrogen oxides (NO_x) for cleaner air and sulphur dioxide (SO_2) for reduced acidification (Trafikanalys, 2015).

However, trends in the transport sector suggest that these goals are far from being met (Trafikanalys, 2015). In the EU in 2012, greenhouse gas emissions from the sector were 20.5% above the 1990 level (European Commission, 2016). In Sweden, although greenhouse gases from the sector are lower than in 1990, the pace of reduction of emissions is too slow. In fact, emissions from freight transport activities continue to increase, while emissions from passenger transport have decreased. At this moment, the ambitious goals are far from being accomplished (Trafikanalys, 2015). Consequently, there is an urgent need for action to accelerate progress towards society's environmental goals.

1.1.1 The role of logistics in societal freight transport trends

Although freight transport activities have negative impacts on the environment, they contribute positively to the other two pillars of sustainability, namely economic development and social responsibility. Freight transport activities are essential for commerce and business and contribute to general social well-being by making essential products available to people at different locations. For companies, freight transport activities serve to move goods between locations within the supply chain to fulfil customer demand. Therefore, managing the flow of goods within and between companies in the supply chain through efficient logistics is a core business function in companies (Lambert and Cooper, 2000). However, as McKinnon (2015a) has pointed out, the steadily increasing emissions from freight transport activities are largely the result of various logistics management decisions made in pursuit of efficiency (with a focus on higher profits), and environmental costs have historically not been part of those decisions. Three major trends in logistics can, in part, explain the increasing emissions from freight transport activities.

First, transport work has increased, mainly owing to increased trade and longer transport distances. There has been a steady growth in international trade in recent decades, as companies expand their presence in foreign markets (Golicic *et al*., 2010). Among logistics management strategies that will influence transport distances are more centralised distribution systems and sourcing materials from other countries (McKinnon, 2003). In Europe, there was an increase of approximately 36% of tonne-km between 1995 and 2007 (European Commission, 2011a). In Sweden, the total amount of transport work more than doubled between 1960 and 2011 (Trafikanalys, 2012).

Second, the use of road freight has increased. As companies have developed agile supply chain processes to boost responsiveness, smaller inventories and smaller and more frequent deliveries to customers require a fast transport solution (Golicic *et al*., 2010). Different transport modes do have different characteristics and limitations (see e.g. Kohn and Brodin, 2008), such that the demands on specific transport operations direct the choice of mode. The increasing importance of time, speed and reliability in transport operations has therefore led to a higher dependence on road transport (Golicic *et al*., 2010) at the expense of rail and sea transport. On a European level, road freight transport increased by 35% in Europe from 1995 to 2004 (European Commission, 2006), and in Sweden, road freight nearly doubled in terms of tonne-km between the early 1970s and 2011 (Trafikanalys, 2012). As road transport contributes the greatest environmental burden in terms of greenhouse gas emissions when comparing all major transport modes in the sector (Chapman, 2007), the growth of road freight transport is inevitably leading to an increase in the sector's environmental impact.

Third, traffic work (vehicle-km) has been impacted by the above-mentioned logistics trends of smaller and more frequent deliveries, leading to an increased usage of distribution vehicles, as a larger share of smaller vehicles is now being used (Trafikverket, 2011; Ruesch *et al*., 2016). In addition, the goods are now characterised by lower weight and greater volume, which means more vehicles distributing the same amount of goods in terms of transported tonne (Banverket *et al*., 2008). In Sweden, the growth in road freight traffic has increased faster than the total amount of transport work: from 1997 to 2007, vehicle-kms doubled (Smidfelt Rosqvist and Dickinson, 2012).

1.1.2 Approaches to reducing the environmental impact of freight transport

To limit or reverse the trend towards unsustainable freight transport, the following general approaches can be considered to reduce environmental impact from freight transport activities (based on Björklund, 2005; Lammgård, 2007; IPCC, 2014b):

1. Reduce the environmental impact of each transport mode (emissions/vehicle-km)
2. Use environmentally friendlier transport modes (emissions/tonne-km); or
3. Diminish the need for transport (tonne-km and vehicle-km).

These three approaches are related to changes within transport and logistics. Reducing the environmental impact of each transport mode is related to technical advances in transport, for example energy-efficient engines and sustainable fuels (European Commission, 2011b; Trafikverket, 2012; Wismans *et al*., 2016) or clean vehicle technologies (World Economic

Forum, 2009; Wismans *et al*., 2016). Using environmentally friendlier transport modes is related to the choices of switching modes, such as from road to rail (Trafikverket, 2012; Eng-Larsson and Kohn, 2012; Shift2Rail, 2016), or using intermodal transport (Behrends, 2011; OECD, 1997). To diminish the need for transport, efficient andadvanced logistics are important (Trafikverket, 2012), for example using transport and infrastructure more efficiently (European Commission, 2011b), changing logistics and transport configurations (World Economic Forum, 2009) or increasing the load factor in transport operations (Trafikverket, 2012). More specific examples include improving routeing and scheduling by using vehicle telematics (Baumgartner *et al*., 2008) or increasing the load in vehicles by using higher-capacity vehicles (Greening *et al*., 2015) or a greater degree of consolidation (Ülkü, 2012).

Using such approaches or, better still, combining them is undoubtedly a promising way to contribute to environmentally sustainable freight transport in companies (Åkerman and Höjer, 2006; Miljörådet, 2008; McKinnon and Piecyk, 2010). However, relying on technical advances to reduce emissions/vehicle-km will not be enough on its own (Johansson, 2013). Rather, the role of logistics needs to be understood. In particular, efficiency strategies, such as transporting the same amount of goods using fewer vehicle-km, should be implemented (Johansson, 2013; European Commission, 2011).

1.1.3 The need for more research on logistics and the environment

Actions related to companies' logistics activities may therefore play an important role in environmentally sustainable freight transport. Previous transport research has paid more attention to technologies that 'fix' freight transport emissions than to ways in which logistics can be improved to reduce the need for freight transport (Marchet *et al*., 2014). Abukhader and Jönsson (2004) concludes: 'The costs and benefits of implementing environmental technologies or strategies for the logistical systems are still being discussed in the literature, but the impact of logistical decisions or the performance of a total logistics system on the environment are not being discussed or evaluated' (p. 147). Further, although green logistics research has been on the rise over the last 10 years, a recent literature review by Marchet *et al*. (2014) confirmed the large focus on technological advances in previous studies. Marchet *et al*. (2014) observe that a number of initiatives identified in the logistics and transport literature are related to distribution and sustainable transport. The most widespread are initiatives related to technical advances (reducing emissions/vehicle km): alternative fuels, alternative vehicles, more recent/less polluting vehicles and reduced speeds. Other initiatives are alternative transport modes, shipment consolidation, full vehicle loading and routeing and the redesign of logistics systems, although each of these initiatives are the subject of few articles in the literature (Marchet *et al*., 2014).

1.1.4 Linking logistics activities to the environmental impact of freight transport

Logistics activities and the environmental impact of freight transport are linked in complex ways. A broad view must be taken, as logistics activities at different decision levels, strategic, tactical and operational, influence one another. Explaining the interconnection among logistics activities is important for understanding their influence on one another and their environmental impacts (Martinsen and Huge-Brodin, 2014), which is complicated by the fact that logistics activities support several other functions in companies (Blanco and Cottrill, 2014). Few studies highlight such interrelations in logistics systems.

Links between different logistics variables and the environmental impact of freight transport activities are suggested by Drewes Nielsen *et al*. (2003), Aronsson and Huge-Brodin (2006), Piecyk and McKinnon (2010) and McKinnon (2015a). These studies are all based on an early work by McKinnon and Woodburn (1996), in which four levels of decision making in logistics are distinguished: logistical structures, pattern of trading link, scheduling of product flow and management of transport resources. These form a hierarchy in terms of strategic decisions, creating opportunities or limitations for tactical and operational decisions. Drewes Nielsen *et al*. (2003) also link the four decision levels to transport logistics indicators, transport indicators and environmental impact. Aronsson and Huge-Brodin (2006) have added product design to the upper level of logistics structures in their model. In addition, Piecyk and McKinnon (2010) add product-related factors and external factors to the original list of four and further emphasise the relationship among determinants (the six levels of factors), logistics variables and their environmental impact. These frameworks illustrate that environmental consequences from freight transport activities are shaped by conditions that are created outside the transport system, such as shippers' logistics activities. Also, these frameworks illustrate that there are interdependencies between different logistics activities, such that choices concerning logistics structures create opportunities and set limitations for choices concerning planning and management, which in turn create opportunities and limitations for choices about operational work (Aronsson and Huge-Brodin, 2006). Understanding the link between specific logistics activities and the environmental performance of freight transport activities will clarify and suggest logistics actions of importance for contributing to environmentally sustainable freight transport.

1.1.5 Taking a shipper's perspective

Given that several actors can be involved in shippers' logistics activities, such as the shipper and the transport provider, different actions will be relevant depending on which actor perspective is taken (Pålsson and Johansson, 2016). In this thesis, a shipper's perspective is taken, on the grounds that shippers have a central role in reducing environmental impact from transport resulting from their logistics activities, although the relationship between their activities and their environmental performance is indirect and therefore not always evident. As pointed out by Pålsson and Johansson (2016), 'LSPs [logistics service providers] have a direct impact on the freight transportation system because they bear the operational responsibility for the freight transport emissions, while the freight owners have an indirect impact through their logistical decisions' (p. 676).

In addition, few studies investigating environmentally sustainable freight transport explicitly take a shipper's perspective. A recent literature review indicates that only two of 72 papers relating to environmental issues in logistics and transport take a shipper's perspective (Marchet *et al*., 2014). More often, the perspectives are taken of third party logistics providers and others, such as carriers and terminal operators (Marchet *et al*., 2014).

A shipper is a company in the supply chain that supplies physical goods. A shipper can additionally be a buyer of physical goods; however, in this thesis, it is the outgoing goods flow that is of interest. Shippers commonly outsource freight transport activities to a third party (Langley Jr *et al*., 2014; Lammgård, 2007) such as a transport provider, which is the predominant view of shippers in this thesis. Shippers who organise and execute freight transport activities to deliver customers' orders themselves are not in focus in this thesis.

1.2 Purpose and research questions

As described above, previous studies emphasise that shippers' logistics activities create conditions for freight transport activities and their resulting environmental impact, although the links between logistics activities and the environment are vaguely described. If the aim is to achieve environmentally sustainable freight transport in the future, logistics actions are needed to create the right favourable conditions. To that end, more detailed understanding about the link between specific logistics activities and the environmental performance of freight transport activities is needed. To gain such detailed understanding the focus in this thesis is on one key variable that previous research has identified as being of crucial importance for reducing environmental impact from transport, namely improving the load factor (McKinnon, 2015b). The thesis, thus, takes its starting point in the overall goal of explaining how shippers can contribute to environmentally sustainable freight transport by their logistics actions, while, focusing on the link between shippers' logistics activities and load factor performance makes it possible to provide clarifications in detail. The purpose of this research is expressed as follows:

The purpose is to explain how shippers' logistics actions contribute to environmentally sustainable freight transport by clarifying the link between logistics activities and the resulting load factor performance.

Four research questions are posed to contribute to the purpose of this thesis, related to the conceptual model of the system studied, seen in Figure 1. The research questions each deal with different parts and links between elements in the system and they are justified in the next sub-sections. RQ1 takes a holistic view of the system, in terms of describing what actions are of relevance for shippers' contribution to environmentally sustainable freight transport. The subsequent questions are narrower, with the focus on improving the load factor. RQ2 addresses how to evaluate the load factor performance, which is the performance variable of the studied system in focus and needs to be understood in order to explain its links with other parts of the system. RQ3 uses the results from RQ2 and explains how logistics activities influence the load factor performance. Finally, the logistics actions that a shipper can take to improve their load factor performance are described in RQ4, based on the results from the previous two questions indicating how the actions change the logistics activities and thereby influence load factor performance.

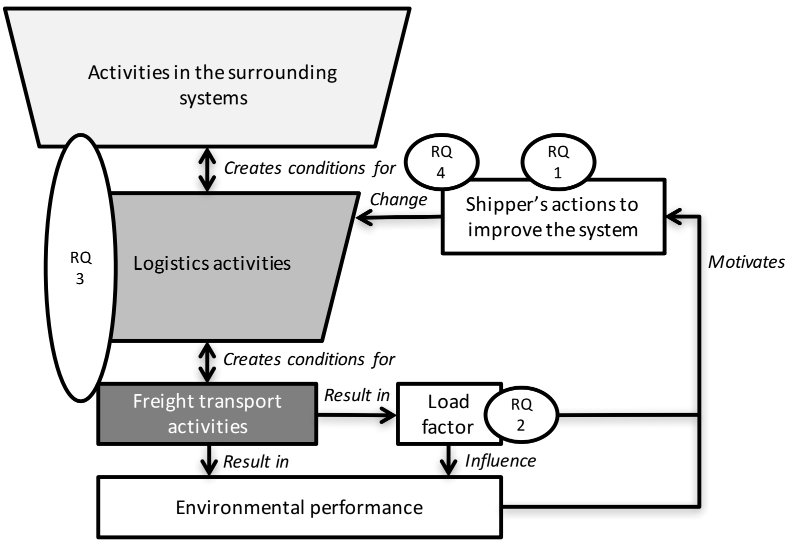


Figure 1: The research questions in relation to the key elements of the studied system

1.2.1 Logistics actions relevant for shippers

To explain how shippers' logistics actions contribute to environmentally sustainable freight transport, an overview of which actions that possibly can provide such contributions is a first step. Previous research has offered few summaries regarding what shippers can do to contribute to environmentally sustainable freight transport. The area of green logistics has received growing attention and recent studies relating to such actions (Hung Lau, 2011; Perotti *et al.*, 2012; Evangelista, 2014) lack a clear shipper's perspective. Work by Martinsen and Huge-

Brodin (2014) has provided some guidance, but from the perspective of the relationship between the shipper and the logistics service provider. Also, Pålsson and Johansson (2016) include both shippers and logistics service providers in their study.

Different actions are relevant depending on the actor perspective taken (Pålsson and Johansson, 2016). Therefore, the interest is not only in the logistics actions that contribute to environmentally sustainable freight transport in general but also in actions that have the potential to be realised in the particular situation of the shipper. Hence, the perceptions of the shippers must be taken into account, since their view can indicate both a perceived potential for improvements as well as an interest in making changes. To make sense for shippers and increase the likelihood that they will take actions to improve the system, their problems situation must be understood (cf. Checkland, 1999).

This rationale leads to the first research questions, which is framed as follows:

RQ1: What logistics actions are of relevance for shippers' contributions to environmentally sustainable freight transport?

1.2.2 Evaluating load factor performance

Several authors identify the need to evaluate improvements if progress towards different goals is to be achieved; for example, Kaplan (1990) argues that if there are no measures, there is no improvement, and Zhu *et al*. (2007) emphasise that for managers, measurements are 'necessary for long-term improvements and practice adoption decisions' (p. 1050). Thus, for shippers, evaluation of related performance goals is necessary. In particular, in the initial phases of the improvement work to reduce the environmental impact of transport, there is a need to identify how the results will be measured (Golicic *et al*., 2010). This not only permits evaluation of progress from actions taken to date but also supports decisions and prompts future choices (Blanco and Cottrill, 2014).

One key performance variable when evaluating the environmental performance of transport systems is the load factor (Piecyk and McKinnon, 2010; McKinnon, 2015b). Improving load factor is acknowledged to be a relevant action for reducing environmental impact from freight transport (shown in the results from RQ1, section 5.1, as well as in the study by Pålsson and Johansson, 2016), creating a perceived potential for improvement and generating high interest in implementing the appropriate actions. Since the load factor is a key variable not only for environmental performance but also for evaluating transport costs (Lumsden *et al*., 1999) and the efficiency of logistics and transport systems (Léonardi and Baumgartner, 2004; Simons *et al*., 2004; Samuelsson and Tilanus, 1997b), the load factor is of relevance to environmental, financial and efficiency goals among shippers.

Load factor has primarily been measured in previous research as part of a larger performance measurement system (considering efficiency, environmental and/or cost issues in particular). However, measuring load factor as just one of several variables is not sufficient for evaluating the progress of actions taken to improve the load factor and motivate future choices for shippers. Measuring load factor on the vehicle (i.e. vehicle utilisation) makes sense for transport providers' overall performance but is insufficient for shippers if they are, for example, shipping single pallets. Instead, for shippers in that situation, it will be more valuable to measure load factor in relation to the packaging used (Pålsson *et al*., 2013).

In addition, load factor is measured with regards to different dimensions, for example weight (Ülkü, 2012), volume (Potter and Lalwani, 2008) or empty running (McKinnon and Ge, 2006).

This means that there is no standardised way of evaluating the load factor performance and little is known about what metrics are most appropriate to evaluate progress, support decisions and thereby guide shippers on what actions are relevant. The second research question is therefore framed as follows:

RQ2: How can shippers evaluate load factor performance?

1.2.3 Logistics activities' influence on shippers' load factor performance

Improving the load factor has been identified in this thesis as a key variable for shippers' contribution to environmentally sustainable freight transport. In the second research question motivated above, evaluating load factor performance was addressed as a first important step for guiding improvement work to improve the load factor. For shippers, understanding their load factor performance will help them identify what logistics actions can be taken to improve it.

Previous research recognises that logistics activities shape the amount of environmental impact arising from freight transport, for example Aronsson and Huge-Brodin (2006) and Piecyk and McKinnon (2010). Shippers' logistics activities have an indirect impact on the environmental performance of freight transport (Pålsson and Johansson, 2016), which makes it difficult to explain the relationship properly. With regards to logistics influences on load factor performance, previous research most often mentions load factor within wider topics, such as transport efficiency or green logistics (McKinnon and Ge, 2004; Niwa, 2014), yielding few details about the influence of logistics activities on load factor performance. As pointed out by McKinnon (2015b), several factors influence load factor performance, including both constraints and opportunities for improving the load factor, such as market-related, regulatory, inter-functional, infrastructural and equipment-related factors. The influences are not always obvious, as there are several interdependencies between activities.

More detailed information is needed on how logistics activities and the circumstances they create influence load factor performance. The third research question addresses these issues.

RQ3: How do logistics activities influence shippers' load factor performance?

1.2.4 Shippers' logistics actions improving their load factor performance

For shippers to contribute to environmentally sustainable freight transport, improving load factor performance is clearly a key action area. Evaluating the performance and identifying which logistics activities influence the shippers' load factor help to explain what particular logistics actions a shipper can take to improve their load factor performance.

Previous studies offer several suggestions for improving the load factor, which may be of relevance to shippers. The actions listed in Table 1 may be more or less relevant for a specific shipper, depending on the need to take action and the current performance level of the load factor. Previous studies mostly point out single actions, with limited descriptions of how these actions change the shippers' logistics activities. As pointed out in relation to RQ3, there are also interdependencies between activities, and consequently actions in different areas may influence one another, for example redesigning the dimensions and shape of packaging may affect how to load the packages, such as on a pallet, and the stacking height that may be achieved. Further, the influence on load factor performance is often described in previous research based on single metrics, such as weight (Ülkü, 2012) or occupied floor space (Ljungberg and Gebresenbet, 2004), which say nothing about the utilised volume. Load factor improvements are also often described in general terms, without specifying any numbers or definitions of load factor.

Table 1: Examples of actions to improve load factor

Area	Actions
Warehousing	• Increasing warehouse sizes (Aronsson and Huge–Brodin, 2006) • Reducing the number of warehouses (i.e. centralisation) (Aronsson and Huge–Brodin, 2006; Kohn and Brodin, 2008) • Relocating warehouses (Aronsson and Huge–Brodin, 2006)
Order and delivery	• Adjusting the frequency of delivery to shops, e.g. by adhering to the nominated day delivery system (McKinnon, 2000) • Reducing variations in order size (Piezyk and McKinnon, 2010)
Packaging	• Redesigning the dimensions and shape of packaging (Wu and Dunn, 1995; McKinnon, 2000; Gustafsson *et al*., 2004) • Packing more efficiently on each loading unit (Gustafsson *et al*., 2004) • Choosing an appropriate packaging system (Pålsson *et al*., 2012)
Loading	• Harmonising load units (A.T. Kearney Management Consultants, 1997) • Standardising load carriers (Aronsson and Huge–Brodin, 2006) • Choosing an appropriate loading method (McKinnon, 2000) • Increasing stacking height (McKinnon, 2000)
Consolidation	• Consolidating internal flows (Kohn and Brodin, 2008) • Improving horizontal collaboration among shippers (Cruijssen, 2012) • Consolidating by freight forwarder in terms of sharing vehicle capacity (McKinnon, 2000) • Coordinating distribution in urban logistics (Ljungberg and Gebresenbet, 2004)

To identify what different logistics actions is relevant for shippers in their situations requires more details regarding actions' changes of the logistics activities and in turn what influences these have on load factor performance. To consider these issues, the fourth research question is posed:

RQ4: What logistics actions can a shipper take to improve their load factor performance?

1.3 Project outlook

This research was initially part of the collaborative project 'Integrated Logistics Development for Sustainability and Competitiveness' (2009–2013), involving five PhD students at Chalmers University of Technology and the University of Gothenburg. The project's main funder was VINNOVA and the co-funder was the Logistics and Transport Foundation (LTS). Additionally, five other partners, companies as well as local and regional authorities, collaborated in the project.

During 2013–2016, the research was part of another collaborative project, 'Increased Transport Efficiency through Better Utilization of Loading Capacity', which involved three PhD students at Chalmers University of Technology. As before, VINNOVA was the main funder and LTS the co-funder. The project involved also three shippers as well as national and local authorities.

1.4 Outline of the thesis

This thesis is a compilation of six papers that present the results from five studies undertaken in the period 2009–2016. Figure 2 illustrates the relationships between the studies, the papers and the research questions.

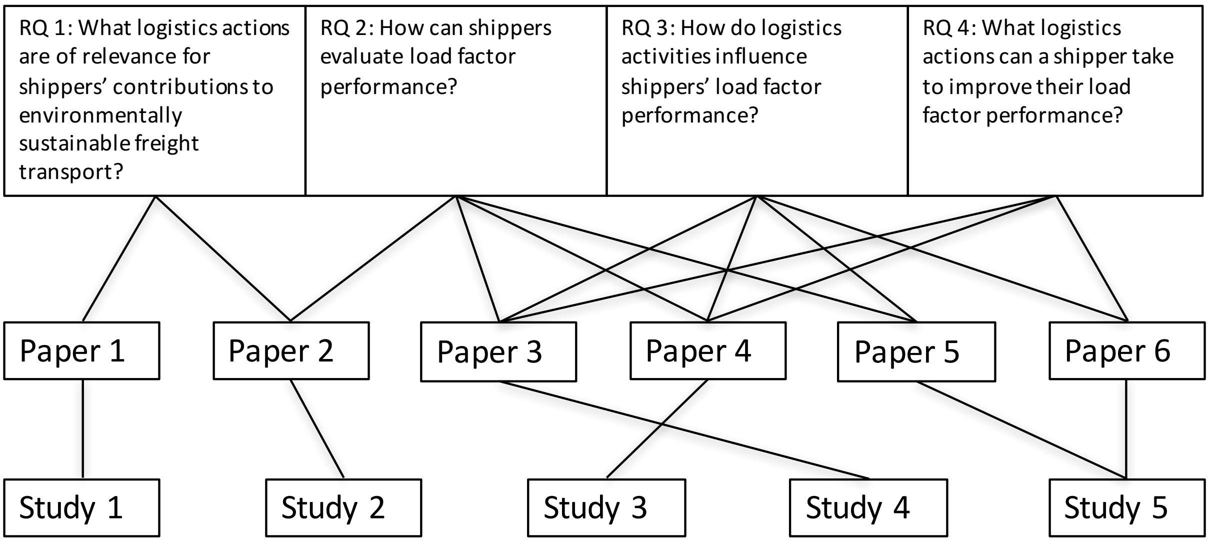


Figure 2: The relation between the studies, the resulting papers and the research questions

Chapter 2 presents an overview of previous research related to the main concepts of this thesis. Chapter 3 describes the methodological choices in terms of research process, approach, design and trustworthiness of the research. Chapter 4 summarises the extent to which the six appended papers contribute to answering the research questions. Chapter 5 contains an analysis of the results from the papers in relation to each of the research questions, with further discussion and conclusions. Chapter 6 discusses the findings in relation to the purpose of the thesis, sets out the contributions of the present research and presents practical implications, as well as suggesting possible future research directions. Finally, chapter 7 outlines the conclusions of the study.

2 Frame of Reference

This chapter defines the main concepts related to the research in this thesis and provides an overview of earlier research related to these concepts.

This chapter defines the main concepts related to the purpose and research questions outlined in this thesis and provides an overview of earlier research related to these concepts. The purpose and the four research questions are based on the research needs in green logistics. However, it is not only this field of research that is important for defining the main concepts of relevance for this thesis. Since the purpose is *to explain how shippers' logistics actions contribute to environmentally sustainable freight transport by clarifying the link between logistics activities and the resulting load factor performance*, the concept of environmentally sustainable freight transport is central to the overarching aim, to which the literature in the field of sustainability and transport provides an important foundation. Specifically, earlier literature in supply chain management, logistics management and logistics performance is relevant to define each concept that forms an element in the conceptual model of the studied system in this research (shown in Figure 3). Crucially, literature in the area of systems approaches illuminates and underpins the view of the logistics system here studied and helps explain the link between its elements.

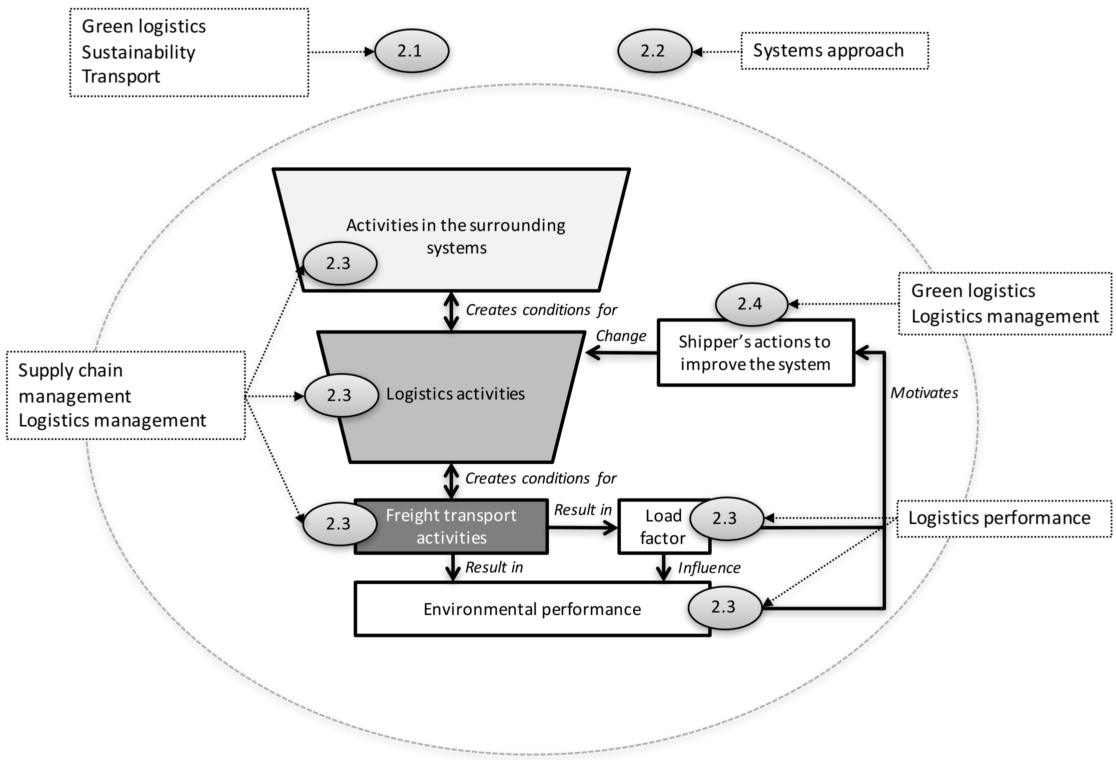


Figure 3: The sub-chapters that define the main concepts based on the previous literature

Figure 3 shows the sub-chapters, in which the main concept related to the conceptual model is defined, based on previous literature. In chapter 2.1, the main research themes in green logistics literature cover the role of greening freight transport in relation to logistics and supply chain management, which, together with the literature on sustainability and transport, defines 'environmentally sustainable freight transport'. In 2.2, the systems approach applied for understanding the links between logistics activities, performance measurement and actions to improve the system is described. In 2.3, logistics and supply chain management literature as well as logistics performance literature define each element in the logistics system studied here.

Further, in 2.4, green logistics literature provides an overview of the influences on load factor and environmental performance of logistics activities, as well as action areas that can improve the system based on previous research.

2.1 Environmentally sustainable freight transport – central for green logistics

To explain how shippers' logistics actions contribute to environmentally sustainable freight transport, it is important to distinguish what comprises environmentally sustainable freight transport. First, a broader discussion about sustainability explains the focus on environmentally sustainable freight transport, as well as its intended meaning in this thesis. Second, a brief overview of the research area of green logistics is presented. Further, green logistics is compared with green and sustainable supply chain management (SCM) to distinguish the role of freight transport within these research areas.

2.1.1 Environmentally sustainable freight transport – underpinned by the view of sustainability

Although freight transport activities feature significantly in green logistics literature, there is no particular mention of freight transport with regards to sustainability. In this thesis, the purpose is to explain how shippers' logistics actions contribute to environmentally sustainable freight transport, sustainability being a core concept that has implications for the understanding of environmental issues in freight transport.

Two critical issues in sustainability are important for defining environmentally sustainable freight transport in this thesis, which differ from the traditional and commonly used triple bottom line approach (Norman and Macdonald, 2004). First, a holistic view needs to be taken of the natural system and its resources, given that natural sustainability sets the boundaries on action to achieve social and economic goals (Sverdrup and Svensson, 2004). Further, long-term thinking is necessary to understand the lasting effects within the boundaries of natural sustainability (Sverdrup and Svensson, 2004), there being a need to align 'long-term goals with the short-term economic reality' (Holmberg and Robért, 2000, p. 296).

The triple bottom line comprises three aspects identified as important to our society: **environmental** concern, **social** welfare and **economic** development (Norman and Macdonald, 2004). Definitions of sustainability often incorporate the importance of simultaneously striving towards these three goals, for example Elkington's definition, which involves the simultaneous pursuit of economic prosperity, environmental quality and social equity (Elkington, 2002). In essence, it can be difficult to adapt to the vague concept of sustainability in a company environment. Norman and MacDonald (2004) critically review the concept of the triple bottom line, concluding that it is 'good old-fashioned single-bottom line plus vague commitment to social and environmental concerns' (p. 13). It is a challenge to green logistics that economic goals take precedence over environmental goals in companies (Abbasi and Nilsson, 2012). As Vachon and Klassen (2008) state, 'it is unlikely that environment-related goals and objectives take precedence over primary operational performance criteria such as cost quality and delivery' (p. 801).

Instead, in order to attain sustainability, considerations of social and economic sustainability must be met within the boundaries set by natural sustainability criteria (Sverdrup and Svensson, 2004), such that natural sustainability takes precedence over social and economic sustainability. The motivation is based on the fact that there is 'no exception from thermodynamics and mass conservation, regardless of ideology or excuse' (Sverdrup and Svensson, 2004, p. 144). Holmberg and Robért (2000), thinking along similar lines, developed principles for sustainability to be used in a framework for strategic planning in organisations. The use of these principles as a guideline for sustainability facilitates an understanding of the root causes of current unsustainable activities. These principles are about striving towards a balance between the resources used in society and nature, meaning the activities in society should not systematically degrade biodiversity, change the ecological system or deplete its resources. Thus, these principles satisfy the criteria of long-term thinking and a holistic view of the natural system. In Figure 4, the 'natural sustainability' view adopted in this thesis is compared with the triple bottom line view.

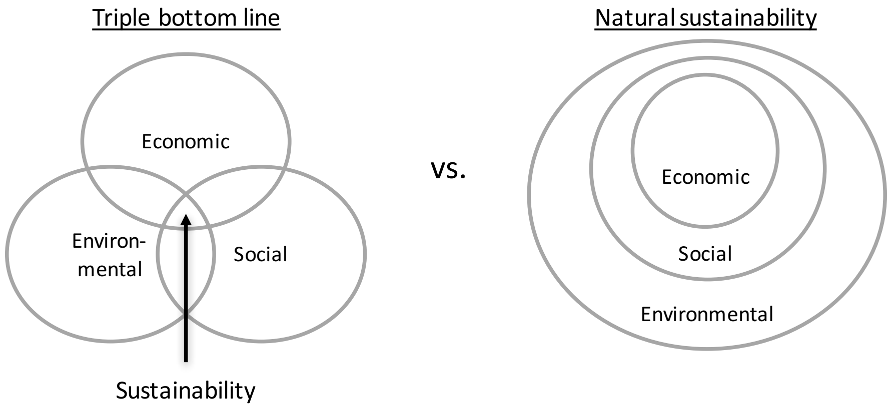


Figure 4: Comparison of the relationship between environmental, social and economic dimensions in the triple bottom line view (Elkington, 2002) and the 'natural sustainability' view (Sverdrup and Svensson, 2004)

In the area of sustainable transport, other studies emphasise the importance of achieving a balance between resources use in the natural and societal systems. The OECD uses the concept of environmentally sustainable transport (EST), defined as transport that '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). Gudmundsson and Höjer (1996, pp. 280) echo the focus on resources: 'To safeguard a natural resource base within critical loads, levels, and usage patterns'. Similarly, Behrends identifies principles for sustainable freight transport, in which he disfavours upstream sources of unsustainability: 'A sustainable freight transport system does not use fossil resources or renewable resources over their rates of generation and does not emit air pollutants' (Behrends, 2011, pp. 70-71).

Applying the sustainability view to freight transport requires a focus on environmental concerns, specifically the major environmental impacts that must be reduced in order to achieve environmentally sustainable freight transport and also highlighting the 'natural sustainability' point of view described above. The areas that are important to consider in attempting to achieve environmentally sustainable freight transport are resource depletion, emissions to the air, pollution, land use, inefficiency and social damage. Resource depletion refers to the use of fossil fuels (Chapman, 2007; Behrends, 2011) and other resources over their rates of regeneration (if renewable) or over the rates of renewable substitutes (if non-renewable) (OECD, 2002). Emissions to the air refer to greenhouse gases (Chapman, 2007) and air pollution, such as from NO_x, SO_2, particulate matter (PM) (European Environment Agency, 2006). Pollution includes pollution of water, such as ballast water from ships (Field *et al.*, 2002) and waste, e.g. from in-use and end-of-life vehicles (Giannouli *et al.*, 2007). Land use, in particular infrastructure development, is another important consideration (Behrends *et al.*, 2008; European Environment Agency, 2006). Inefficiency may be described as unnecessary transport operations and underutilisation of load capacity, e.g. low capacity efficiency (Samuelsson and Tilanus, 1997) and empty running (McKinnon and Ge, 2006). Finally, social damage relates to traffic congestion, accidents and health risks, which are particularly prominent in urban areas (Behrends *et al.*, 2008).

Reducing the impact of all these issues is important for environmentally sustainable freight transport. This thesis focuses particularly on inefficiency, specifically, the underutilisation of load capacity, i.e. improving the load factor. By improving efficiency, other environmental impacts may be reduced as well. Further, improving the load factor has the potential to contribute both towards long-term goals, in terms of reducing environmental impact, and to short-term economic wins, for example by saving transport costs (see, e.g., Bø and Hammervoll, 2010; Kohn and Brodin, 2008).

2.1.2 Green logistics – what is it?

As freight transport activities are considered to have the greatest environmental impact within the logistics system (Wu and Dunn, 1995; World Economic Forum, 2009), freight transport issues have received much attention in the green logistics literature.

Green logistics can be defined as 'the study of the environmental effects of all the activities involved in the transport, storage and handling of physical products as they move through the supply chains in both forward and reverse directions. It assesses the nature and scale of these effects and examines the various ways in which they can be reduced' (McKinnon, 2015a, pp. 4-5).

Although green logistics is 'a rapidly evolving subject' (McKinnon, 2015a), study of the environment within logistics is still considered relatively new and has been described as an 'underdeveloped' research area (Grant *et al.*, 2013). Wu and Dunn (1995) provided the first overview of environmentally responsible logistics by pinpointing which logistics decisions in the value chain have an effect on the environment. Murphy *et al.* (1996) were among the first to use the term 'green logistics', and analysed the popularity of adopting a number of green logistics strategies among firms, e.g., recycling materials, reusing components or reducing materials. From this starting point, research in this area has been growing and deepening, considering a number of themes.

Recently, there have been a number of literature reviews on the subject of green logistics (e.g. Abukhader and Jönsson, 2004; Dekker *et al.*, 2012) or related subjects, such as environmentally sustainable logistics (e.g. Marchet *et al.*, 2014) and green and sustainable supply chain management (e.g. Abbasi and Nilsson, 2012; Srivastava, 2007; Sarkis *et al.*, 2011; Seuring and Müller, 2008). Abukhader and Jönsson (2004) performed a literature review of green logistics and supply chain management research and identified three main themes: environmental assessment, reverse logistics and green supply chains. McKinnon (2015a) further extended this list with a number of additional evolving themes within green logistics research, namely reducing freight transport externalities, city logistics and logistics in corporate environmental strategies. In this thesis, the research adds to current knowledge within the theme 'reducing freight transport externalities', by explaining how logistics actions contribute to environmentally sustainable freight transport and, within the theme of 'environmental assessment', explaining how shippers can evaluate load factor performance (RQ2).

Several authors take a broader perspective on green logistics by emphasising the influences of different logistics decisions on freight transport externalities. Based on the work by McKinnon and Woodburn (1996), a few authors have followed the same logic, e.g. Drewes Nielsen *et al.*

(2003) and Aronsson and Huge-Brodin (2006). Piecyk and McKinnon (2010) further developed the four-level decision making suggested by McKinnon and Woodburn (1996), which included six factors influencing carbon dioxide (CO_2) emissions from road freight. Developing the same theme further, McKinnon (2015a) presented an analytical framework for green logistics, in which the supply chain structure, efficiency of vehicle routing, vehicle-carrying capacity, vehicle utilisation, level of backhaul, distribution of vehicle-kms, timing of deliveries, spatial delivery pattern and warehousing/materials handling, as well as IT, determine the external costs of logistics operations.

Another example of a study taking the broader perspective on green logistics but from an operations research perspective is Dekker *et al.* (2012). The authors provide an overview of operations research contributions to green logistics, i.e. in terms of the relevance of decisions related to supply and transport chain design, planning and control. Their paper discusses the influences on transport of strategic, tactical and operational decisions.

2.1.3 Freight transport as part of green logistics and green supply chain management

As described above, freight transport is widely discussed in green logistics literature. In order to understand its role in relation to the scope of a supply chain, a comparison between green logistics and green/sustainable supply chain management is presented (see Table 2).

Table 2: Comparison of definitions of sustainability and green supply chain management/logistics

Term	**Definition**	**Reference**
Sustainable supply chain management	Sustainability must integrate issues and flows that extend beyond the core of supply chain management: product design, manufacturing by-products, by-products produced during product use, product life extension, product end-of-life and recovery processes at end-of-life.	Linton *et al.* (2007)
Green supply chain management	Integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to consumers and end-of-life management of the product after its useful life.	Srivastava (2007, p. 54)
Green supply chain management	Integrating environmental concerns into the inter-organisational practices of SCM, including reverse logistics.	Sarkis *et al*. (2011, p. 3)
Green logistics	The study of the environmental effects of all the activities involved in the transport, storage and handling of physical products as they move through the supply chains in both forward and reverse directions. It assesses the nature and scale of these effects and examines the various ways in which they can be reduced.	Mckinnon (2015a, p. 4)
Green logistics	Green logistics is an environmentally friendly and efficient transport and distribution system.	Rodrigue *et al.* (2001, p. 2)

Sustainable supply chain management is a broader concept than ‘normal’ SCM, including product life extension, product end-of-life and recovery processes (Linton *et al.*, 2007). This may also be seen in the definition provided by Srivastava (2007), in which green supply chain management involves product design, material sourcing and selection, manufacturing processes, delivery of the final product to consumers and end-of life treatment. Further, Sarkis *et al*. (2011) incorporate reverse logistics in their definition, including issues such as end-of-life treatment, which is also referred to as a closed loop supply chain (see, e.g., Quariguasi Frota Neto *et al.*, 2010) and has similarities with the more recent concept of a circular economy (see, e.g., Winkler, 2011). In such end-of-life treatment activities, freight transport is naturally involved, if not explicitly in focus. Although the scope in green logistics literature has been extended towards supply chain management in terms of including functions, processes and relationships between functions (McKinnon, 2003), the focus in green logistics is still on reducing transport externalities to a larger extent, which differs from that of green supply chain management literature.

2.2 Systems approach

Logistics research traditionally has a systems approach, as mentioned by a number of authors, e.g. Coyle *et al.* (1996), Lambert and Stock (2001), Bowersox *et al.* (2002) and Gammelgaard (2004). The traditional components of a logistics system are functions (Bowersox *et al*., 2002) or activities (Lambert and Stock, 2001), such as those related to transport, 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 to customer service levels at the lowest possible total cost' (Bowersox *et al*., 2002). '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, Bardi and Langley, 1996, p. 53).

Explaining how shippers' logistics actions contribute to environmentally sustainable freight transport involves a systems approach, which is appropriate in this thesis, where the focus is on clarifying the link between logistics activities (interacting variables) and the resulting load factor performance as one way to contribute to environmentally sustainable freight transport (the higher overall achievement). However, the systems approach applied in this thesis deserves more explicit description. Although logistics research traditionally leans towards the systems approach, it is often not clear how the systems approach influences the research or why it is adopted (Lindskog, 2012; Holmberg, 2000). 'Logisticians often claim to use systems thinking when managing the flow of goods and information from the point of origin to end customers, but few authors explain why and how the concept is used' (Lindskog, 2012, p. 853).

2.2.1 Systems 'schools'

There are varying schools of systems approaches as well as fields of application, which creates a wide range of ways in which systems analysis may be performed in each specific situation (Svedin, 2004). First, there may be different reasons for applying the systems approach, such as achieving basic understanding of a phenomenon or to support decisions. Further, the studied system may vary, for example being a natural eco-system, a socio-economic system or a combination of these, or a technical system such as a machine, infrastructure or computer software (Svedin, 2004).

Similarly, various systems approaches have been developed over time, dating back to early cybernetics and general systems theory. Within general systems theory, Boulding's paper from 1956 (Boulding, 1956) is a well-known starting point for systems ideas (Checkland, 1999). Ramage and Shipp (2009) categorise system thinkers with regards to, for example, general systems theory, early and later cybernetics, system dynamics, soft and critical systems, complexity theory and learning systems. Adding to that list, Olsson (2004) also describes the system schools of operations research, systems engineering and systems analysis. From the early schools of general systems theory and cybernetics emerged operations research and systems analysis. Based on these approaches, soft and critical systems were developed. Several authors distinguish between 'hard' and 'soft' systems approaches (e.g. Nilsson and Gammelgaard, 2012; Checkland, 1999; Lindskog, 2012; Olsson, 2004). A 'hard' systems approach is based on systems engineering and operations research, in which mathematical modelling and optimisation have a central role in the analysis (Lindskog, 2012). A 'hard' systems approach rests on the positivist paradigm, which incorporates the essential view of social agents as deterministic (Lindskog, 2012). Checkland (1999) describes the 'hard' systems as those that 'exist in the world outside ourselves', based on the view that the world is basically a set of interacting systems that can be engineered to work better. Olsson (2004) links the hard systems approach to physical and life sciences such as physics, chemistry and biology. By contrast, the 'soft' systems approach tends to relate to humans in the social world (Olsson, 2004), in which different actors interpret situations differently, thus requiring an interpretive stance to be taken (Lindskog, 2012). Importantly, Checkland (1999) emphasises that soft systems are about 'the process of our dealing with the world', in which the observer may 'spy complexity and confusion; but can organize exploration of it as a learning system' (p. A11).

Previous research thus seems to treat 'hard' and 'soft' systems approaches as two contrasting views of the world, while in reality different approaches may be used depending on the components in the studied system and the specific questions raised. Also, the systems approaches span several dimensions and do not have only two clear ends, as exemplified by the overlap in views between the different approaches in Arbnor and Bjerke (2009). In the management context, Crawford and Pollack (2004) emphasise the use of seven dimensions to analyse the 'softness' and 'hardness' in projects, so that management approaches can be more informed and responsive, taking into account issues related to both stances. Critical systems thinking has fostered discussion about the strengths and weaknesses of each individual approach. Further, in critical systems thinking, the issue of pluralism is an important consideration, and 'it might be useful to employ them [systems approaches] in combination to address different purposes' (Jackson, 2010, p. 135).

Owing to the lack of explicit system descriptions in logistics research, it is difficult to position logistics research in relation to these systems approaches. However, a number of logistics studies refer back to early systems research (Lindskog, 2012; Nilsson and Gammelgaard, 2012), such as system dynamics. Further, logistics research is often said to be predominantly rooted in the positivistic paradigm (Mentzer and Kahn, 1995; Nilsson and Gammelgaard, 2012), which is related to the 'hard' systems approach and the use of quantitative approaches (Naslund, 2002). There has been growing criticism of the sole use of traditional 'hard' systems approaches in logistics and, by the same token, calls to apply other, 'newer' approaches to logistics research, i.e. grounded in the more interpretivist approach (Mears-Young and Jackson, 1997; Naslund, 2002; Nilsson and Gammelgaard, 2012). The 'soft'systems approach (Mears-Young and Jackson, 1997; Naslund, 2002) can also be seen as a complementary to the existing 'hard' approach often used in logistics research.

2.2.2 Systems approach in this thesis

As in traditional logistics systems approaches, the system studied in this thesis is seen as a set of different activities that are interlinked, although their interactions and overlapping relationships are complex. In the logistics system, activities are interlinked in terms of creating conditions for one another. Further, the activities in the logistics system are influenced by activities in the surrounding systems as well.

The traditional systems approach is not enough, however, since the activities are performed in a social setting in which different actors are involved, who may have different perceptions of the system and its goals. Naslund (2002) describes problems in a logistics system as 'ill structured, even messy, real world problems'; here, the soft systems methodology is useful to make sense of such complex situations for the actors involved, making it more likely that actions to improve the system can be taken (Checkland, 1999). For the purposes of this thesis, it is important to clarify the link between logistics activities and the resulting load factor performance, in terms of both identifying relevant actions to improve the system, as well as motivating the actors involved.

The activities in the system are performed in relation to continuously changing internal circumstances, as well as in the surrounding systems. How an actor in the system perceives the situation will change from time to time and one actor will have a different perception from another. Here, a basic assumption is that individuals take purposeful actions based on their perceptions of the world; such actions lead to new experiences, which in turn yield new experiential knowledge (Checkland and Scholes, 1990). Consequently, there is continuous learning about the system. Measuring the performance of the system will facilitate an understanding of the system's output and motivate actions to improve it. This means that, depending on when (in time) the performance is measured, different results will be identified. In addition, the system will be perceived differently in various situations. In Figure 5, this view of the system is described; activities are related to continuously changing circumstances, where constant learning about the system is achieved through taking actions and measuring performance. The focus of this thesis is on activities, although of course measuring the performance and how actions can improve the system is important; however, the particular system learnings are not emphasised here.

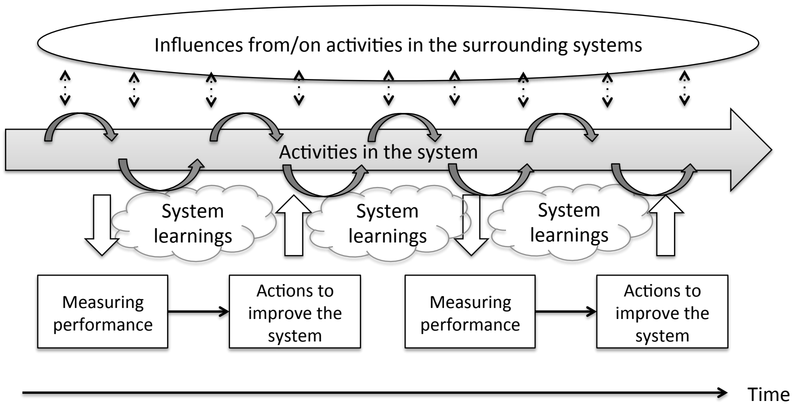


Figure 5: Activities in the system in relation to continuously changing circumstances, based on Checkland (1999)

- **Links between activities**

An activity can be described as work performed (by people, equipment, technologies or facilities) (Vitasek, 2013) to convert input to output (Lambert and Stock, 2001). Activities are interlinked, such that there is some type of influence between one or several activities, in either direction. To be more specific, activities create conditions from one to another (due to serial dependency) or for one another (due to reciprocal dependency). Serial dependency is when the output from one activity is the input to the next (Thompson, 1967; Håkansson and Persson, 2004). Reciprocal dependency is when 'the output from each activity is the input for the others' (Thompson, 1967, p. 54) or 'there is mutual exchange of inputs and outputs between two parties' (Håkansson and Persson, 2004, p. 14). To clarify how logistics activities influence shippers' load factor performance (research question 3, RQ3), the links between activities are described in terms of serial and reciprocal dependencies; if one activity **creates a condition** for another activity or if activities create conditions for one another.

- **Measuring performance**

  Companies measure their performance for several reasons: to identify success, to evaluate improvements, to understand processes, to identify problems and to support decisions (Gunasekaran and Kobu, 2007). Actions are taken in companies to achieve a certain performance, and the aim of measuring performances is to quantify the effect of actions (Neely *et al.*, 2005). For shippers, to understand how actions contribute to environmentally sustainable freight transport, the performances of shippers' freight transport must be assessed.

  The results from the interlinked activities are measured (involving another set of activities) in relation to the purpose of the system. In this thesis, the purpose is to explain how shippers logistics actions contribute to environmentally sustainable freight transport, which is central for green logistics (cf. McKinnon, 2015a) but differs compared to the cost focus in traditional logistics systems analysis (cf. Bowersox, 2002). Since the historical focus within logistics has been on increasing the company's profit, the environmental impact from freight transport activities has been put to one side. Different and possibly contradictory goals in companies create a complex situation for the actors involved. Measuring performance will help them to understand the effects of actions taken to improve the system. Therefore, performance measures should be designed not only to capture the results of the activities in a comprehensive and accurate way but also to provide guidance for further action.

- **Actions to improve the system**

  An action is aimed at improving the system in order that it can fulfil its purpose. More specifically, an action is a change of an activity so that **new conditions are created**, which is an output from one activity and an input to another activity. As an example, changing the packaging by using a more robust packaging material will create new conditions for loading the goods on the vehicle, such as being able to double-stack items on top of one another without risking damage and thereby improving the load factor in the vehicle.

2.3 The logistics system studied

Logistics actions to improve the system are viewed as changes of activities that in turn create new conditions for one another, the freight transport activities and their resulting environmental performance. This thesis considers shippers' logistics activities and the resulting environmental performance of the freight transport activities.

2.3.1 Logistics activities

When describing which activities are involved in logistics management, the definition of the Council of Supply Chain Management Professionals (CSCMP) can serve as a starting point. 'Logistics management is 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, 2016). According to this definition, logistics management involves activities on all levels: operational, tactical and strategic. The activities include inbound and outbound transport management, fleet management, warehousing, materials handling, order fulfilment, logistics network design, inventory management, supply/demand planning and the management of third party logistics providers. In addition, logistics activities are, to a varying degree, involved in sourcing and procurement, production planning and scheduling, packaging and assembly and customer service (CSCMP, 2016). On a general level, it is difficult to be more precise regarding exactly which activities are involved in logistics management, as this depends on the situation where it takes place, as also pointed out by Lambert and Cooper (2000), who describe logistics as one of several management functions in supply chain management. Further, supply chain management consists of a number of core processes into which each of these management functions is integrated. Thus, logistics management is integrated into several key supply chain processes, such as customer relationship management, customer service management, demand management, order fulfilment, manufacturing flow management, procurement, product development and commercialisation and returns (Lambert and Cooper, 2000).

Of particular interest for this thesis is the order fulfilment process, also called the order to delivery process, which is one key process to be managed from a logistical perspective (Forslund *et al.*, 2008; Croxton, 2003). The order fulfilment process details the outgoing goods flow and related freight transport activities in the supply chain. The process starts when an order is received from the customer and ends when the product is delivered (Zhang *et al.*, 2010). The order fulfilment process can also be distinguished between the strategic and operational levels (Croxton, 2003). The strategic order fulfilment process can 'establish the structure for managing the process, and the operational process that is the execution of the process once it has been established' (Croxton, 2003, p. 21). Consequently, the strategic order fulfilment process is about, among other things, understanding customer requirements, defining requirements for lead time and customer service, determining the location of warehouses and transport modes and deciding on order sizes and packing requirements (Croxton, 2003). The operational order fulfilment process includes activities such as planning order flow and transport, picking products, packing products and loading. Activities included in the order fulfilment process are thus related to both material and information flows (Croxton, 2003). In shippers' logistics activities, the activities in the order fulfilment process are central.

2.3.2 Logistics activities link with freight transport activities

Freight transport activities are the operations that are involved in moving the goods from point of origin to point of consumption (Lambert *et al.*, 1998). Although the transport of goods is a central logistics activity (e.g. CSCM, 2016), in this thesis, activities related to the movement of goods, namely freight transport activities, are viewed as being part of the interlinked transport system. This way of structuring logistics and freight transport as interlinked systems is similar to Wandel *et al.*'s (1992) three-layer model of logistics (see Figure 6) and the proposed model by Woxenius and Sjöstedt (2003). In Wandel *et al.*'s model, shippers' logistics activities are part of the upper level, the material flow, while freight transport activities are part of the second level, the transport flow. The transport flow refers to transport services handling load units between the nodes and links in their network, while the material flow is the flow of products between nodes in the supply chain, creating demand in the transport market (Wandel *et al.*, 1992). Also, the logistics and transport are described as interlinked systems (Woxenius and Sjöstedt, 2003), in which the object is a product forwarded in the logistics system and goods moved in the transport system. These authors further distinguish the infrastructure in terms of location of manufacturing, storage and delivery points in the logistics system and the ways and terminals in the transport system (Woxenius and Sjöstedt, 2003). The shippers' logistics activities studied in this thesis can be seen as part of the material flow level in Wandel *et al.*'s model or as part of the logistics system in the model by Woxenius and Sjöstedt (2003). Wandel, *et al.* (1995) indicate a hierarchical relationship between the material flow and transport flow in terms of the transport market. In this thesis, the logistics system and the transport system are seen as complementary systems, interlinked by creating conditions for each other. Further, the company perspective, i.e. that of the shipper, is taken, which means that logistics activities are within the company limits. Further, the freight transport activities are (most often) performed by a transport provider acting in the transport system. Activities in the surrounding systems, that may be performed by other supply chain actors, are interlinked with the shipper's logistics activities by creating conditions for one another, shown as a separate system level linked to logistics activities (Figure 6).

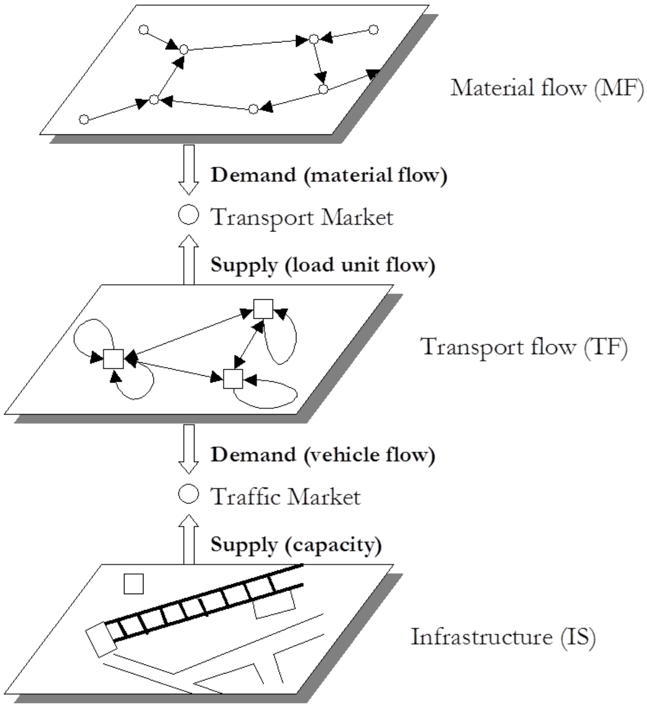


Figure 6: The link between material flow and transport flow, as part of the three-layer model (Wandel et al., 1992)

2.3.3 Actors involved in activities in logistics, transport and the surrounding systems

This thesis looks at the shipper's logistics activities. A shipper is a company in the supply chain that supplies physical goods. In addition, a shipper can be a buyer of physical goods, but it is outgoing goods flow that is of interest here. A shipper can organise and execute the related freight transport activities to deliver the customer orders itself, but more commonly, freight transport activities are outsourced to a third party, i.e. a transport provider.

As there are interactions between the shipper's logistics activities, freight transport activities and activities in the surrounding systems, it is relevant to consider which actors are involved in such activities. Behrends *et al.* (2008) described an actor-based model of the transport system adapted from Sjöstedt (1996). Their model is organised around three elements in the transport system: goods, vehicles and infrastructure. The shipper creates demand for transport services of goods that is matched by the vehicle operators, involving the transport industry, the operators and the forwarding industry (Behrends *et al.*, 2008). Behrends *et al.* (2008) also point out several other actors involved in a transport system, related to the vehicle (the vehicle industry and the energy industry), traffic (traffic controller), policy makers (the authorities) and academia. Further, from a logistics perspective, Jonsson (2008) describes the logistics system in a supply chain involving the supplier, the company (the shipper) and the customer. From a supply chain perspective, the following actors are involved in different stages: supplier, manufacturer, distributor, retailer, customer (Chopra and Meindl, 2013). Further, competitors are also important because of their influence on the company in question (Chopra and Meindl, 2013). Actors involved in activities related to logistics, transport and the surrounding systems are summarised in Table 3.

Table 3: Actors involved in activities related to logistics, transport and the surrounding systems (based on Behrends et al. (2008) and Jonsson (2008))

System perspective	Actors involved
Society	Authorities, academia, organisations
Supply chain	Supplier, manufacturer, distributor, retailer, customer, competitors
Logistics	Suppliers, shippers, customers
Transport	Forwarding industry, operators, transport industry
Traffic	Traffic controller
Vehicle	Vehicle industry, energy industry
Infrastructure	Planning agencies and regulators

As can be seen, several actors are involved in activities related to logistics and freight transport. Those involved in the surrounding system include the authorities, suppliers, customers, competitors and the shipper itself. The reason for identifying the shipper as part of the surrounding system is that activities that are not part of logistics activities, such as in marketing and sales, can also have an influence on logistics activities. Further, as shippers can organise and execute freight transport activities themselves, the shipper can also be involved in freight transport activities. Further, if outsourced, the transport provider can also be involved in activities that are part of the shipper's logistics activities. Exactly what role the shipper plays in relation to the other actors will differ depending on the situation. Examples of the actors' involvements in relation to activities in the system studied is given in Figure 7.

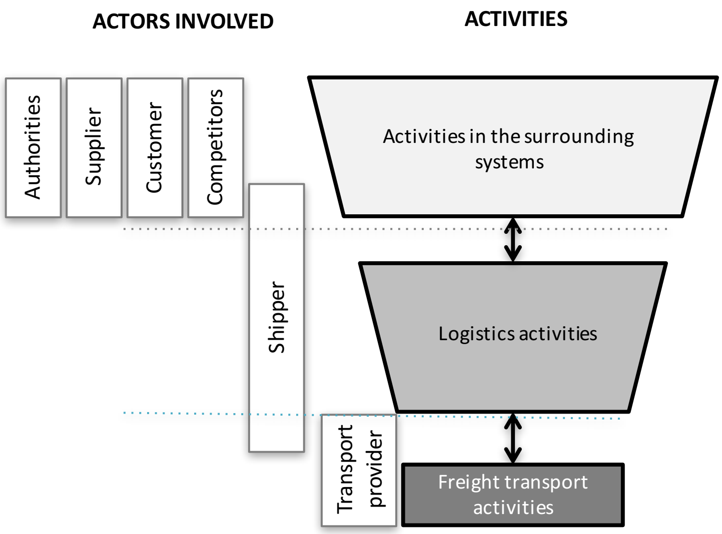


Figure 7: Actors related to logistics activities, freight transport activities and activities in the surrounding system

2.3.4 Load factor – a key measure for environment, logistics and transport

The load factor is a performance measure of transport efficiency: it is the ratio of the actual load carried to the maximum load that could be carried (McKinnon and Ge, 2004). In measuring the environmental performance of freight transport operations, the load factor is a key performance variable (Piecyk and Mckinnon, 2010). In relation to different logistics performance measures, load factor can be classified as a non-financial (De Toni and Tonchia, 2001) utilisation measure of the physical usage ratio type (Caplice and Sheffi, 1994). Load factor (in terms of a physical usage ratio) can also be described as an input/output measure, namely a ‘hard’ measure (Chow *et al.*, 1994).

For transport providers, the load factor is measured as part of their transport system, and examples from the literature include measuring overall vehicle effectiveness (Simons *et al.*, 2004), efficiency in less-than-truckload distribution systems (Samuelsson and Tilanus, 1997) and CO_2 efficiency in road freight transport (Léonardi and Baumgartner, 2004). For shippers, load factor performance is also of relevance to evaluating the efficiency of their distribution systems in terms of reducing costs (Lumsden *et al.*, 1999) or for external benchmarking (see McKinnon, 2009, for road freight transport key performance indicators). In general, improving the load factor performance has been shown to reduce environmental impact and transport costs for shippers (Bø and Hammervoll, 2010; Kohn and Brodin, 2008). Apart from measuring load factor in the abovementioned performance measurement systems (the shippers logistics efficiency and transport providers’ transport efficiency), the load factor is also relevant to measurements on a macro level, for example for evaluating environmental impact in terms of CO_2 emissions from road freight transport (Piecyk and Mckinnon, 2010). Further, transport data provide the basis for a statistical analysis of vehicle movements and the amount of the load on a national level (Transportstyrelsen, 2011) or on a European level (McKinnon, 2010a).

Consequently, the load factor is central for evaluating logistics performance in a shipper’s system and transport performance in a transport provider’s system, as well as the environmental performance (see Figure 8). In this thesis (RQ2), the focus is on evaluating load factor performance on an operational level in the shippers’ logistics system.

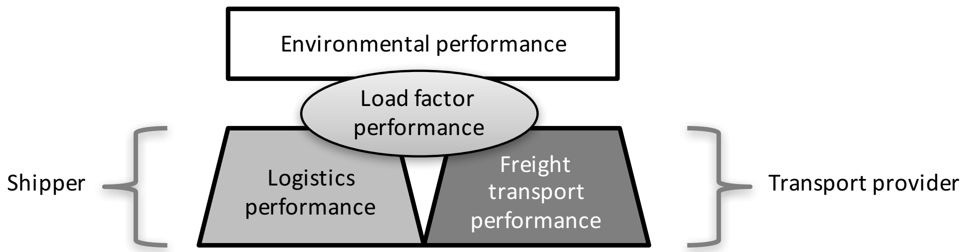


Figure 8: Load factor performance as part of different performance measurement systems

Load factor performance is measured differently depending on which performance system the load factor is part of and on the purpose of measuring. For example, when measuring environmental performance, the weight-based load factor is central to evaluating the vehicle’s fuel consumption (Bäckström, 1999), whereas for logistics performance in a shipper’s system, the packaging load factor may be the appropriate parameter to measure (Pålsson *et al.*, 2013). However, there is no uniform way of measuring load factor in the literature, and different measures are used in terms of weight, volume or others, e.g. ‘tonnes/vehicle’ (Eom *et al.*, 2012), ‘internal volume/external volume with lid’ (Pålsson *et al.*, 2013) or ‘per cent of occupied floor space’ (Ljungberg and Gebresenbet, 2004). Measuring only one dimension may be misleading, since measuring all floor space in the vehicle says nothing about the utilised height or weight. Further, load factor is often mentioned without any measurement details and definitions (e.g., Lumsden *et al.*, 1999; Kohn and Brodin, 2008). The several ways of measuring load factor make it difficult to compare results between studies, as well as to fully understand load factor performance.

Caplice and Sheffi (1994) suggest a set of evaluation criteria for logistics performance metrics. Depending on the purpose of measuring, different criteria have more or less importance. As there is a trade-off between criteria, not all can be met simultaneously (Caplice and Sheffi, 1994). For example, to provide actionable guidance for shippers, it is important that the performance metric be useful. According to Caplice and Sheffi (1994), this means it will be difficult to include all relevant aspects of the process in the metric, as there is a trade-off between usefulness and integration. In Table 4, the suggested evaluation criteria are outlined. These evaluation criteria will be used for analysing how different performance measures and data quality fulfil the different purposes of measuring load factor performance (RQ2).

Table 4: Caplice and Sheffi's evaluation criteria for logistics performance metrics (Caplice and Sheffi, 1994)

Criteria	**Description**
Validity	The metric accurately captures the events and activities being measured, as well as the controls for any exogenous factors.
Robustness	The metric is interpreted similarly by the users, is comparable across time, locations and organisations and is repeatable.
Usefulness	The metric is readily understandable by the decision maker and provides a guide for action to be taken.
Integration	The metric includes all relevant aspects of the process and promotes coordination across functions and divisions.
Economy	The benefits of using the metric outweigh the costs of data collection, analysis and reporting.
Compatibility	The metric is compatible with the existing information, material, cash flows and systems in the organisation.
Level of Detail	The metric provides a sufficient degree of granularity or aggregation for the user.
Behavioural Soundness	The metric minimises incentives for counter-productive acts or game playing and is presented in a useful form.

2.4 Logistics actions contributing to environmentally sustainable freight transport

This thesis purpose is to explain how shippers' logistics actions contribute to environmentally sustainable freight transport by clarifying the link between logistics activities and the resulting load factor performance.

In previous green logistics research, several studies indicate that logistics has an influence on the environmental impact from the transport operation (e.g. Wu and Dunn, 1995; Golicic *et al.*, 2010; Dekker *et al.*, 2012). Still, these studies do not go into detail on the specific links between logistics activities and environmental impact from freight transport, but instead give rather a broad overview.

To clarify these links, this thesis take inspiration from the work of McKinnon and Woodburn (1996), which was further developed by Aronsson and Huge-Brodin (2006) and Piecyk and McKinnon (2010).

Over a number of studies, McKinnon developed an analytical framework, relating a number of factors to CO_2 emissions from road freight transport (McKinnon and Woodburn, 1996; McKinnon, 2003; Piecyk and McKinnon, 2010):

1. **Structural factors** related to the 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 the scheduling of product flow.
4. **Functional factors** related to the 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.

Aronsson and Huge-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 9. Their first three levels are operational, tactical and strategic, whereas the fourth level concerns product design. In addition, they have linked the four levels to the system levels concerned. Even if this framework does not specifically describe the details of the different choices in the different parts of the system, it illustrates that environmental consequences from freight transport operations are determined by conditions that are set in other parts of the system. This fact is an important consideration in understanding the dependencies between different activities and their influence on environmentally sustainable freight transport, as well as load factor performance.

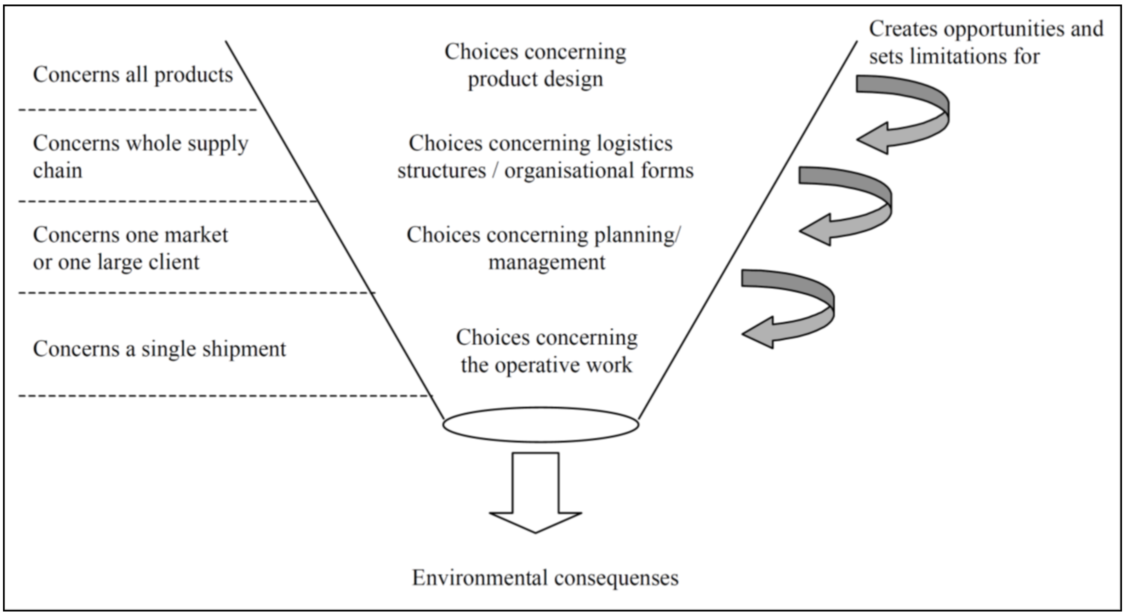


Figure 9: Framework model describing different logistics decision levels and their funnel-like relationship (Aronsson and Huge-Brodin, 2006)

The next section provides an overview of the literature on the types of actions that contribute to environmentally sustainable freight transport in general and to load factor in particular.

2.4.1 Actions contributing to environmentally sustainable freight transport

There are three general approaches to reducing the environmental impact from freight transport activities (based on Björklund (2005), Lammgård (2007) and IPCC (2014b)):

1. Reduce the environmental impact of each transport mode,
2. Use environmentally friendlier transport modes, or
3. Diminish the need for transport.

These three approaches of reducing the environmental impact of freight transport will be used to provide a general categorisation of the actions contributing to environmentally sustainable freight transport in research RQ1. This type of categorisation also relates to the environmental performance of the actions. Reducing the environmental impact of each transport mode (less emissions/vehicle-km) is linked to technical advances at the vehicle level. Using environmentally friendlier transport modes (less emissions/tonne-km) is linked to a modal shift and the use of intermodal transport. Diminishing the need for transport means reducing transport, on the one hand (tonne-km), and traffic, on the other (vehicle-km).

Table 5: Action areas of relevance for environmentally sustainable freight transport

Action areas of relevance for environmentally sustainable freight transport	**Reference**
Optimisation of efficiency through the use of energy-efficient vehicles, the optimisation of the distribution process through better routeing and scheduling, the use of integrated delivery to reduce transport, the use of environmentally friendly technology in transport, managing reverse flows to reduce transport.	Hung Lau (2011)
Green supply, distribution strategies and transport execution, warehousing and green building, reverse logistics, cooperation with customers, investment recovery, eco-design and packaging, internal management.	Perotti *et al.* (2012)
Distribution strategies and transport execution, warehousing and green building, reverse logistics, packaging management, internal management, collaboration with customers, external collaborations.	Colicchia *et al.* (2013)
Vehicle use, transport modes and intermodality, energy efficiency, recycling materials and packaging, environmental training and information, supply chain reorganisation, supply chain collaboration on shared green targets, collaborative planning and environmental control.	Evangelista (2014)
Mode choice and intermodal transport, logistics systems design, transport management, vehicle technology, behavioural aspects, alternative fuels, environmental management systems, choice of partners, emission data, efficient buildings, other.	Martinsen and Huge-Brodin (2014)
Using closer suppliers, relocating production plants and warehouses, improved transport planning, packaging design, load carrier design, increasing loading capacity in vehicles, changing mode of transport from air/road to other, implementing traffic control technologies, eco-driving, non-fossil fuels, cleaner vehicle technologies.	Pålsson and Johansson (2016)

Previous studies offer several suggestions for opportunities to reduce the environmental impact of freight transport, e.g., within the research area of green logistics and green supply chain management, which can be related to the above three approaches. Different terminology is used for such opportunities, such as practices, activities and initiatives. In this thesis, such opportunities are referred to as actions, implying an action is a change related to the activities in the system (see section 2.2 for a further description of an action). At the time of the first study in this thesis, which provides a broad overview of such actions within the abovementioned approaches, no literature reviews of the particular area of actions contributing to environmentally sustainable freight transport was found. However, recently, several reviews have described such actions. Therefore, the results from study 1 are compared to the recent research in chapter 6. In Table 5, action areas of relevance for environmentally sustainable freight transport are compiled based on recent literature reviews.

2.4.2 Actions contributing to improved load factor performance

Specific actions to improve the load factor are one essential way of managing the transport resources more efficiently, in terms of transporting the same amount of goods (tonne-km) with less vehicle-km, and are thus of major importance for improving the environmental impact of freight transport.

The literature provides several single examples of actions that can improve load factor performance in the areas of logistics structures (Aronsson and Huge-Brodin, 2006), order and delivery (Piecyk and McKinnon, 2010), packaging (Pålsson *et al.*, 2013), loading (McKinnon, 2000), transport operations (McKinnon and Ge, 2004), consolidation (Tacken *et al.*, 2014), collaboration (Islam and Olsen, 2014), information technology (Léonardi and Baumgartner, 2004) and regulations (McKinnon, 2005). Different perspectives are taken; here, some examples from the shipper's and the transport provider's perspective are provided. From a shipper's perspective, Aronsson and Huge-Brodin (2006) discussed centralisations of warehouses and their increased load factor due to main flow consolidation. Further, Bø and Hammervoll (2010) identified that ordering more volume products on low volume days influences the load. In a third example regarding the shipper's packaging system, Pålsson *et al.* (2013) suggested replacing a one-way packaging system with a returnable packaging system. From a transport provider's perspective, Léonardi and Baumgartner (2004) observed that scheduling and telematics applications created an opportunity to improve load factor. Further, Tacken *et al.* (2014), considering German logistics service providers, found that consolidation is an important means of improving the load factor, in terms of vehicle utilisation. Further, McKinnon, in a number of publications, discussed the issue of load factor in terms of improving vehicle loading or vehicle utilisation, providing several examples of how load factor can be improved (McKinnon, 2000; McKinnon, 2010b; McKinnon, 2015b).

However, there is no structured overview of what logistics actions a shipper can take to improve load factor performance. A more detailed understanding is needed of which logistics activities are concerned by actions taken, in what way such logistics activities are changed, how the activities link to other logistics activities and the influence on load factor performance.

Summary of key concepts

In the preceding sections, the key concepts of this thesis have been defined and related to previous research. Figure 10 schematically illustrates these concepts and the main points within them that capture their essence.

2.1: Environmentally sustainable freight transport is underpinned by the view of sustainability that emphasises the **long-term perspective** and a sustainable **balance between resources used in nature and society**, that is, where natural sustainability criteria set the boundaries for meeting social and economic goals. Environmentally sustainable freight transport is in essence about minimising resource depletion, emissions, pollution, land use, inefficiency and social damage. With its particular focus on reducing inefficiency from freight transport, this thesis is positioned within the theme **reducing freight transport externalities** and **environmental assessment.**

2.2: The systems approach, applied in this thesis, is described as a set of **interlinked activities that create conditions from one to another and for one another**. There are **continuously changing circumstances** in the system, as a result of activities, dependencies and influences from the surrounding systems, which make the actors' perceptions of the system situation-specific. **Measuring performance creates understanding** of the results of activities undertaken, as well as guiding further actions. **An action is a change of an activity so that new conditions are created** via an output from one activity and input to another.

2.3: In the logistics system studied, logistics activities related to the **order fulfilment process** are particularly relevant in this thesis. The logistics system and the transport system are seen as **interlinked systems.** In the logistics system, products are forwarded, while in the transport system, goods are moved. Different **actors are involved** in logistics and freight transport activities, as well as in activities in the surrounding systems, involving the **shipper, transport provider, suppliers, customers, competitors and authorities**. To progress towards environmentally sustainable freight transport, **load factor is a key measure.** Previous studies apply **different load factor measures, depending on their purpose and what system is measured**, which makes the **results difficult to compare and understand**.

2.4: Previous research is used to identify important considerations when structuring logistics actions that may contribute to environmentally sustainable freight transport, for example the **funnel-like relationships** between logistics decisions and the **three approaches** to reducing the environmental impact of freight transport. **Several recent literature reviews** identify relevant action areas for green logistics. In particular, this thesis can contribute to **a structured overview** that clarifies the **links between logistics activities and the resulting load factor performance**.

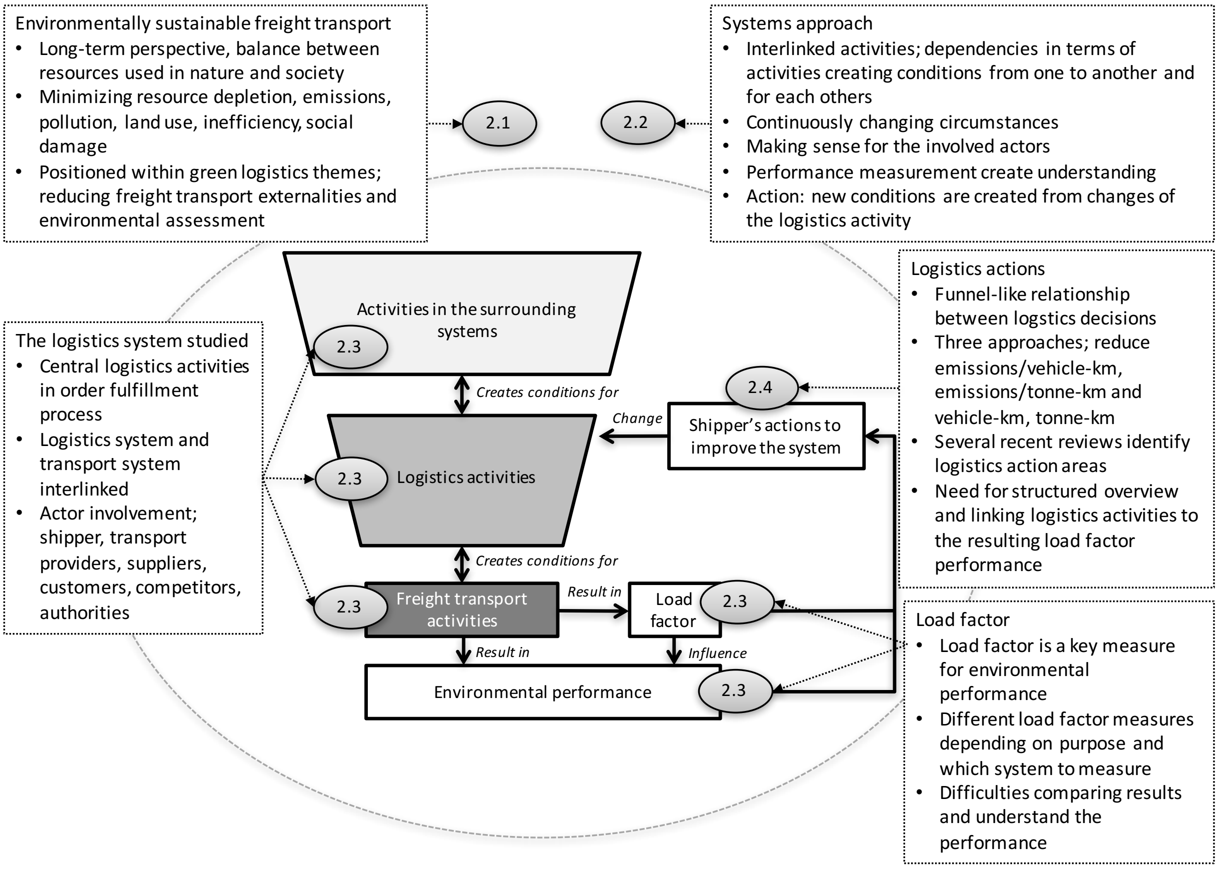


Figure 10: Summary of the essence in previous research incorporated within the main concepts in this thesis

3 Methodology

This chapter describes the methodological choices made for the thesis. An overview of the research process is presented, followed by an account of the research strategy, research design and data analysis and an assessment of the trustworthiness of the research.

The purpose of this thesis is to explain how shippers' logistics actions contribute to environmentally sustainable freight transport by clarifying the link between logistics activities and the resulting load factor performance. Four research questions are raised in Chapter 1 to help fulfil that purpose. The results from five studies, which in turn are reported in six papers, contribute to answering the research questions. The relationship between the research questions, resulting papers and studies is shown in Figure 11, the papers being numbered according to their contribution to the research questions.

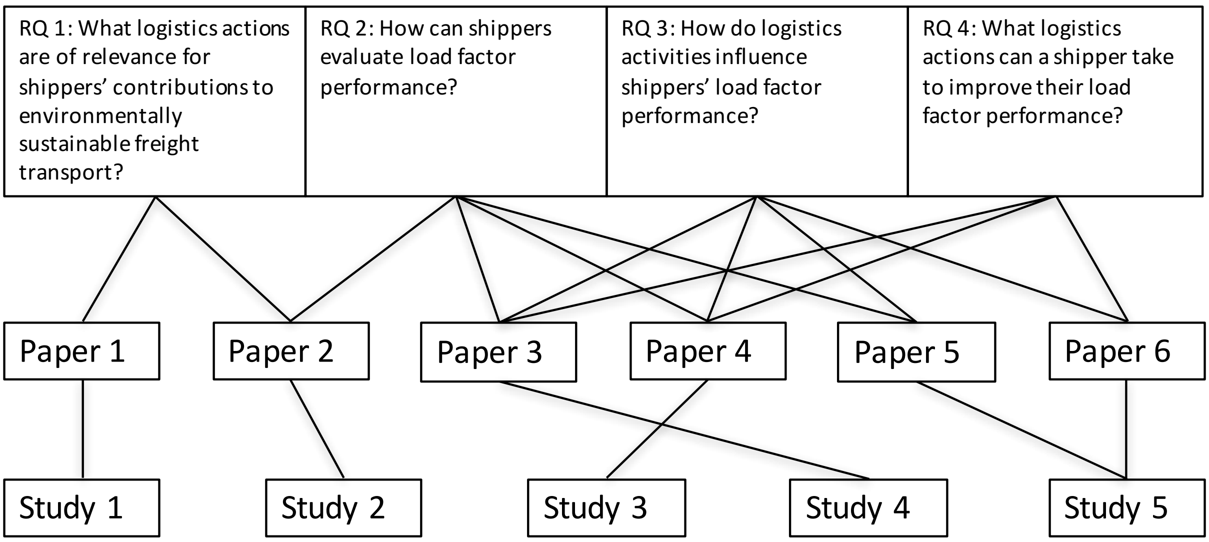


Figure 11: The relation between the studies, the resulting papers and the research questions

The studies and the written papers are also shown in chronological order in Figure 12. The studies consist of several phases, each design phase being followed by collection of the principal data, analysis and writing. Although the studies began at different times, the analysis and writing stages overlapped. In addition, some of the studies were in progress for some period of time. The boxes in Figure 12 highlight the time when the main focus was on conducting the study in terms of designing, collecting and analysing data. An arrow pointing to the resulting paper shows when the writing and presenting of data took place.

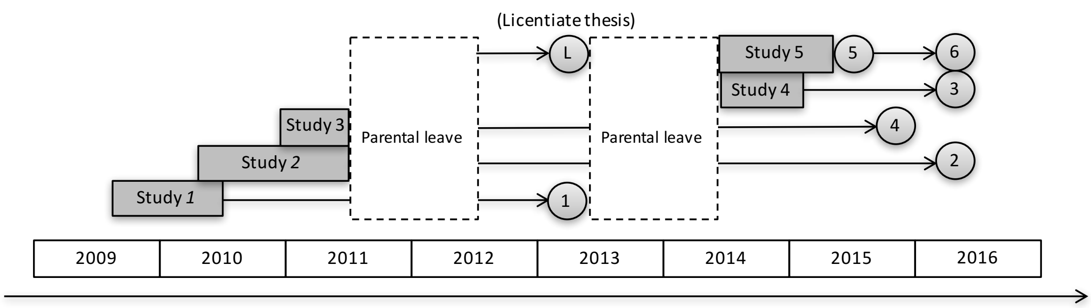


Figure 12: Timescale for the research process

The following sections further describe the rationale behind the methodological choices that were made about the conduct of these five studies.

3.1 Research process

The research process is presented to provide a background for the methodological choices described in the following chapters. According to Croom, the process of research is highly individual: 'very few research projects or doctoral projects follow a neat, linear project plan' (2009, p. 43). In reality, the process becomes iterative and greatly depends on the actual situation in the specific project and the researchers who are responsible. The research process in this thesis is described in relation to the background of the researcher, initial thoughts and the conditions in which the research took place (i.e. involvement in different research projects).

Having studied industrial ecology and conducted practical work in logistics and the environment within the master's programme, I found sustainability within logistics the most attractive topic for research. Further, since systems thinking is central in industrial ecology, I naturally adopted systems thinking for my work. Sustainable logistics was also the focus of the project of which my PhD position was part, entitled 'Integrated Logistics Development for Sustainability and Competitiveness'.

During the initial phase of my studies, my prime concern was to become familiar with previous research on sustainable logistics. I reviewed the literature on this and related matters, such as environmental/green issues in transport, logistics and supply chain management. The first phase of the research was largely related to understanding the problem area. The main challenges at this stage included obtaining an overview of the broad research topic that was defined in the project mentioned above, as a starting point, and then splitting the research into manageable studies. Within the project specification, the aim of my research was to contribute a holistic view of the logistics system that would analyse how to proceed towards sustainability taking into account framing conditions.

Based on the literature review, I decided that the focus would be logistics actions and determining how these actions can enable environmentally sustainable freight transport. One initial concern at the beginning was to understand what it is that different actors are physically able to do, what they are currently doing and what else is needed to reach an environmentally sustainable freight transport system. Study 1 (presented in Paper 1) was thus designed with a focus on identifying actions that could reduce the environmental impact from freight transport; this was based both on the literature and on practitioners' perceptions.

Along with this work, I also participated in another project entitled 'Analysis Tool for Calculating the Environmental Impact and Efficiency of Transport Systems', which involved several research organisations (Northern Lead, IVL and CPM) and practitioners (shippers), of which the second study (presented in Paper 2) formed part. The focus was on measuring environmental performance by using an external cost tool that was developed within the project; this demonstrated how shippers could use the tool to evaluate their freight transport activities.

The results from the first study suggested that it was necessary to delve more deeply into actors' systems in order to understand what opportunities they had to take action in their specific situations. I narrowed the scope to take on the shippers' perspective and to focus on one promising action area for shippers: increasing load factor. Accordingly, I looked for companies that were highly interested in increasing load factor and invited them to participate in the study. The third study was designed to examine shippers' opportunities to improve load factor (presented in Paper 4).

After the licentiate thesis (and my second period of parental leave), my PhD position was part of the research project entitled 'Increased Transport Efficiency through Better Utilisation of

Loading Capacity'. This new project made it possible to design two studies within my area of interest (presented in Papers 3, 5 and 6) and to achieve close collaboration with shippers. In addition to the organisations that were involved, the three PhD students and three senior researchers who were part of the project also built up much knowledge around the subject, affording many opportunities for internal seminars and discussions.

In addition to the above studies, I participated in a VINNOVA-financed collaborative project, with the aim of exploring the shippers' and transport providers' viewpoints of the different challenges involved in improving a company's environmental performance from various freight transport activities; the results from a series of focus group discussions are reported in Santén and Arvidsson (2011). Although that work is not part of the results of this thesis, the focus groups provided a better understanding of shippers' viewpoints of their challenges, for example in terms of their lack of understanding of the environmental performance of their freight transport activities.

3.2 Research approach

The research undertaken in this thesis adopted two major research approaches, the systems approach and the abductive approach. These approaches are described separately below.

3.2.1 Systems approach

In order to explain how logistics actions contribute to environmentally sustainable freight transport, and in particular to clarify the link between logistics activities and load factor performance, this thesis adopted a systems approach. Although logistics research tends to lean towards the systems approach, the approach in this thesis differs from the traditional positivistic-influenced logistics systems approach (Vafidis, 2007) in taking inspiration from soft systems methodology (Checkland, 1999). Below is a summary of the systems approach applied, discussed in more detail in section 2.2.

The system studied in this research is seen as a set of different activities that are interlinked, although their interactions and overlapping relationships are complex. Activities are interlinked by creating conditions for one another. From the perspective of the shipper, not only are their logistics activities interlinked but also interlinkages exist with activities in the surrounding system, as well as the freight transport activities (Figure 13).

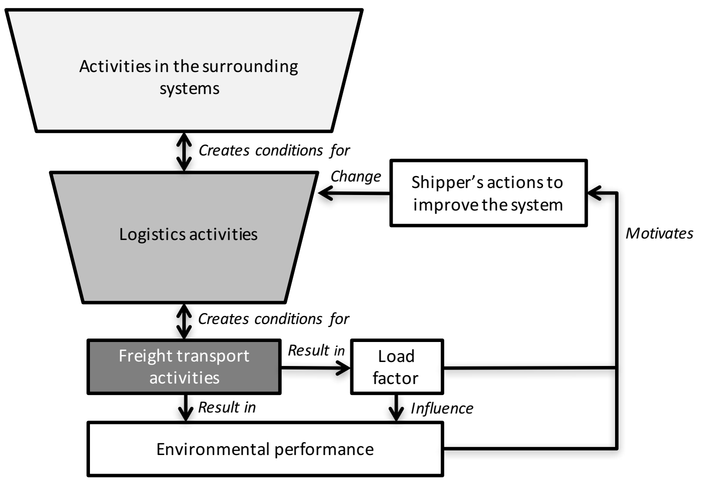


Figure 13: Conceptual model of the logistics system from a shipper's perspective

Since logistics activities are performed in a social setting in which different actors are involved, the actors' various perceptions of the system need to be taken into account in order to make sense of the complex situation. If actors involved understand the situation better, they will be more likely to take actions to improve the system (Checkland, 1999). Such actions lead to new experiences, which in turn yield new experiential knowledge (Checkland and Scholes, 1990). Further, actors' perceptions of the system evolve over time because of continuously changing circumstances in the system and in the surrounding systems. Measuring the performance of the system helps actors understand the system's output and motivates actions to improve it.

In order to explain how logistics actions contribute to environmentally sustainable freight transport in a way that makes sense for the actors involved, an in-depth and rich understanding is required of the situation in which logistics actions are performed. This makes qualitative methods such as case studies the preferred choice (Ellram, 1996). Qualitative research studies usually emphasise words rather than quantified data (Bryman and Bell, 2007) and are used to formulate 'subject- and situation-related statements, which are empirically well founded' (Flick, 2009). In this thesis, therefore, experiences from the real world illustrate the link between logistics activities and environmentally sustainable freight transport in general and load factor performance in particular, thereby explaining these relationships. However, the performance of the system is measured using quantitative data (where possible). Consequently, this thesis uses primarily qualitative research methodologies to explain the contributions of logistics actions to environmentally sustainable freight transport, although quantitative data and analysis in the case studies complement understanding of the phenomena being explored.

3.2.2 Abductive approach

Rather than being driven by theory, the research undertaken in this thesis is phenomenon-driven, with a focus on 'identifying phenomena of interest for both practice and theory', and the empirical data are used to position or build theory (Schwarz and Stensaker, 2014, p. 486). A phenomenon can be described as 'a fact or situation that is observed to exist or happen, especially one whose cause is in question' (Oxford English Dictionary, 2008). Thus, new theoretical understandings emerging from this thesis, based on phenomena related to the link between logistics actions and environmentally sustainable freight transport, contribute to green logistics research. The distinction between theory-driven and phenomenon-driven research has similarities with Arlbjørn and Halldorsson (2002), who discuss four approaches for creating knowledge within logistics research: theory test vs theory development, and solid theory-based vs loose theory-based. Further, three levels of theory development are identified: grand theories, middle-range theories and small-scale theories. In conformity with this terminology, new concepts are developed in this research, specifically small-scale theories with a loose theory base, in which links between logistics activities and load factor performance are clarified and conceptualised. A high degree of practical relevance is aimed for.

To understand the link between logistics actions and environmentally sustainable freight transport, an abductive approach is taken, allowing new theoretical insights to be created by systematically moving between the theoretical and empirical worlds (Kovacs and Spens, 2005; Dubois and Gadde, 2002). As Alvesson and Sköldberg (2008) pointed out, the aim with abduction is to achieve an understanding of the phenomenon so that underlying structures can be identified and explained. Abductive research originates from the fact that most 'great advances' follow neither pure deduction nor induction (Kovacs and Spens, 2005), and case studies would usually apply abduction in reality (Alvesson and Sköldberg, 2008). As Dubois and Gadde (2002) found, the researcher could increase his or her understanding of both theory and various empirical phenomena by 'going back and forth' between theory and empirical data and between different research activities. Abductive research starts with a 'real-life phenomenon' (Spens and Kovács, 2006), and theory may be created along the way (Dubois and Gadde, 2002).

In this thesis, the initial research design was based on a broad understanding from previous research in green logistics (see section 2.1.2 for an overview). New directions alongside the evolving research were allowed, which also made it necessary to look for additional studies and theories from the literature, as well as making new observations from empirical findings.

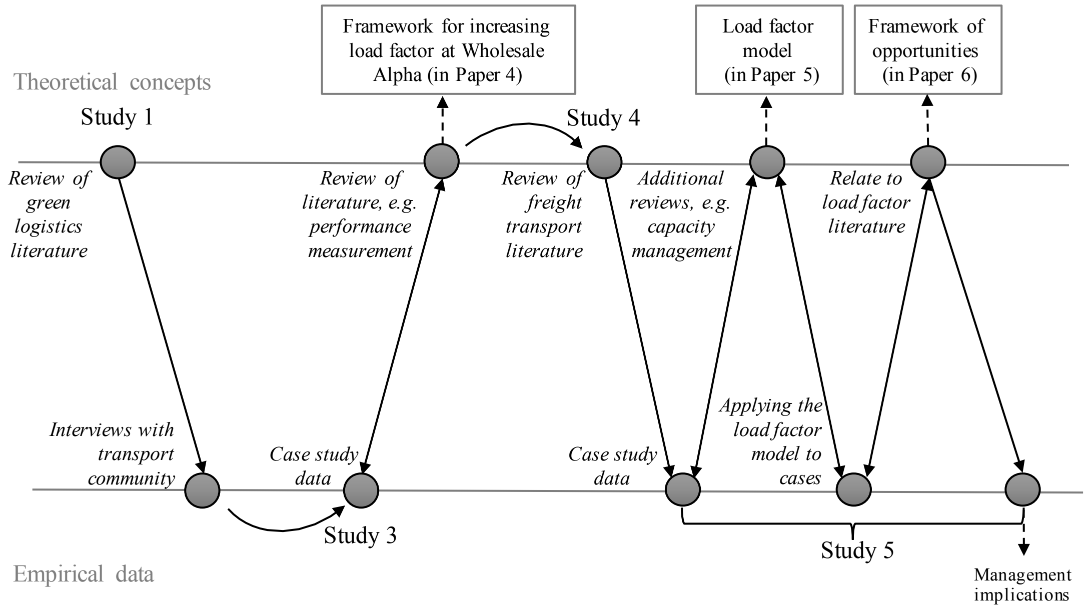


Figure 14: The abductive research process in this thesis, illustrating movement between the theoretical concepts and the empirical data

In the abductive research process used, the small-scale theories developed in Studies 3 and 5 ('the framework for increasing load factor at Wholesale Alpha', 'the load factor model' and 'the framework of opportunities') and reported in Papers 4, 5 and 6, are good examples of the consequence of going back and forth between theoretical concepts and empirical data, see Figure 14. In the first study, a literature review guided the collection of empirical data with which to compare theory and practice in the field of green logistics regarding actions of importance for sustainable freight transport. The insights that were gained from the first study directed the focus in Study 3, where the phenomenon studied was the concept of load factor in a shipper's outgoing flow of goods, explored in a single case. The framework for increasing load factor at Wholesale Alpha was created based on initial ideas from the empirical data and was further developed in the light of previous research, in particular the literature on logistics performance measurement. The results from Study 3 guided the design of the structured literature review of load factor in Study 4, which focused on measurement and influencing factors. These results were used for designing Study 5, which explored, by means of case studies, logistics actions that improve load factor performance in shippers' outgoing goods flow. Prior knowledge of the load factor area (Studies 3 and 4) meant that the initial focus of Study 5 was on understanding particular actions that were applied in the cases to improve the load factor and the details of particular changes made. However, in order to understand the effects of the changes, more detailed explanations of how load factor was improved and the structure of the load factor model were required. The literature on consolidation and capacity management helped clarify aspects that determine load factor performance (in terms of the balance between required capacity and available capacity), enabling the development of the model. The load factor model was applied to the cases to illustrate the load factor improvements achieved by logistics actions. Also, the load factor model was related to opportunities to improve load factor in the cases, as well as in the previous literature, which formed the structure and content of 'the framework of opportunities'.

3.3 Research design

As described in 3.2, the design of the research was not linear and fixed in advance, but flexible in order to adapt to the situation and learning related to the phenomena under study. As Maxwell (2005) observed, 'You will need to continually assess how your design is actually working during the research and how it influences and is influenced by the context in which you are operating, and to make adjustments and changes so that your study can accomplish what you want' (p. 3).

Still, the initial understanding of the subject determined the early choices in collecting evidence and analysing data. Flexibility in the design allowed the research questions to be modified according to expanded insights along the way. In this section, the purpose and the type of research designs are related to each paper and the final research questions.

The purpose of this thesis, to explain how shippers' logistics actions contribute to environmentally sustainable freight transport by clarifying the link between logistics activities and the resulting load factor performance, makes it obvious that the research is explanatory in nature and that it takes a shipper's perspective. Historically, there have been three major purposes of qualitative research: *explorative*, *explanatory* and *descriptive* (Marshall and Rossman, 2006). The differences between these purposes are described in Table 6.

Table 6: Differences between explorative, descriptive and explanatory research (Marshall and Rossman, 2006)

Purpose of study	**Description**
Explorative	To investigate little-understood phenomena; to identify or discover important categories of meaning; to generate hypotheses for further research
Explanatory	To explain the pattern in relation to the phenomenon in question; to identify plausible relationships shaping the phenomenon
Descriptive	To document and describe the phenomenon of interest

Although the purpose of this research is explanatory, exploration and description were also needed to answer the four research questions. For each study, depending on the type of research questions, and also depending on where in the research process a study took place, the research had elements of explanation, exploration and/or description. The research undertaken in this thesis is divided into four research questions, and the four studies help to answer the four research questions using different types of research: an initial study, a literature review and case studies (Figure 15).

Study 1, the initial study, provided the main input to answering RQ1 in a descriptive way. It consists of an overview of the actions that contribute to environmentally sustainable freight transport and analyses which areas of action are relevant for shippers. The study's conclusion, that increasing the load factor is one such action area, directs the focus in Studies 3, 4 and 5.

The literature review in Study 4 yielded information on previous load factor research in terms of measurement and influences on load factor, thereby contributing to answering RQs 2, 3 and 4.

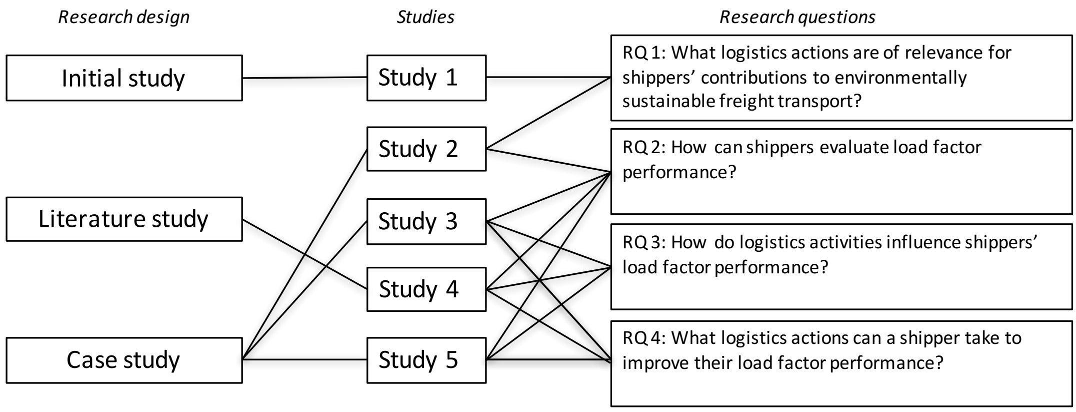


Figure 15: The research designs for each study and their relation to the four research questions

Because few previous studies have focused solely on load factor, a little-understood phenomenon, Study 3 explores opportunities for increasing load factor from a shipper's perspective in a single case study. A framework is developed whose principles provide the basis for the later studies and contribute to answering RQs 2, 3 and 4.

Study 2 (which contributes to answering RQs 1 and 2) and Study 5 (which contributes to answering RQs 2, 3 and 4) consist of case studies and are chiefly explanatory, although the analysis also required description so as to provide in-depth understanding about the phenomenon.

3.3.1 Initial study

The aim of the initial study (Study 1) was to compare theory and practice in the field of logistics actions of importance for environmentally sustainable freight transport. The study included a literature review and interviews with practitioners. The outcome was a broad overview of possible logistics action areas contributing to environmentally sustainable freight transport, which was compared with the practitioners' perceptions of the actions that are currently implemented and those that are perceived to be important for the future.

The literature review in Study 1 was of the narrative type (in comparison with the more systematic literature review undertaken in Study 4). A narrative literature review allows for a more 'wide-ranging' scope than a systematic literature review and can be used to obtain an initial impression of the topic under consideration (Bryman and Bell, 2007). Since this literature review was performed at the beginning of the research, its aim was to learn about the research area of logistics and transport related to sustainability and the environment. Any actions that would reduce the environmental impact from freight transport were sought out in different areas of research, for example transport, logistics and supply-chain management. It was also necessary to ascertain which concepts and terminology are commonly used in the literature. The focus was not only on shippers at this stage; rather, a holistic view was taken. The aim of the search was to be inclusive, rather than exclusive, which made the criteria for what to include in the search rather loose.

Green logistics was then (2009–2010) in its early stages, as it still is, and literature on the particular topic of logistics and environmental impact was limited. Aronsson and Huge-Brodin

(2006) identified only 45 articles on the subject during the period 1995–2004. The literature review in Study 1 included scientific articles, policy documents and reports; scientific articles were searched using the Scopus database, while policy documents and reports were searched on national and European Union-level governmental websites. In addition, 'snowballing' was applied to locate relevant literature (see Wohlin, 2014). A list of actions was then created and categorised by certain action aims: reducing environmental impact for each mode of transport, using environmentally friendlier transport modes and diminishing the need for transport. The action list was then used in the second step, which compared both theory with practice and different groups of actors with one another, including shippers, transport operators, freight forwarders and authorities.

Several studies have reported on the poor implementation of logistics actions aimed at reducing environmental impact in practice (Léonardi and Baumgartner, 2004; Golicic *et al*., 2010). Therefore, it was considered important to gain a better understanding of the perceptions of the actors with regards to what actions were implemented and what actions were seen as important to implement in the future, so that future research could be focused on areas that made sense for them. Semi-structured interviews were used to allow the researcher to be flexible about the order of the questions and to include questions of interest depending on the specific respondent (Bryman and Bell, 2007). Also, to gain a full appreciation of the respondent's views, it was helpful to be able to combine open and specific questions, as well as adding follow-up questions. Respondents were also given the space to discuss any issues related to the subject in more detail to provide a better picture of their situation. Follow-up questions thus depended on the situation. Twelve interviews were conducted in total, three for each of four actor groups: shippers, freight forwarders, transport operators and authorities.

The interviews consisted of two parts: a main section with questions and a final section with an evaluation of actions, based on the literature (Appendix A is an example of the interview guide that was used). The questions covered a number of areas related to the background of the company or organisation, its environmental goals, challenges in and reasons for taking action, any actions that were implemented at the time and planned for the future and the actors' responsibilities. The interview guide was adjusted depending on which actor group the respondent belonged to. The final part of the interviews included an evaluation of the action list that had been developed from the literature, the purpose of which was to identify to what extent each action was important in order to reduce the environmental impact of freight transport for each respondent's organisation. The responses complemented the information gleaned from the questions in the first part of the interviews.

3.3.2 Literature study

Although a preliminary narrative literature review formed a natural part of the research process, the purpose being to locate additional studies and theories for the evolving research, a more systematic literature study was undertaken in Study 4. According to Bryman and Bell (2007), a systematic literature review follows a clear structure that is explicitly and transparently described, thus allowing for replication.

Since load factor is often merely one of several aspects examined in previous research, there are few studies with a sole focus on load factor. No compilations of load factor research have been found in previous literature and therefore such an overview identified both relevant issues that are used to guide the subsequent study and theoretical concepts to be input to the analysis of RQs 2, 3 and 4 in this thesis. The literature review in Study 4 compiled previous load factor research in terms of 1) how load factor is measured and 2) what influences load factor. The output was described by problematising how previous studies measure load factor, describing the factors that influence load factor and identifying research gaps and further research. Structured searches were performed between March and June 2014, using the ProQuest Summon database. A fairly broad range of search terms was used to capture the fact that several terms are used as a synonym for 'load factor' in different situations. All articles that had a low focus on load factor were excluded from the compilation. In total, 76 articles were categorised according to general information, research method, system perspective, load factor measurement and influencing factors. For further details about the method used, see Paper 3.

3.3.3 Case studies

A case study includes several dimensions, which can make the definition of a case somewhat confusing (Gerring, 2007). In this thesis, the case study method was selected because cases are capable of providing rich, in-depth knowledge about the phenomenon, as well as a holistic understanding of the complex interrelations in a specific context (e.g. by using multiple sources of evidence). The dimensions of a case study are set out below.

First, a case study is the analysis of a phenomenon, as Thomas (2015) avers. A phenomenon can be a person, event, decision, period, project, policy, institution or other system (Thomas, 2015). Second, the phenomenon is studied 'in depth and within its real-life context' (Yin, 2009, p. 18). Achieving an in-depth understanding of the phenomenon is highly important for this thesis, since it also facilitates understanding of the complex interrelations within specific contexts (Ellram, 1996; Eisenhardt, 1989), which in this thesis concern the link between logistics activities and load factor. The case study also allows phenomena to be investigated over some period of time (cf. Gerring, 2007), allowing for new directions and questions to arise along the way.

Further, the holistic view is important, described as 'seeing something in its completeness, looking at it from many angles' (Thomas, 2015, p. 23). The systems view applied in this thesis means that a holistic view is achieved by investigating how the different activities are interlinked, although their interactions and overlapping relationships may be complex. Looking at the case from different angles means that multiple methods may be included. Yin (2009) states that a case study 'relies on multiple sources of evidence' (p. 18). In the research undertaken in this thesis, the multiple sources of evidence illuminate interrelations between activities in a more holistic way, by combining the interviews of various respondents (which express different viewpoints) and observations from outside. Marshall and Rossman (2006) point out that a case study is a complex design, which has to do with the multiple methods used, but also that the phenomenon is studied in its real-life context, which is not always distinguishable (Yin, 2009). This means that there are many variables of interest, which cannot always be 'controlled' and foreseen.

Three case studies were conducted in this thesis (Table 7). Study 2 differed from Studies 3 and 5, in which phenomena were studied. Also, Study 2 had a different role, complementary rather than central to answering the research questions. The reasons for selecting the particular cases and the data collection methods used are described in the sections below.

Table 7: Comparison of the case studies

Study	No. of cases	Phenomena studied	Time allowed for data collection	Applied data collection methods
2	1	Evaluation of the external costs of transport of a shippers' supplies to a project site	4 months	Semi-structured interviews, archival records
3	1	Logistics actions improving load factor performance in a shipper's outgoing goods flows	2 months (additional follow-up interviews after 1 year)	Semi-structured interviews, observations and archival records
5	3	Logistics actions improving load factor performance in shippers' outgoing goods flows	2 months (additional follow-up interviews after 1 year) – Fast Response 1 year – Distribution Round 1 year – Project Flow	Semi-structured interviews, observations and archival records

Case selection

The purpose of Study 2 was to analyse the role that uncertainty in input data plays in the evaluation of the environmental performance of shippers' freight transport activities; in particular, the study used an external cost evaluation tool in practice. For evaluating a shipper's goods flow, a shipper that had a large interest in assessing the environmental performance of its transport activities was chosen; the transport was operated by third parties in order to demonstrate the evaluation of 'less than truckload' (LTL) shipments, in which both suppliers and shippers were organising the transport.

For Studies 3 and 5, it was important that the shippers focused on load factor improvements, since this was the central purpose of the research.

Because Study 3 was explorative, a single case study was examined, allowing in-depth understanding of the phenomena to be attained (Ellram, 1996). In addition, a shipper that outsourced its freight transport was chosen because it could demonstrate both LTL and 'full truck load' (FTL) shipments, two typical methods of transport that offer different conditions for measuring the load factor performance (within a share of the vehicle or within the vehicle as a whole). The shipper also had a large product range, which added the dimension of determining how best to combine goods efficiently, compared with dealing with only one type of product.

A multiple-case study approach was conducted for Study 5, since its goal was explanatory; this format permitted an appreciation of the application of load factor models in various situations and of how shippers take different opportunities to improve their load factor performance in practice. The cases had to be able to illustrate different aspects for determining load factor, including several load factor levels and having different characteristics in the transport flows. Further, the shippers purchased the transports from a third party, which made it possible to see how purchased capacity was used.

The data collected on Wholesale Alpha (the shipper) in Study 3 also illustrated the use of the load factor model in Study 5. In Study 5 (which again involved Wholesale Alpha), the case was named Fast Response. In addition, in Study 2 (Project Flow) and Study 5 (Project Delivery), different flows were studied within the same large multinational company (although the two cases were completely separate). The two goods flows involved separate divisions within the company, they were located in different cities and they handled different product types (see Table 8 for additional differences).

Table 8 summarises the characteristics of the goods flow in the cases studied, namely the types of businesses that the cases involve, the product and load unit types, the types of purchased transport services, the goods flow and which types of customers the goods were supplied to.

Table 8: Characteristics of the goods flow

Study	**Case**	**Type of business**	**Product type**	**Load unit type**	**Transport services purchased**	**Goods flow studied**	**Customer**
2	Project Flow	Manufactu-ring, energy, automation technology	Lightweight goods (e.g. cables, computer screens, and safety relays)	Mostly parcels	LTL, several transport providers contracted	From supplier to project site	Metal industry company
3	Wholesale Alpha* and Freight Beta	Wholesaler, technical products	Wide product range (e.g. fittings, tools, machinery)	Pallets, plastic boxes, steel racks, parcel cages	LTL and FTL, one contracted transport provider	Warehouse to district terminal	Professional users of technical products
5	Fast Response*	Wholesaler, technical products	Wide product range (e.g. fittings, tools, machinery)	Pallets, plastic boxes, steel racks, parcel cages	LTL and FTL, one contracted transport provider	Warehouse to district terminal	Professional users of technical products
	Distribu-tion Round	Wholesaler, food	Food (frozen, refrigerated, groceries)	Pallets	Own account transport, some external transport providers	Warehouse to shops	Swedish shops
	Project Delivery	Manufactu-ring, energy, automation technology	Large heavy equipment and components	Large boxes	FTL, one contracted transport provider	Manu-facturing site to harbour	Int'l energy company

*Wholesale Alpha and Fast Response is the same case, but data are used in two different studies.

Data collection in the cases

Several data collection methods were used in the case studies. In all cases, semi-structured interviews were conducted, following an interview guide that included themes and questions but allowed for additional questions to be asked in order to probe further. If two researchers were involved, both took notes and were mutually responsible for creating a protocol directly after the interview, which made it possible to discuss ways to interpret the respondents' answers. Also, archival sources were used for collecting load and transport data in all cases, and observations complemented understanding of the packing and loading operations in Studies 3 and 5.

The purpose of Study 2 was to analyse the role that uncertainty in input data plays in the evaluation of the environmental performance of shippers' freight transport activities; the study used an external cost evaluation tool in practice, which meant the focus was on finding transport input data. Interviews were conducted by telephone; the project seminars served as an opportunity to present the preliminary results and discuss them with the shipper. In addition to these contacts, information on input data that were transferred from the transport provider and the shippers' own databases was sent via e-mail; any additional explanations of these data were made over the telephone.

The purpose of Study 3 was to explore opportunities to increase load factor from a shipper's perspective; the interviews focused on understanding what the shippers did to increase load factor, as well as their logistics goals and activities, their reasons for taking different actions, the effects of the actions, the measurement of load factor improvements and any future opportunities. Observations were done to complement the data from archival sources, which collected load factor data in volumetric terms.

Table 9: Details of the interviews conducted for each case

Study	**Case**	**No. of inter-views**	**Type of interview**	**Additional contacts**	**Type of respondents**	**No. of re-searchers**
2	Project Flow	6	Telephone	Mail, phone, project seminars	Logistics, project and purchasing manager	2
3	Wholesale Alpha and Freight Beta	11 shippers, 6 transport providers	Personal meetings (shipper), telephone (transport provider)	Mail, phone, site visits	Shipper: logistics, transport, environment and sales; Transport provider: regional/local transport operations, sales	1
5	Fast Response	11 (shipper)	Personal meetings	Mail, phone, site visits	Shipper: Logistics, transport, environment and sales	1
	Distribution Round	5	Personal meetings (4), telephone (1)	Mail, phone, project seminars, site visits	Logistics, transport planning and order, transport operating manager	2
	Project Delivery	5	Personal meetings (4), telephone (1)	Mail, phone, project seminars, site visits	Logistics and transport, project supplier, global packaging manager, transport planner.	2

In Study 5, the shippers' opportunities to increase load factor were studied in detail in order to explain how logistics activities influence load factor performance, which required having an in-depth understanding of the actions taken and the influences on load factor within each company. The interview questions delved into the companies logistics activities, general influences on load factor, the changes the companies already had done or was about to do, details of the implementation of changes, the order in which changes occurred, the reasons for making changes, any constraints on changes, the involvement of different functions/actors and how the changes influenced load factor performance. For the interview guide used in three of the interviews in the Distribution Round Case, see Appendix C. Data from archival sources complemented the interviews, permitting load factor performance to be calculated; the observations also added to the understanding of how items were packed and loaded onto the purchased transport share/vehicle.

In Study 2 (Project Flow) and Study 5 (Project Delivery), data were collected while activity was taking place. In the Project Flow case, this meant that data on goods flow could be collected while the supplies were being delivered to the project site. In the Project Delivery case, it meant that the data collection took place while logistics actions were being implemented. In the other two cases in Study 5, data were collected after the actions had been implemented. Table 9 shows details about the interviews in each case (from Studies 2, 3 and 5), namely number of interviews, types of interviews, which additional contacts were made in each case, the types of respondents and the number of interviewers.

3.4 Data analysis

This section describes the analysis of the papers and then the analysis with regards to each research question.

3.4.1 Analysis of the papers

Table 10 summarises the main steps in qualitative and quantitative data analysis performed in each paper.

With regards to qualitative analysis, describe, categorise and connect were made (Maxwell, 2005). Here, 'describe' meant describing the central issues in the studied phenomenon, e.g., of the logistics actions that the studied shippers were implementing. These descriptions aided understanding of the complex relationships in the cases, for example links between activities and load factor. Under the heading 'categorise', data were grouped according to either predetermined categories or categories developed during coding. The 'connect' stage involved identifying interrelations between variables, or as Maxwell defines it, 'seeing the actual connections between things' (Maxwell, 2005, p. 106).

With regards to quantitative analysis, calculations and simulations were used. Calculations were performed by using load and transport data to evaluate load factor performance, as well as external costs (in Paper 2); see Fridell *et al*. (2011) for freight transport external costs analysis. Moreover, Monte Carlo simulations were performed in Study 2 to analyse the impact of uncertainty of input data on the external costs results (see e.g. Vose, 2008, for further descriptions of Monte Carlo simulations). In Papers 4, 5 and 6, load factor calculations were performed based on quantitative data collected. Further, in order to detect differences in means of daily number of packages/load metres across two groups (two different years) analysis of variance (ANOVA) was performed in Paper 4.

Between one and three researchers were involved in the data analysis for each paper. More details regarding the analysis of the collected data in the cases are provided in each paper.

Table 10: Data collected and data analysis for each paper

Paper	Collected data in the case studies	Data analysis	No. of researchers
1	• Action identification (literature review) • Actions in practice (interviews) • Actions of importance (interviews)	• Categorise actions, with regards to - Action aims - Actor perspectives • Connect actions to sustainability principles	1
2	• Load and transport data (archival sources and interviews) • Accessibility and uncertainty of collected transport data (archival sources and interviews)	• Calculate external costs and uncertainties in a shipper's transport activities • Analyse the impact of specific input data uncertainties on the external costs results (using Monte Carlo simulations)	3
3	• 76 articles with a focus on load factor (literature review)	• Categorise data in papers according to - General information - Research method - System perspective - Load factor measurement - Influencing factors	3
4	• Data concerning logistics goals and activities, work to increase load factor, reasons for taking action, effects of actions taken, measurement of load factor improvements and future opportunities (interviews) • Load and transport data (archival records) • Load factor data (observations)	• Describe actions • Categorise data • Identify connections among categories • Calculate long-term effects on load factor • Calculate volumetric load factor performance • ANOVA of the means of packages/load metres across two groups analysis of variance	1
5	• Data on the characteristics of the goods flow, current load factor measurements and reasons for low/high load factor (interviews) • Load and transport data (interviews, observations and archival records)	• Describe how required and available capacity was determined in cases • Categorise data according to required and available capacity and to each load factor level • Identify aspects determining required and available capacity • Calculate load factor performance	2
6	• Data about changes made to increase the load factor (interviews) • Load and transport data (interviews observations and archival records)	• Describe changes in detail • Describe how required and available capacity was determined • Calculate load factor performance before and after changes • Connect identified actions to framework of opportunities	2

3.4.2 Data analysis for each research question

Four research questions were formulated (analysed in Chapter 5) for the purpose of this thesis. The collected data were first analysed and reported on, in each paper. Thereafter, the results from the studies and papers were used to answer the research questions.

Table 11 summarises the contributions of each study and paper, which serve as an input to the qualitative data analysis performed to answer each research question, where the same steps – describe, categorise and connect – were followed (Maxwell, 2005).

RQ1 asks what logistics actions are of relevance for shippers' contributions to environmentally sustainable freight transport; Papers 1 and 2 provide input to the analysis. The analysis first describes identified actions and their possible contribution to environmentally sustainable freight transport, using results from both these papers. Actions identified in Paper 1 are related to the shippers' logistics activities, freight transport activities and activities in the surrounding system (see 2.3 for more details). Description of shippers' perceptions of important actions in relation to other actors' perceptions creating an understanding of their view of the relevance of actions and their awareness of the influences on the freight transport system of their logistics activities.

RQ2 asks how shippers can evaluate load factor performance. Using the results from Papers 2, 3, 4 and 5, this issue is described in relation to the logistics and the transport system, respectively. Further, different choices of performance metrics and the ways to calculate load factor are described, based on the results in the papers. Caplice and Sheffi's (1994) evaluation criteria for logistics performance metrics are used to distinguish between the features in the resulting frameworks.

RQ3 asks how logistics activities influence shippers' load factor performance. Papers 3, 4, 5 and 6 provide input for the analysis. First, logistics activities are related to areas of influence (based on previous literature in Paper 3). The influence on load factor performance are explained by identifying the conditions created from logistics activities that serve as direct or indirect input to the load factor performance (based on case study descriptions in Papers 4 and 6). After this, the way in which different conditions influence shippers' load factor performance is explained by linking the conditions created in different activities to the details in the load factor model (which is described in Paper 5).

RQ4 asks what logistics actions a shipper can take to improve their load factor performance; Papers 3, 4 and 6 provide input. In this analysis, the case study descriptions are important examples of actions taken in practice. Actions are described in terms of (a) actions taken in cases, (b) which logistics activities are concerned by the changes, (c) type of change, and (d) what new conditions are created (as output from one logistics activity and input to others). The resulting load factor performance is linked to the implemented logistics actions.

Table 11: Analysis of each research question

Research question	Paper	Study	Results from the studies and papers used in the analysis	Analysis of research question
RQ 1: What logistics actions are of relevance for shippers' contributions to environmentally sustainable freight transport?	1	1	– Actions and action areas related to three approaches – Actors' perceptions of actions of importance	– Describe actions and their possible contribution to environmentally sustainable freight transport – Connect identified actions to shippers' logistics activities, freight-transport activities and activities in surrounding systems – Describe shippers' perceptions of important actions in relation to other actor's perceptions – Describe actions of relevance for shippers' transport activities
	2	2	– Illustrating evaluation of external costs of a shipper's transport activities	
RQ 2: How can shippers evaluate load factor performance?	2	2	– Descriptions of load factor measurements with regards to the transport system	– Describe how load factor can be measured, with regards to a) the logistics and transport system b) choice of metrics and c) calculation of load factor – Connect the features of the two suggested frameworks to Caplice and Sheffi's evaluation criteria for logistics performance metrics (Caplice and Sheffi, 1994)
	3	4	– Compilation of measurement of load factor in previous literature and its challenges	
	4	3	– Framework for increasing load factor at Wholesale Alpha (indicator measures)	
	5	5	– Load factor model and approach for calculating load factor	
RQ 3: How do logistics activities influence shippers' load factor performance?	3	4	– Eight areas of influence described	– Connect activities to areas of influence and related logistics activities – Describe conditions created from different logistics activities and their input to others – Connect conditions created as output from one activity, to a) the logistics activities the conditions are input to (if any) b) the load factor performance
	4	3	– Framework for increasing load factor at Wholesale Alpha (logistics variables) – Case study descriptions	
	5	5	– Load factor model	
	6	5	– Case study descriptions	
RQ 4: What logistics actions can a shipper take to improve their load factor performance?	3	4	– Eight areas of influence described	– Describe logistics actions in terms of a) action taken in cases b) which logistics activities the changes concerned c) type of change d) new conditions created as an output from one logistics activity and input to others – Connect actions to the resulting load factor performance
	4	3	– Framework for increasing load factor at Wholesale Alpha (indicators) – Case study description	
	6	5	– Framework of opportunities – Case study descriptions	

3.5 Trustworthiness of the research

The criteria below were selected to evaluate the undertaken research in this thesis in terms of trustworthiness, credibility, transferability, dependability and confirmability (Halldórsson and Aastrup, 2003; Marshall and Rossman, 2006; Bryman and Bell, 2007). These criteria were preferred to more commonly used criteria such as validity and reliability because – having been developed for the purposes of qualitative research (and not primarily for quantitative research) – they may be more suitable for evaluating this type of research (Bryman and Bell, 2007).

Credibility means ensuring that the research follows good practices and that any members who take part in the study have had the opportunity of confirming that the researcher properly understands the social world that is the subject of the research (Bryman and Bell, 2007). This can also be explained as being equivalent to internal validity, which refers to the extent to which the conclusions about cause and effect between factors are supportable (Croom, 2009); this is of particular relevance for explanatory studies. For the fourth study – a structured literature review – this construct was not applied. Respondent validation, or triangulation, can be used to verify that the research is credible (Bryman and Bell, 2007).

Respondent validation was used in all the case studies (Studies 2, 3 and 5). Semi-structured interviews were central to the data collection process for all of them; in that process, some respondents were interviewed more than once. Hence, the results from the first interview round could be discussed and any necessary clarifications could be made. Further contact was also made (e.g. by mail or phone) in order to clarify any ambiguities in the collected data. Moreover, in Studies 2 and 5, where the case companies were part of a larger project, several workshops were held (including presentations of the results), which allowed comments and thoughts to be gathered from the different companies involved.

The credibility of the research was verified by applying triangulation of sources and analyst triangulation (see Patton, 1999). Triangulation of sources was used in Studies 3 and 5, various data sources being used to support the findings: interviews, archival sources and visual observations. Further, analyst triangulation was used in the studies (except in Study 3): two researchers were involved in the interviewing and also, in Papers 2, 3, 5 and 6, two or three researchers were analysing the data so as to reduce bias and ensure accurate case descriptions and interpretations.

Transferability refers to the degree to which the findings can be generalised across social settings (Bryman and Bell, 2007), 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). Although most researchers consider that it is difficult to generalise findings from qualitative research owing to the small number of samples and the focus on depth rather than breadth, it may be possible to generalise a part of the findings or of the approach used; such generalisations would be related to the theoretical parameters of the research (Marshall and Rossman, 2006). All of the studies undertaken for this thesis provided some kind of theoretical contribution (in terms of categorisations, models or frameworks) that could be of value to other researchers.

The first study contributes with an overview of logistics actions categorised according to three approaches to reducing environmental impact and thus providing a better understanding of actions relations to environmentally sustainable freight transport. The second study illustrates an approach for analysing the impact of input data uncertainties on the results of an environmental performance evaluation – which can be applied to other shippers' context. In Study 3 (reported in Paper 4), a framework is developed for how to increase load factor at Wholesale Alpha. Although the framework is developed based on just one case, logistics managers can use its principles to identify actions they can take to improve load factor performance and ideas about load factor measurement. Study 4 categorises the areas that influence load factor. The categorisation serves as an overview of possible influencing areas, which can be used to understand the influences on load factor in different situations. In Study 5, the resulting load factor model and the approach to calculating load factor (in Paper 5), as well as the framework of opportunities for improving load factor performance (in Paper 6), provide a structure for measuring load factor performance and for determining opportunities for improving the load factor. There is nothing to indicate that these findings could not be applicable to shippers in other situations, for example shippers in other industries that handle different types of goods than exemplified in the cases studied. In general, the descriptions of the empirical data provided in Studies 2, 3 and 5 make it possible for others to judge the transferability of the findings to other contexts (Bryman and Bell, 2007).

Dependability, according to Marshall and Rossman (2006, p. 203), is a situation 'in which the researcher attempts to account for changing conditions in the phenomenon chosen for study and changes in the design created by an increasingly refined understanding of the setting'. The criterion parallel to dependability that is used in quantitative research is *reliability*, which is the extent to which a study can be replicated (Yin, 2009). Replicating a qualitative study is difficult, however, given that the social world is in a state of constant flux (Marshall and Rossman, 2006), making each situation different from every other. Nevertheless, it is often possible to replicate the methodological choices and the role the researchers play in a study. In this thesis, all contacts with the respondents in the case studies were documented, which means that it is possible to follow the data collection process and analysis in detail. The author used documented interview guides for the semi-structured interviews and wrote detailed interview protocols; the interviews were recorded in Studies 1 and 5. The analytical process was also documented in detail, describing the components of the system studied, categorisations of data, connections between components in the system and calculations of load factor performance. The results from all the searches were documented for the structured literature review in Study 4, and the choices that were made for every research step in each of the papers were explicitly described.

Confirmability refers to the objectivity of the research, meaning, in practical terms, that the researcher did not allow any personal values to influence his or her research (Bryman and Bell, 2007). One way to confront this potential problem is to confirm the research with others to see whether or not it makes sense (Marshall and Rossman, 2006). In the present research, a constant dialogue on the research design, analysis and results was maintained with the author's research colleagues and supervisors. To ensure inter-observer consistency (Bryman and Bell, 2007) where two researchers were involved, both researchers carefully reviewed all notes from the interviews and, when performing analyses, they met to discuss their different interpretations of the data. Furthermore, the findings from Studies 1, 3, 4 and 5 have resulted in conference papers, each of which was discussed at a session of the conference. Study 2 yielded a case report and the preliminary results were presented at a national conference in Sweden. Other researchers thus had the opportunity to interrogate the studies. In addition, the findings of Studies 2, 4 and 5 were presented on several occasions at project meetings and workshops within the scope of the larger project.

Table 12: The components of trustworthiness in the studies: credibility, transferability, dependability and confirmability

Study	Credibility	Transferability	Dependability	Confirmability
1	Triangulation	Categorisation of actions	Documentation of data collection and analysis	Conference publication and presentation; two researchers involved
2	Respondent validation	Approach for analysing impact of input data uncertainty on environmental performance evaluation results	Documentation of data collection and analysis	Project seminars; conference presentation; several researchers involved
3	Respondent validation, triangulation	Principles of the framework for increasing load factor	Documentation of data collection and analysis	Conference publication and presentation
4	Not applicable to a literature review	Categorisation of influential factors	Documentation of data collection and analysis	Project seminars; conference publication and presentation; several researchers involved
5	Respondent validation, triangulation	Structure of load-factor model and framework of opportunities	Documentation of data collection and analysis	Project seminars; conference publication and presentation; two researchers involved

4 Summary of appended papers

This chapter summarises the appended paper, outlining the contribution to the research questions.

Six appended papers, which report on five studies, contribute to answering the research questions outlined in this thesis (Figure 16).

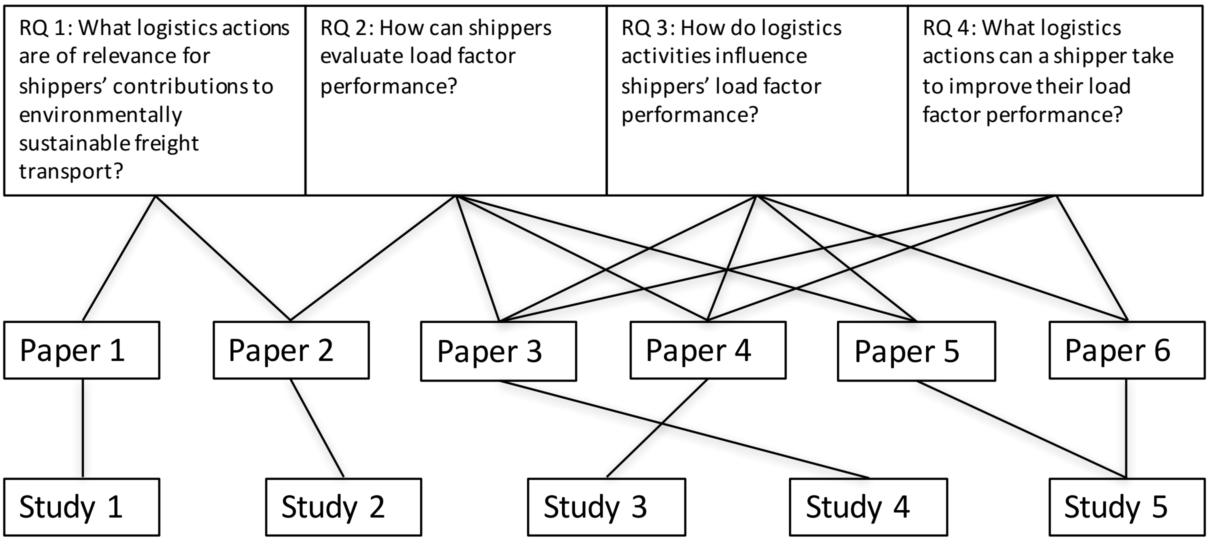


Figure 16: The relation between the studies, the resulting papers and the research questions

4.1 Paper 1. 'Actions for sustainable freight transport – comparing theory and practice'

The first paper contributes to answering RQ1. It takes a holistic view of the logistics system, presenting actions found in the literature review that reduce the environmental impact of road freight transport. The paper compares the theoretical overview with actors' views of the actions that are important for contributing to sustainable freight transport.

4.1.1 Purpose

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

4.1.2 Method

Actions were identified by reviewing the literature and by conducting interviews with the main actors in the logistics system: transport buyers, freight forwarders, transport operators and authorities. Findings from the literature review are compared with the practitioners' perceptions.

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

4.1.3 Results and contribution

The main findings in this article are the identification of logistics actions that are important for reducing the environmental impact of freight transport. A wide range of actions were identified that can be implemented by the main logistics actors. These actions were grouped into three categories according to whether they contribute to reducing environmental impact for each transport mode, contribute to use of an environmentally friendlier 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 most important for a sustainable future. Further, the way in which these actions contribute to sustainability was analysed by discussing how the most important of those identified by the actors 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 academics 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 to combine different actions in order to contribute to all four sustainability principles.

4.2 Paper 2. 'Measuring the environmental performance of shippers' transport activities: the impact of uncertainty in input data'

Paper 2 contributes to answering RQ1, by illustrating how shippers can evaluate the environmental performance of freight transport activities, taking uncertainties into account, and RQ2, by describing challenges in collecting load factor data for shippers and illustrating such assumptions and their uncertainties.

4.2.1 Purpose

The purpose of this paper is to analyse the role that uncertainty in input data plays in the evaluation of the environmental performance of shippers' freight transport activities. This is accomplished by illustrating the impact of uncertainty in input data, as well as the uncertainty of the evaluation results. This paper further discusses how shippers can handle such uncertainties in input data.

4.2.2 Method

Based on data from a real case, the external costs from a shipper's transport activities are evaluated to illustrate uncertainties in input data and the uncertainties in the evaluation results. The impact of uncertainty in specific input variables are analysed using Monte Carlo simulations.

4.2.3 Results and contribution

In the case studied, challenges were encountered in collecting accurate data, which meant that assumptions, with varying uncertainties, were used to complete the external cost calculations. In particular, load factor and vehicle data were not accessible to the shipper, and hence these values were most uncertain. The evaluation demonstrates that the results of an external cost evaluation can contain large uncertainties. The Monte Carlo simulations showed that the load factor uncertainties impacted the external costs results to the largest extent in relation to distance, vehicle type and emission factor.

The paper highlights the importance of awareness of input data uncertainty and its impact on the evaluation results when measuring the environmental performance of shippers' transport activities, which means that use of the results is limited by uncertainties in the results. The degree of effort that should be made to reduce the level of uncertainty depends greatly on how the results will be used, whether for the purpose of evaluating progress, guiding decision making, reporting or benchmarking.

4.3 Paper 3. ‘Achieving transport efficiency through increased load factor: a literature review of measurement and influencing factors’

In Paper 3, previous literature on load factor research is reviewed to describe a) how load factor is measured and b) what influences load factor. Consequently, the third paper contributes to answering both RQ2 and RQ3.

4.3.1 Purpose

The purpose of this paper is to provide an overview of load factor research, specifically with regard to what influences load factor and how load factor is measured. In addition, further research is suggested.

4.3.2 Method

This paper reviews the literature by making structured searches of keywords related to load factor in the Summon search tool. The search found 76 papers with a focus on load factor.

4.3.3 Results and contribution

The findings show that load factor issues are often treated as one aspect among others and are rarely the sole focus. Regarding measuring load factor, the paper reports on *different dimensions to be measured, as well as different origins of load factor numbers*. It is concluded that difficulty in getting reliable data about load factor and comparing results between studies makes measuring load factor a complex and not standardised task. In order to compare the results of different studies, a standardised measuring method is needed. The literature review considers the influence of load factor, opportunities and constraints in eight areas of influence: *logistics structures, order and delivery, packaging and loading, transport operations, consolidation, collaboration, information technology and external factors*. The review concludes that previous research gives little detail on how companies can increase load factor and how different influencing factors are interlinked. More detailed information on how companies can increase the load factor is needed in order to better understand links between the different factors and their influence on load factor.

4.4 Paper 4. ‘Toward more efficient logistics – increasing load factor in a shipper’s road transport’

Paper 4 contributes to answering RQs 2, 3 and 4, by exploring a shipper’s actions to improve load factor performance.

4.4.1 Purpose

This paper explores how shippers can increase load factor in their road transport by identifying opportunities for logistics action and the influences on load factor performance measures created by such opportunities.

4.4.2 Method

A case study is undertaken of the outgoing goods flow from the central warehouse of a large retailer in Sweden. Data are collected from interviews with the shipper and its contracted freight forwarder, as well as from archival sources and visual observations, and applied to produce a framework.

4.4.3 Results and contribution

A framework is developed that relates a shipper’s logistics actions to load factor indicators, corresponding measures and logistics variables. The framework consists of three load factor indicators: packaging, loading and booking and corresponding measures – order rows/load unit, load unit/load metre used and load metre used/load metre booked. The overall load factor is measured by order rows/load metre booked. Examples of a shipper's actions to increase load factor illustrate the relationships in the framework**.** The framework's principles can be used to support shippers in finding opportunities to increase the load factor.

The framework clarifies the concept of load factor as a whole by explaining each logistics action's contribution to increasing load factor, as well as the actions' combined effect in the context of a shipper and its purchased transport share.

4.5 Paper 5. 'Shippers' transport efficiency: a model for measuring load factor'

Paper 5 is a conceptual paper and contributes to answering RQs 2 and 3 by proposing a model that structures load factor as required compared to available capacity, and describes how shippers can measure their load factor.

4.5.1 Purpose

In the light of the lack of clarity regarding how shippers can measure their load factor, this paper takes a first step towards structuring and describing load factor and its components. The purpose of the paper is to develop a model that clarifies and describes how shippers can measure load factor.

4.5.2 Method

A model is developed based on existing literature and empirical data from two cases. The data are collected from several semi-structured interviews with logistics and transport staff, internal data bases and observations of the packing and loading activities.

4.5.3 Results and contribution

A model is developed to structure the load factor concept based on the balance between required and available capacity ('the load factor model'). The load factor model structures load factor on different levels (packaging, shipping, vehicle and fleet level) and highlights the dynamics between levels. Required capacity is determined by order details, item characteristics, number of items and the consolidation of items in the load at each load factor level. Available capacity is determined by the type and number of load units at each load factor level. The model takes a holistic view by reflecting the interaction between load factor levels, observing, for example, that a good balance on one level may lead to imbalance at a higher level. Required capacity is the volume or weight of the load on each packaging level and available capacity is the volume or weight in the load unit (excluding packaging material). Measuring the overall load factor (comparing the required capacity on the lowest load factor level with available capacity on the highest load factor level) indicates how well packaging material is used.

The proposed approach to measuring load factor describes how shippers can measure their load factor performance in practice and includes methods for calculating required and available capacity, where two alternative methods can be applied, depending on data availability and the circumstances of the case.

Paper 5 conceptualises load factor and how to measure it, which could help shippers to increase their understanding of their load factor as a step towards identifying opportunities to improve load factor and evaluate those improvements.

4.6 Paper 6. 'Shippers' opportunities to increase the load factor: managing imbalances between required and available capacity'

Paper 6 focuses on what actions shippers can take to improve their load factor performance, and is based on the results from Paper 5. Paper 6 contributes to answering RQs 3 and 4.

4.6.1 Purpose

The purpose of this paper is to structure shippers' opportunities to increase the load factor according to required and available capacity.

4.6.2 Method

A framework of opportunities is presented based on the literature and a multiple case study provides in-depth understanding of its application. Data collection consists mainly of semi-structured interviews focusing on changes resulting in improved load factor. Also, on-site observations of the shippers' packing and loading processes are made and internal databases support the calculation of load factor performance.

4.6.3 Results and contribution

A framework is developed with which to describe shippers' opportunities for increasing, decreasing or reallocating required or available capacity. Changing the required capacity can be achieved by changes to number of items, item characteristics and ways of consolidating items. The available capacity can be changed by the number of items and type of unit. Number of items can be changed by consolidating orders/items differently to match available capacity. Also, changes to order agreements and pricing are ways to reallocate capacity between time periods. With regards to available capacity, number of units can be changed by buying, selling and modifying the terms of contracts or by improving forecasting of the required capacity. Moreover, capacity can be reallocated by postponing maintenance and changing the time for utilising load unit capacity. Further, changes to available capacity can be achieved by shifting the type or the design of the unit.

In the cases studied, changes to increase load factor are undertaken, illustrating how opportunities can be applied in companies. The paper discusses how to use the load factor model (reported in Paper 5) to measure the existing load factor and thereafter identify areas and aspects that could be changed. The load factor model may additionally be used to evaluate the implications of changes.

Paper 6 proposes a framework of opportunities that can support shippers in managing imbalances between required and available capacity.

5 Analysis

This chapter analyses the results from the papers, and the conclusions from the analysis are discussed in relation to each research question.

In this chapter, the results from the appended papers are analysed and discussed in relation to each research question. At the end of the chapter (section 5.5), the conclusions from each research question are summarised. In Figure 17, the research questions are related to the conceptual model that describes the system studied. Each research question addresses different parts, and links between elements in the system.

In RQ1, a holistic view of the system is taken, in which relevant actions for shippers are identified by linking actions to shippers' logistics activities, to the contributions to environmentally sustainable freight transport and also to actors' perceptions of the actions that will be important for reducing the environmental impact of freight transport in the future.

The subsequent questions are narrower in scope, focusing on one such promising action, namely improving the load factor. RQ2 focuses on how to evaluate load factor performance, that is, the output of the studied system, which needs to be understood in order to explain links from other parts of the system to load factor performance. RQ3 uses the results from RQ2 by explaining how logistics activities influence the load factor performance. Finally, the logistics actions a shipper can take to improve their load factor performance are described in RQ4, using the results from the previous two questions.

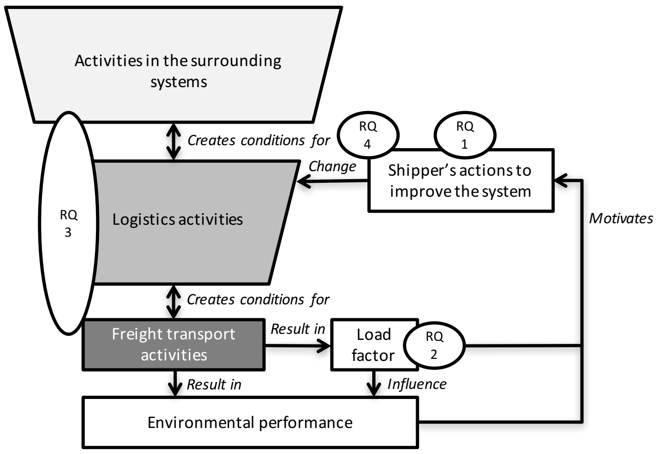


Figure 17: The research questions in relation to the conceptual model of the system studied

5.1 Relevant logistics actions for shippers

RQ1, the initial question in the research, concerns what logistics actions are of relevance in terms of shippers' contributions to environmentally sustainable freight transport. The literature provides several suggestions for actions aimed at reducing environmental impact, although previous studies have not been clear about the shipper's role. The first research question considers relevant actions that shippers may take, clarifying how each action area is involved in pursuit of the goal. It further describes which of shippers' common logistics activities are related to each action area and, taking into account actors' (shippers, freight forwarders, transport operators and authorities) own perceptions of which actions are important for contributing to environmentally sustainable freight transport, as well as their shared and diverging views, discusses the shippers' interest in different logistical actions. An action is relevant for the shipper if 1) it results in reduced environmental impact from the shipper's freight transport activities (improved environmental performance), 2) the action is related to the shipper's logistics activities and 3) the actors perceive the action as being of importance. The results from Paper 1 provide a broad overview of possible actions and their link to environmental performance. The identified action areas are related to logistics activities that can be part of a shipper's system, which further influence or are influenced by the activities in the surrounding systems, as well as the freight transport activities (Figure 18).

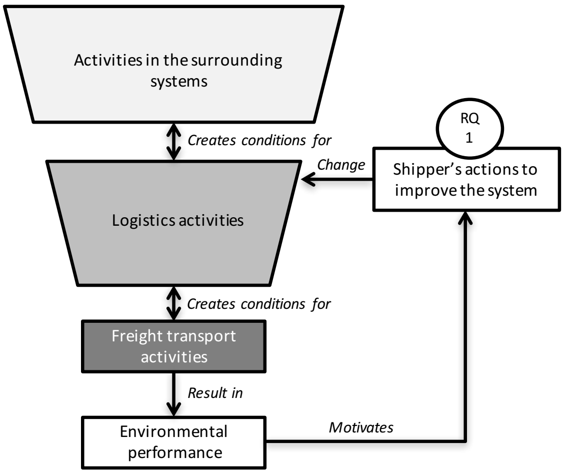


Figure 18: Shippers' actions related to logistics activities and freight transport activities, activities in the surrounding systems and environmental performance

5.1.1 Overview of actions and their link to environmentally sustainable freight transport

In Paper 1, identified action areas have been grouped according to three action aims, or approaches, to reduce environmental impact due to freight transport (based on Björklund, 2005; Lammgård, 2007; and IPCC, 2014b). The three aims are: 1) reduce the environmental impact for each transport mode, 2) use an environmentally better transport mode, and 3) diminish the need for transport. Action preconditions are also identified, based on policies and regulations that span all three action aims. In Figure 19, the action aims, preconditions and areas are summarised. The identification of these actions is based on findings in the literature and described further in Paper 1.

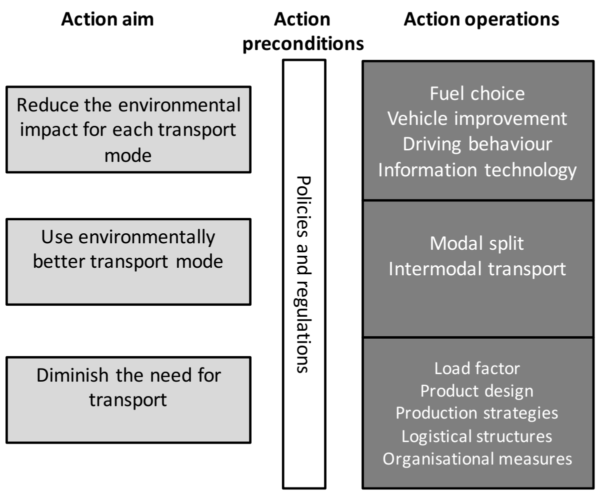


Figure 19: Action areas identified and categorised according to action aims (based on Paper 1)

First, the environmental impact (emissions/vehicle-km) of each transport mode can be reduced through technical advances, such as vehicle improvements (to design or engine development, for example) or the use of fuels that are better for the environment. Changes in driving behaviour will also affect the environmental impact of specific transport modes, for example eco-driving. Further, information technology can play a vital role, for example in supporting efficient driving behaviour. Second, the use of environmentally better transport modes (reducing emissions/tonne-km) entails a modal shift and the use of intermodal transport. Third, the need for transport could be lessened by reducing traffic (vehicle-km) and transport (tonne-km) levels. Logistical advances such as increasing the load factor, improved product design, as well as improved production strategies, logistics structures and organisational measures, could diminish the need for transport. Within each of the abovementioned action areas, more specific actions are identified (see Table 13 for summary).

Apart from the abovementioned action areas, identified in Paper 1, evaluating the environmental performance of freight transport activities is important for understanding the effects of the actions taken and for providing guidance on what further actions are relevant to take to improve the performance of the system (as described in Paper 2). In order to perform evaluations of the environmental performance of freight transport, input from load and transport data are required. Understanding to what extent uncertainties in the input data impact the evaluation results enables wise use of the results (in Paper 2, a case provides examples of such uncertainties and how to handle them).

Table 13: Action areas and identified actions from the literature (Paper 1)

Action area	Identified actions
Fuel choice	Alternative fuels
Vehicle improvement	Truck hybrids More efficient engines Better aerodynamic designs for the vehicles
Driving behaviour	Eco-driving
Information technology	Route optimisation Support system for better planning and visualisation of transport
Modal shift	Shift to more sea transport Shift to more rail transport
Intermodal transport	More intermodal transport 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 Adapt packaging for efficient logistics
Production strategies	Reduce the use of just-in-time (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 Centralised distribution system Decentralised distribution system Choose more regional suppliers
Organisational measures	Increased quality of the environmental work within the organisation Increased co-operation between organisations Increased focus on demands on suppliers, contract design and conditions for delivery, etc.

5.1.2 Linking actions to shippers' logistics activities, freight transport activities and activities in the surrounding systems

As a step towards identifying which actions are of relevance for shippers' contributions to environmentally sustainable freight transport, logistics actions in Paper 1 are related to shippers' logistics activities. The shipper is one of several actors in the transport community that may take action within the identified action areas. Other actors are involved in freight transport activities, for example, the freight forwarder and transport operator (which are synthesised as transport provider) or the suppliers, customers, competitors and authorities (which form part of activities in the surrounding systems). The shipper has more or less influence on each of these action areas, depending, for instance, on where in the supply chain it acts and its involvement in the transport solutions. Also, it is very common nowadays for a third party to perform the freight transport activities (as in the shippers interviewed in Paper 1). It should be noted that the specific activities that are part of the shipper's logistics system may vary between contexts and thus between shippers as well.

A wide range of a shipper's logistics activities may be affected by taking action within the action areas identified in Paper 1. One of the key processes to be managed from the logistics perspective is the order fulfilment process (see 2.3), including strategic and operational activities, which may be involved in several of the identified actions. The strategic order fulfilment process is about defining the requirements for lead time and customer service (which is related to actions within the area of *production strategy*), determining the locations of the warehouses, plants and suppliers (which is related to actions within the area of *logistics structures*) and determining modes of transport (which is related to actions within the areas of *intermodal transports* and *modal shift)*, to mention some examples. Operational order fulfilment is, for example, about planning transport (which is related to *information systems*, in terms of support systems for better planning and visualisation of transport) and picking, packing and loading goods (which is related to *load factor*, in terms of increases in the load factor at a general level).

Apart from activities in the order fulfilment process, there are other activities related to logistics, pointed out in section 2.3, which may be affected by taking action within the actions identified in Paper 1. Transport management activities can be related to the specific action of packaging adapted to efficient logistics within the area of *product design,* and supply/demand management as well as inventory management can be related to the action area of *production strategies*.

It is not only shippers' logistics activities that may be affected by the suggested action areas; several action areas are related to the transport provider's freight transport activities or activities in the surrounding systems. If transport is outsourced to a third party, shippers' logistics activities are indirectly linked to fuel choice, vehicle improvements and driving behaviour, since such actions are part of the transport providers' freight transport activities when performing transport movements. These action areas may be influenced by the shippers' logistics activities through management of the third-party logistics providers, in terms of setting demands/requirements for the transport operations, something all the shippers interviewed are currently doing. With regards to activities in the surrounding systems, product design (in terms of reducing the material used in products) is normally not of concern for logistics activities. However, dematerialisation of products has a direct impact on the weight and volume of the load to be shipped, which is one example of the link between activities in the surrounding systems and logistics. Further, logistics activities of other shippers in the supply chain form part of activities in the surrounding system, are linked to the logistics activities of the shipper in focus. One example is the logistics structures and production strategies, where, for example, the customers' choices regarding centralisation of warehouses will have an effects on where to ship the goods, while the requirements regarding frequency, order size and time for delivery have an impact on the logistics set-up.

Further, depending on where in the supply chain the shipper is located, the logistics activities that are part of its business processes may vary; for example, product design can be part of the shipper's activities if it is a manufacturer or part of a supplier's activities if the shipper is further down in the supply chain. Therefore, the shipper may need to collaborate with other parties. Increased co-operation is seen as a cross-cutting activity that can involve all types of activities and also different actors. As an example, the area load factor can be related to shippers' logistics activities, freight transport activities and activities in the surrounding system. This is because consolidation with other operators/companies' goods is related to activities in all three systems and involves several actors.

Figure 20 summarises action areas and their link to shippers' logistics activities (the dotted lines indicate an indirect link). Logistics actions can also be taken among other shippers in the surrounding system, which then influence the shippers' logistics activities and vice versa.

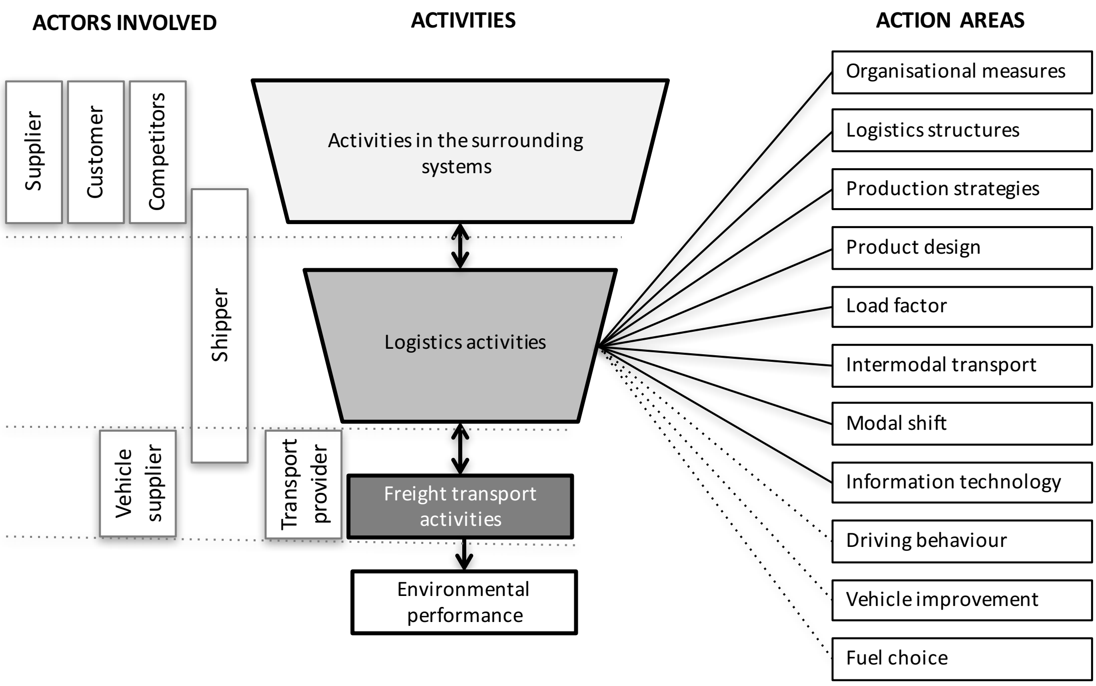


Figure 20: Overview of the links between action areas and shippers' logistics activities

5.1.3 Actions of importance for actors

Three shippers' views regarding which actions are of importance in reducing the environmental impact of freight transport are described in Paper 1 (in terms of examples of actions taken and which actions are perceived as most important for the future). Further, comparisons with the viewpoints of other actors, including transport providers (freight forwarders and transport operators) and authorities, are offered. The actors' views are shown in Table 14.

A wide range of actions were taken by the three shippers interviewed. All three participated in collaborative forums and placed environmental demands on their contracted transport providers. In addition, they focused on shifting the transport mode, improving packaging and increasing the load factor. For the future, they highlighted two actions as being extremely important for reducing the environmental impact of freight transport operations: increasing the load factor and using more efficient engines. Other actions that were important to the shippers were adapting packaging for efficient logistics and increasing collaboration between organisations. Regarding the other actors' viewpoints, the transport operators and the freight forwarders commonly viewed alternative fuels as important. Further, the freight forwarders perceived that more flexible time restrictions for pick-up and delivery were important. The companies interviewed stressed that this is because the shippers' requirements for later pick-up and earlier delivery times are putting negative pressure on the freight forwarders, impeding flexible planning and more efficient distribution. The authorities viewed collaboration between actors as important, as well as consolidating goods, especially in cities.

Table 14: Actors' perceptions of the actions that are important for environmentally sustainable freight transport

Actor	Examples of actions taken	Actions of most importance for the future
Shipper	Reduce number of warehouses, environmental demands upon transport providers, better packaging, increase the load factor, shift to more sea transport (from air), participate in collaborative forums.	Use more efficient engines, increase the load factor (in particular by consolidating goods from companies and operators), adapt packaging for efficient logistics, increase co-operation between organisations, allow longer vehicles.
Freight forwarder	Increase the load factor, environmental demands upon transport operators, alternative fuels (test), tools for information communication, participate in collaborative forums.	Allow longer vehicles, increase number of night deliveries through fewer restrictions, more flexible time restrictions, use alternative fuels and eco-driving.
Transport operator	Eco-driving, tools for route optimisation and planning, co-operation with trucking industry and rail company, alternative fuels (tested), intermodal solutions.	Use alternative fuels, intermodal transport, more flexible time restrictions, reduced frequency and larger quantities in one order.
Authorities	Collaborative forums, platform for research within green corridors, city distribution, consolidation of goods, e-business, environmental demands upon transport providers.	Increase co-operation between organisations, increase the consolidation of goods (especially in city – logistics).

5.1.4 Discussion: actions of relevance for shippers

For shippers, logistics actions are of relevance if they are to result in reduced environmental impact, if they are related to the shippers' logistics activities and if the actors perceive them as important actions for the future.

In this thesis, the overview of actions and their links to environmentally sustainable freight transport (three approaches to reducing environmental impact) and shippers' logistics activities provide a holistic understanding of ways to improve the shipper's environmental performance. Various recent reviews have described actions that actors can take to reduce the environmental impact of freight transport (Hung Lau, 2011; Perotti *et al.*, 2012; Colicchia *et al.*, 2013; Martinsen and Huge-Brodin, 2014; Evangelista, 2014; Pålsson and Johansson, 2016). These studies highlight similar action areas that can reduce the environmental impact of freight transport to those provided in this thesis. Several of the reviews also explicitly point out actions related to reverse flow (Hung Lau, 2011; Perotti *et al.*, 2012), which is not emphasised as a specific action area in this thesis, since actions can be applied in different parts of the materials flow in the supply chain. In this thesis, evaluating environmental performance is seen as an important means of motivating actions that will promote environmentally sustainable freight transport, which is also supported by several other authors, such as Björklund *et al*. (2012) and Blanco and Cottrill (2014).

The connection between logistics activities and environment is distinguished in this thesis and is argued to be of importance in understanding the link between actions and their resulting effect. This link has not been particularly evident in the literature, although two recent examples from the abovementioned reviews concern the structuring of actions in relation to factors influencing the environment. Using the analytical framework from McKinnon (2015a) is one way to structure actions, as Martinsen and Huge-Brodin did in their study (2014), while another example is provided by Pålsson and Johansson (2016), which describes actions relating to six factors affecting CO_2 emissions from freight transport, based on McKinnon (2003). Such structuring also distinguishes between actions related to tonne-km and vehicle-km (in terms of length of haul, payload, empty running and transport intensity/traffic intensity), emissions/vehicle-km (energy efficiency or energy intensity) and emissions/tonne-km (modal shift). Differentiating between actions improving, for example, carbon-intensity and energy-intensity could have been included in more detailed approaches, but instead such actions are regarded as part of reducing emissions/vehicle-km.

More details on actions influence on environmental performance can be obtained by evaluating, for example, the external costs of shippers' transport activities. Such evaluations are valuable for providing guidance on what actions are relevant, by testing different transport scenarios or evaluating the effects of actions taken. As discussed in Paper 2, an external costs analysis can provide guidance on future directions and areas of focus, such as what transport mode to use, whether logistics structures should be changed or if shipments could be consolidated. Such broad analysis can also demonstrate which actors may be involved in such a change, for example the transport manager and the sales manager if customer goods are to be consolidated. Further, different actions contribute to different types of improvements in the system. For example, a higher emission factor (Euro class) of the engine is more effective in an urban context than in a rural one (because emissions of NO_x and PM are influenced and not CO_2). Further, actions such as load factor improvements are aimed at improving the efficiency of the transport operation, by reducing vehicle-km transporting the same amount of goods, which has an impact not only on various emissions but also on all other aspects of traffic, such as congestion, noise and accidents. Evaluating external costs can thus provide a holistic view of the environmental impact of shippers' freight transport activities, helping to provide a relative understanding of the external costs from different environmental impacts, which can be a further part of a logistics total cost analysis and prepare the organisation for future increases in transport-related costs (if externalities are internalised).

Another important consideration in this thesis is to distinguish actors' roles, given that different actors may have different opportunities to take action within particular areas. Martinsen and Huge-Brodin (2014) stress how environmental practices can be used as offerings and requirements in the market between LSPs and shippers. Also, Pålsson and Johansson (2016) compare shippers' and LSPs' intentions to take action and conclude that there is a difference in the intentions of the two actors. The fact that activities on the strategic, tactical and operational levels create conditions for one another (as pointed out by Aronsson and Huge-Brodin, 2006) and that several actors may be involved in performing such activities make it important to be clear about actors' roles and the relevance of actions for particular actors, since these will vary, for example between shippers and transport providers. Taking the shippers' perspective, as in this thesis, is important in order to gain an understanding of their particular situation and to provide insights into what logistics actions are most relevant for them.

The interviewed companies and organisations within the four actor groups (shippers, freight forwarders, transport operators and authorities) provide different perspectives on which actions are of importance for contributing to environmentally sustainable freight transport. Previous research on reducing environmental impact from transport has focused on a 'technology fix', that is, reducing the emissions from each transport mode (as also found in the study by

Martinsen and Huge-Brodin, 2014). In Paper 1, technical solutions – alternative fuels and more efficient engines – are perceived as important by a majority of the interviewed actors, which confirms the picture obtained from the literature. However, shippers' logistics activities do not directly concern these areas; rather, they can indirectly influence the technical solutions, for example by imposing demands/requirements on the transport provider. McKinnon (2015a) argues that companies focus on functional decisions, such as decisions on truck fuel efficiency, back-loading and vehicle routeing, at the expense of strategic, commercial and operational decisions; this is similar to the findings in Paper 1. Such functional decisions are of primary concern for transport-providing companies.

The shippers have more direct influence on other action areas, related to using environmentally better transport modes and diminishing the need for transport (see Figure 20). In particular, logistics actions related to increasing the load factor are perceived as important, based on the findings in Paper 1, not only for the shipper but also for the authorities. Transport providers view the load factor as part of their business and a natural part of their daily operations. Improving the load factor means reducing the amount of vehicle-km (transporting the same amount of goods) and, for shippers in particular, increasing load factor means using the purchased transport in a more efficient way. Shippers' opportunities to take action in this area are shown by the examples of such actions applied. Additionally, since shippers perceive load factor improvements as important for reducing future environmental impact, there may be great interest from shippers to implement further actions. This reasoning is similar to Pålsson and Johansson (2016), who evaluate the shippers' and logistics service providers' (LSPs) intention to reduce transport emissions based on the actors' perceptions of the potential of such actions. Other actions that are viewed as important for the future, identified in Paper 1, are closely related to the load factor, such as adapting packaging for efficient logistics and co-operation between organisations, which facilitates the consolidation of the goods of different companies. By contrast, transport providers view shippers' logistics activities as constraining efficient transport and attainment of a high load factor, for example, by demanding shorter lead times and delivering smaller shipments with a higher frequency. This suggests that shippers are unaware of their negative influence on load factor and need to be informed about how they can take action to improve the load factor performance.

In general, regardless of actor focus, several studies have noted that increasing the load factor is a promising action for contributing to environmentally sustainable freight transport (McKinnon, 2000; Léonardi and Baumgartner, 2004; Aronsson and Huge-Brodin, 2006). McKinnon (2015b) states that 'raising vehicle load factors is one of the most attractive sustainable distribution measures to companies because it yields substantial economic as well as environmental benefits' (p. 243).

5.2 Evaluation of shippers' load factor performance

Evaluation of the performance of shippers' freight transport activities is used in this thesis to learn about the performance of the system and the effects of actions taken, as well as to motivate future choices of logistics actions that have the potential to contribute to environmentally sustainable freight transport. Since the load factor is a key variable for improving environmental performance, and since there is no uniform way to evaluate load factor performance, RQ2 focuses on how shippers can evaluate load factor performance.

To this end, descriptions are provided of the methods used to measure the load factor in previous research (based on Paper 3). Based on these descriptions, challenges in measuring the load factor are identified (based on Papers 3 and 4), which informs further exploration of how shippers can measure their load factor performance. Second, suggestions are made for measuring the load factor in a shipper's flow of outgoing goods (based on Papers 4 and 5).

5.2.1 Measuring load factor in previous research

Previous research has used different dimensions of load factor measurement: weight, volume, empty running and others (for examples, see Table 15). Of the 76 reviewed articles in Paper 3, 23 used a weight-based load factor measure, seven measured empty running and four used a volumetric load factor measure. A combination of several measures was used in six articles, such as weight, deck area and height (McKinnon and Ge, 2004). As may be seen from the examples, logistics and transport studies use several ways to measure the load factor.

Although most articles state which dimensions are included in their definitions of the load factor, a large minority (22 of the 76 reviewed articles) do not provide this information, which means that it is not clear what is actually being measured. Most articles measure only one dimension, which has limitations, for example, a weight-based load factor does not take into account vehicle space or deck area (McKinnon, 2010a), and measuring floor space may lead to a 100 per cent load factor, even if the floor is covered by empty pallets (Ljungberg and Gebresenbet, 2004). Further, the literature describes different ways of determining the load factor numbers: assumptions, empirical, secondary data or calculations. Several load factor numbers are based on the first category, assumptions, which appears to be the dominant way of determining the load factor in the literature, and this highlights the difficulty in finding reliable data on the load factor or in comparing results between studies.

The literature review (presented in Paper 3) leads to the conclusion that measuring the load factor is a complex and non-standard task. To avoid misunderstandings resulting from unspecific information, it is necessary to specify what is measured and how the numbers are determined. Moreover, comparing results between companies requires a standardised measuring method.

The literature review also reveals an absence of sharp focus on load factor in the reviewed articles (only 19 articles have this as their main focus), which may also explain the lack of measurement details. The load factor is most commonly measured as one aspect among others in a larger performance measurement system (considering costs or environmental impact), and few measurement details are usually provided.

Table 15: Examples of different load factor measures in the literature (derived from Paper 3)

Dimension	Measure	Reference
Weight	'the ratio of the actual weight of goods carried to the maximum weight that could have been carried on a laden trip'	Ülkü (2012)
	'dividing the total annual freight km per country with the gross hauled freight tonne km and averaging over all years considered'	Giannouli et al. (2006)
	'revenue tonne-km/revenue tonne-km available'	Gucwa and Schafer (2013)
	'the ratio of the tonne-kms that a vehicle actually carries to the tonne-kms it could have carried if it was running at its maximum gross weight'	Piecyk and McKinnon (2010)
	'kg/day'	Johansson (2006)
	'tonnes/vehicle'	Eom et al. (2012)
Volume	'internal volume/external volume with lid'	Pålsson et al. (2013)
	'the volume of products actually despatched against the transport capacity deployed for the movement'	Potter and Lalwani (2008)
Empty running	'the proportion of truck-kms run empty'	McKinnon and Ge (2006)
Others	'ratio of vehicle-kms to tonne-kms'	McKinnon (2010b)
	'roll containers loaded/maximum capacity of roll containers'	Author's interpretation of Quak and de Koster (2009)
	'average ratio of product carriers (pallets, roll containers) to capacity when the vehicle leaves the distribution centre'	Quak and de Koster (2007)
	'unutilised capacity (number of units)'	Kale et al. (2007)
	'per cent of occupied floor space'	Ljungberg and Gebresenbet (2004)
	'average capacity per container train (TEU)'	Woodburn (2013)

5.2.2 Frameworks for measuring load factor performance

The above reasoning prompts further exploration of how shippers can measure the load factor in their outgoing flow of goods. More concretely, Paper 4 describes the following challenges that need to be considered when measuring the load factor among shippers: the level at which the load factor should be measured (e.g. vehicle or packaging), what constrains the load (e.g. weight or volume) and which data are available (discussed in relation to calculating load factor). The vehicle level (which is most common in previous research) is not the only level at which the load factor can be measured; lower levels (e.g. in a share of a vehicle or on a pallet) are also possible. Measuring the load factor on more than one level provides a better understanding of its performance. This information also facilitates understanding of how different types of actions may influence the load factor. Measuring the load factor on different load factor levels is the starting point for the development of a) a framework for increasing the load factor and b) the load factor model.

A framework describing how a shipper (Wholesale Alpha) can increase load factor, including a combined set of indicators, is shown in Figure 21. These indicators are related to three levels: packaging, loading and booking. Corresponding measures are packaging efficiency (order rows/load unit), loading efficiency (load unit/load metre used) and booking efficiency (load metre used/load metre booked). All three measures are dependent on one another, according to the following formula:

Load factor	=	***Packaging efficiency***	×	***Loading efficiency***	×	***Booking efficiency***
[order rows/ load metre booked]		*[order rows/load unit]*		*[load units/load metre used]*		*[load metres used/load metres booked]*

Linking the measures together demonstrates their interdependencies, which means that measuring only one level is insufficient. It is possible that one indicator is efficient while the others are not. Consequently, all levels need to be taken into account.

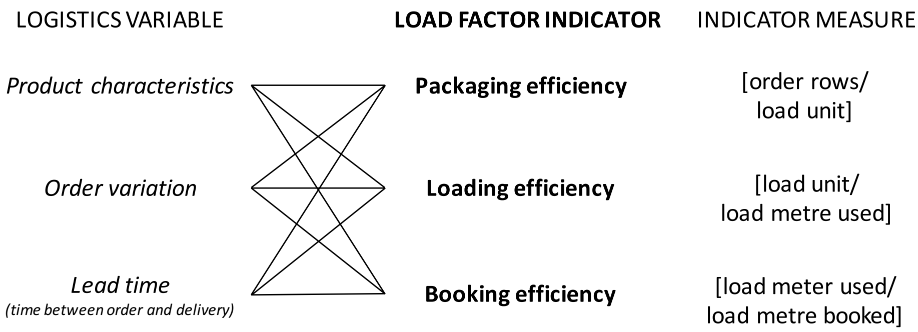


Figure 21: Framework for increasing the load factor at Wholesale Alpha (presented in Paper 4)

Using order rows/load metre booked as an overall load factor measure has its strengths in the case studied (e.g. regarding data availability). Other dimensions may be relevant in other situations, and they can be used applying the same principles as in the framework. Further, to clarify the relationship with maximum possible load, weight and volume/load metre booked need to be measured and compared to the maximum load that could have been carried. Depending on which dimension is restricting the load, either weight or volume measures should be applied.

In Paper 5, the logic of measuring the load factor at different levels (as in the framework shown in Figure 21) is further applied when developing a load factor model (Figure 22). The model structures load factor on different levels (packaging, shipping, vehicle and fleet), based on the balance between required and available capacity. It therefore structures the load factor according to the following definition: the load factor is the ratio of the load carried (required capacity) to the maximum load that could have been carried (available capacity). The load can be measured in either weight or volume, depending on what is constraining the load. Required capacity is the volume or weight of the load on each packaging level, and available capacity is the volume or weight in the load unit (excluding packaging material). Measuring the overall load factor (comparing the required capacity on the lowest load factor level with the available capacity on the highest load factor level) shows how well the total space is filled with first-level items, at the same time indicating how much of the space is filled with the packaging material.

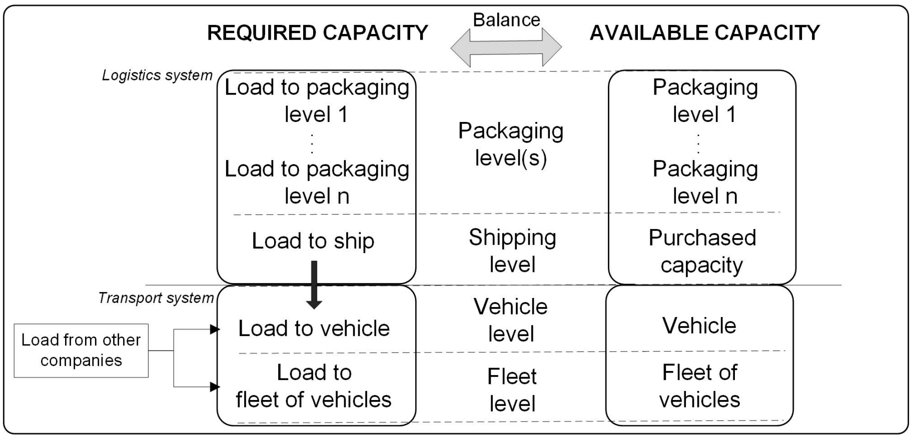


Figure 22: The load factor model (described in Paper 5)

5.2.3 Calculating load factor

The cases demonstrate load factor calculations in both the shipper's logistics system (packaging and shipping level) (see Papers 5 and 6) and the transport provider's system (vehicle level) (see Paper 2).

When calculating the shipper's load factor performance, the existing load factor levels must be identified. Also, the dimension constraining the load is identified (weight or volume), as well as the time period at which to measure the load factor, such as for each departure, day, week or month.

The volume or weight of the required capacity is determined by the item characteristics, the number of items and consolidation of the items. Which items could be consolidated depends on the order details in terms of order size, delivery time, delivery address/es and delivery frequency. Available capacity is determined by the type and number of units; see Paper 5 for further details. In Figure 23, aspects determining the required and available capacity are outlined.

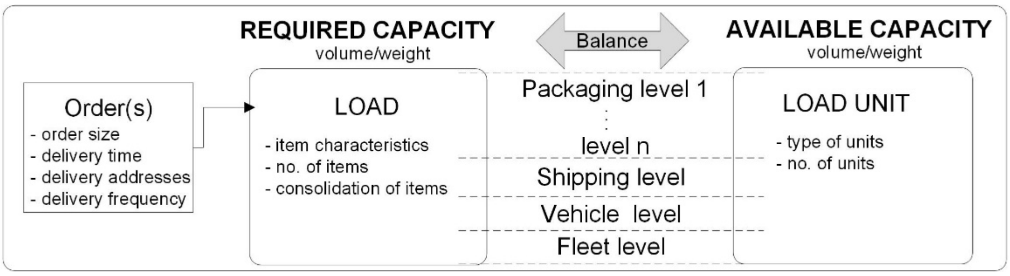


Figure 23: Determining required and available capacity

Determining the required and available capacity on each load factor level requires relevant input data, which, in the cases studied in Papers 5 and 6, were collected through the company's archival records, visual inspections and/or interviews. As pointed out in Paper 5, two different methods can be used, depending on the availability of data; thus, for required capacity, either the weight and/or volume of all items can be summarised, or the weight and/or volume can be measured after all items have been combined. Both methods were adopted in the selected cases. To calculate required capacity by summarising the volume of all items, the way in which the items can be combined on the load unit must be taken into account. The required capacity may be more than the sum of its parts, given that items' characteristics (e.g. stackability and sensitivity) determine how to combine the items on the load unit, for example, whether all items can be stacked on one another without risking damage. If calculating the required capacity by measuring the volume or weight after all items have been combined, the load unit that the items are packed or loaded onto should not be included in the measurement. The available capacity is the volume or weight that the load unit can carry. For further details about how to calculate required and available capacity, respectively, see Paper 5.

For shippers purchasing LTL capacities, evaluating the load factor on the vehicle can still be of interest, since such load and vehicle data are required for evaluating the environmental performance of the freight transport activities. Collecting such load factor data requires information to be transferred from the transport provider to the shipper. In the case studied (in Paper 2), the shipper found it difficult to collect such data and consequently relied on assumptions (based on data in previous studies). However, such assumptions can be very uncertain and impact greatly on the evaluation results. Further, the vehicle load factor will not provide any details regarding the effects of improving the load factor on the packaging and shipping level, and provides limited guidance for shippers on further improvement actions when purchasing LTL capacities.

5.2.4 Comparing 'the framework for increasing load factor' with 'the load factor model'

The two frameworks presented above, 'the framework for increasing load factor' and 'the load factor model', use the same logic in terms of including several load factor levels. However, in 'the framework for increasing load factor', the levels are clearly related to one another in a formula, whereas in 'the load factor model' each level is handled separately and connected by the overall load factor. Packaging efficiency and loading efficiency in 'the framework for increasing load factor' correspond to two packaging levels, as emphasised in 'the load factor model'. Similarly, booking efficiency in 'the framework for increasing load factor' corresponds to the shipping level in 'the load factor model'. Moreover, one difference between the two models is that the distinction between required and available capacity is highlighted in 'the load factor model' and not in 'the framework for increasing load factor'. In the latter, the overall load factor is measured in terms of the load on each load metre booked, which in the suggested case is measured as order rows/load metre booked. An increase from 44 to 46 order rows/load metre booked (7%) was possible by implementing changes related to the three load factor levels. This differs from how load factor is measured in 'the load factor model', where the load factor is the ratio between the required and available capacity at each load factor level. Here, the overall load factor is necessary for understanding the interactions between levels. To assess the potential for further improvements, the relation to maximum load that could have been carried must be known, for example, in the booked vehicle share, which can be obtained using 'the load factor model'.

The primary reason for measuring load factor performance in this thesis is to evaluate the load factor and to provide decision-making support as a means of identifying logistics actions for improving this performance; in other words, the performance measures should be useful (cf. Caplice and Sheffi, 1994). Moreover, if the metric accurately captures the events and activities being measured (valid), it increases understanding of the load factor performance and which activities influence it. Further, including relevant aspects of the process promotes cross-functional involvement (integrative) (Caplice and Sheffi, 1994). In addition, data need to be collected in an adequate amount of detail, which requires a reasonable amount of effort in proportion to the benefits of using the measurement results (level of detail/economy) while in the same time allowing for comparison across time making the measurements repeatable (robust) (Caplice and Sheffi, 1994). Both frameworks provide guidance with regard to usefulness, validity, integrative analysis and level of detail/economy. Measuring the load factor on several levels is useful because it allows relevant actions to be identified that have an influence on each load factor level. Further details are provided in 'the load factor model' by differentiating between required and available capacity and describing determining aspects. The overall load factor measures reflect the results on each load factor level (valid). Moreover, each load factor level reflects the results of different logistics activities, for example, in the order to delivery process, such as packaging, loading and transport booking (in 'the framework for increasing load factor') and within packaging and shipping (in 'the load factor model'), which indicates that they both reflect the outcomes of different activities within the order fulfilment process (integrative). Further, the metrics used in 'the framework for increasing load factor' can be adjusted and easily exchanged for company-specific measures or measured within different time frames or in detail in 'the load factor model', so that different levels of detail can be provided, depending on what is economical. With regards to 'the load factor model', there are different ways to collect data suggested in Paper 5, for example by examining archival records or conducting interviews or observations. Also, depending on which data collection method is chosen, there are two approaches in calculating the load factor, by summarising the required capacity based on figures for each item/load unit or by measuring the result, the first of which would be the more accurate and detailed. It is therefore possible for the shipper to choose an appropriate level of detail in the data, depending on the available data and the effort required to collect it. To allow for comparability, the same calculation method must be followed when evaluating the performance before and after changes. Finally, the way in which the two frameworks can be applied in different situations varies. 'The load factor model' may be applied in different situations, thanks to its general approach, whereas 'the framework for increasing load factor' is based on a single case, so its principles can be applied in other situations. A comparison of the two frameworks is shown in Table 16.

Table 16: Comparison of 'the framework for increasing load factor' and 'the load factor model'

	Framework for increasing load factor (paper 4)	**Load factor model (paper 5)**
Definition of load factor	Load factor (order rows/booked load metre) = packaging efficiency * loading efficiency * booking efficiency	The ratio between required and available capacity
Overall load factor measure	Order rows/load metre booked	The ratio between required capacity on the lowest load factor level and available capacity on the highest load factor level.
Dimension measured	Order rows	Weight and/or volume
Load factor levels	Packaging, loading and booking	Packaging (1…n), shipping, vehicle and fleet
Usefulness	Actions can be related to each load factor level.	Actions can be related to each load factor level. Actions can be further related to required and available capacity and to the determining aspects.
Validity	Reflects the performance of activities on each load factor level. Interdependencies between them are understood by measuring the overall load factor.	Reflects the performance of activities on each load factor level. Interdependencies between them are understood by measuring the overall load factor.
Integration	Reflects the performance of activities related to packaging, loading, and booking.	Reflects the performance of activities related to packaging, shipping, and required and available capacity.
Level of detail/ economy	Principles of the framework are applicable in other contexts. Dimensions can be easily replaced by context-specific measures adjusted to an adequate level of detail.	Suggested metrics (based on weight and volume) can be adjusted in terms of time frame and level of measurement detail. The use of assumptions can be indicated if there are difficulties in collecting detailed data.
Robustness	Allow for comparability. For evaluating the effect of actions, the same calculation method must be followed before and after changes.	Allow for comparability. For evaluating the effect of actions, the same calculation method must be followed before and after changes.
Application in different contexts	Principles applicable in other contexts, dimensions can be easily replaced by context-specific measures.	The cases support usage in shippers' road transport in different contexts. Possibly applicable for other transport modes and for transport providers.

5.2.5 Discussion: Suggested frameworks to evaluate load factor performance

Previous studies have mostly measured load factor at the vehicle level, which is referred to as 'vehicle utilisation' (e.g. McKinnon and Ge, 2004; Browne and Gomez, 2011) or vehicle load factor (e.g. Léonardi and Baumgartner, 2004; Eom *et al.*, 2012). The vehicle load factor is relevant for measuring load factor performance with the aim, for example, of evaluating transport efficiency in the transport system or executing macro-level analysis. However, in this thesis, load factor measurements are performed for the purpose of evaluating and providing guidance for shippers to improve their load factor performance, and various ways of measuring load factor are suggested by applying the principles in 'the framework for increasing load factor' (Paper 4) and 'the load factor model' (Paper 5). Accordingly, it is important to evaluate the shipper's purchased transport share, since this is the load factor level, which is under the direct influence of the shipper (the booking level in 'the framework for increasing load factor' and the shipping level in 'the load factor model'). The purchased share can correspond to a vehicle or a fleet of vehicles, but it commonly means a smaller unit, such as a share of a vehicle.

The suggested load factor levels (the packaging and loading level in 'the framework for increasing load factor' and the packaging levels in 'the load factor model') provide detailed information on the load factor on each separate load unit in the purchased transport share. Few examples of measuring load factor on a smaller level than the vehicle level are found in previous research, a single example being measuring the load factor in a packaging system (Pålsson *et al*., 2013). Measuring load factor on several levels has certain similarities with Samuelsson and Tilanus's (1997a) efficiency framework for regional distribution, which includes capacity as part of several efficiencies, such as boxes and pallets. Still, evaluation of the load factor in the purchased transport share as suggested in 'the framework for increasing load factor' and 'the load factor model' is not found in previous studies.

Also, the suggested frameworks in this thesis provide more structure than previous studies with regards to a comprehensive sets of load factor performance variables measured on different, interdependent levels. By distinguishing between required and available capacity in 'the load factor model' (in addition to the load factor levels), shippers can describe imbalances between required and available capacity on each level and identify different types of actions that can be taken to improve the load factor performance (for further description, see section 5.3 and 5.4). Such detailed measurement makes it possible for shippers to see where there is potential for improving the load factor (e.g. which activities are concerned). On the packaging and shipping levels, the load factor performance is the result of activities in the shipper's logistics system. If purchasing LTL capacities, the shipper's load to ship can be consolidated with other companies' goods (organised by the transport provider). The load factor on the vehicle and fleet levels in such cases thus reflects the results of activities in the freight transport system (Figure 24).

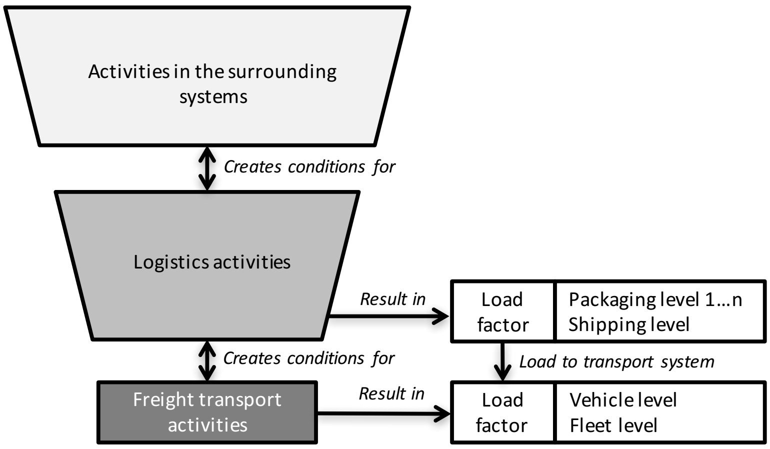


Figure 24: The load factor is a result of logistics and freight transport activities

Different dimensions, such as volume and weight in "the load factor model", may be used to measure load factor and which dimension is most appropriate to use depends on which dimension constrains the load. Although volume most often is the constraining factor when loading goods on a load unit or vehicle (e.g. McKinnon, 2010a), weight-based measures are more commonly used when reporting load factor (e.g. Ülkü, 2012; Eom *et al*., 2012), which means that information about the volumetric load factor is often lacking. This thesis thus provides useful examples and details for measuring load factor based on volume by applying ‘the load factor model’ and the suggested approach for calculating load factor in shippers’ contexts. For environmental calculations, however, it is necessary to use the weight-based load factor, because of that factor’s influence on fuel consumption (Bäckström, 1999), which means that measurement of both volume and weight is relevant, depending on the purpose of the measurement and the intended use of the results.

Using assumptions may be necessary in calculating the load factor, regardless of load factor level, when detailed input data are unavailable or missing. As noted in Paper 2, it is important to be aware of the level of uncertainty of input data, as well as its impact on the results, when evaluating the environmental performance of shippers’ freight transport activities, so as not to draw misleading conclusions. Acceptable levels of uncertainties in the input data differ, depending on the impact they may have on the results and their use.

5.3 Influences on shippers’ load factor performance

This section explains how logistics activities influence shippers’ load factor performance (RQ3). The shippers’ load factor performance concerns the packaging(s) and the shipping levels. Logistics activities that influence the shippers’ load factor performance are identified within four areas (categorised in Paper 3): *logistics structures*, *order and delivery*, *transport operations* and *packaging and loading*. As there is no single activity that influences load factor performance and there are interdependencies between activities, direct and indirect influences on load factor are identified based on the conditions created by activities, which in turn serve as an input for other activities. The critical conditions are identified by taking the aspects determining load factor as a starting point (described in Paper 5). The mapping of logistics activities and the conditions they create (which serve as input to other logistics activities) is done using examples from the cases described in Papers 4 and 6. Figure 25 provides an overview of the areas of influence, which will be related to shippers’ logistics activities, freight transport activities and activities in the surrounding systems in the next section (5.3.1). The conditions created by the activities, which serve as input to other activities, are described in section 5.3.2. The link between activities and the resulting load factor performance is then exemplified based on cases in section 5.3.3. The way in which logistics activities influence load factor performance is discussed in 5.3.4.

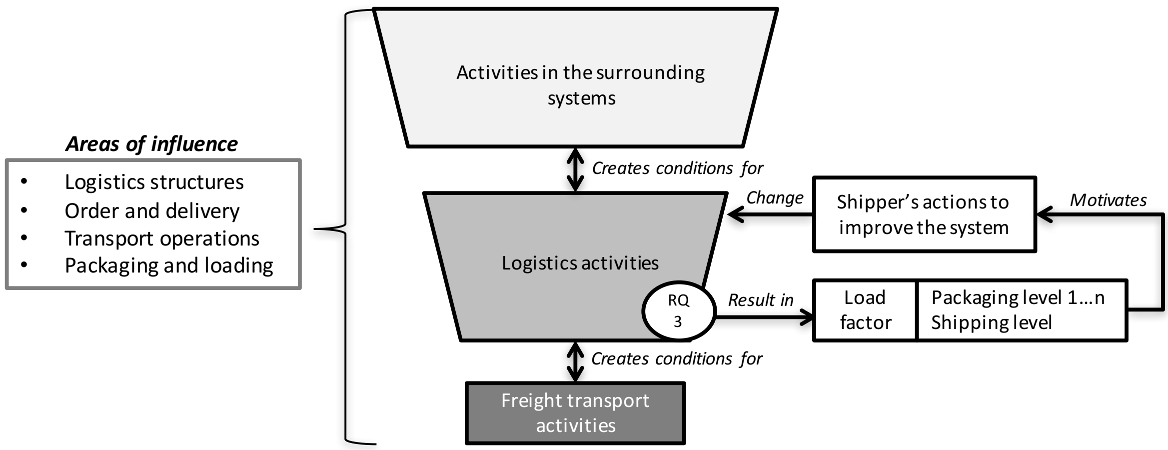


Figure 25: Logistics activities, freight transport activities and activities in the surrounding systems related to four areas of influence create conditions for one another and for the resulting load factor performance

5.3.1 Logistics activities related to influencing areas

In this section, logistics activities are related to the four areas of influence mentioned above. These areas, categorised in Paper 3, are based on factors that influence load factor, considering the different perspectives of shippers, transport providers and/or authorities. In addition to these four areas, which is of functional character, Paper 3 also identifies external factors that influence load factor performance. Such activities are outside of the direct control of the supply chain actors and include governmental activities and societal trends; they are therefore not included in this analysis. Moreover, Paper 3 also identifies factors that can be applied in all functional areas mentioned above, consolidation, collaboration, and information technology, as they may offer opportunities to improve the load factor performance. Actions related to such opportunities will be discussed separately in section 5.4.

Which logistics activities are related to each of the areas of influence is based on a) the identification of factors from the literature review, b) examples from cases and c) the logistics management literature (see section 2.3). ***Logistics structures*** concern logistics activities on a strategic level, namely facility location, such as warehouse network design (shipper/customer), as well as strategic freight transport activities, such as terminal network design (transport provider). ***Order and delivery*** concerns logistics activities on both tactical and operational levels among shippers and their customers and involves sales/customer support (shipper), order planning (shipper/customer), order placing and order receiving (customer). ***Packaging and loading*** concerns logistics activities related to the strategic, tactical and operational levels among shippers and their suppliers, such as product/packaging design (shipper/supplier), packing/loading planning (shipper/supplier) and packing and loading (shipper/transport provider). ***Transport operations*** concern logistics and freight transport activities on a tactical/operational level and involve planning (shipper), transport booking (shipper) and transport execution (shipper and/or transport provider). Which logistics activities occur in a particular part of the system may vary between contexts, for example whether the loading of goods is performed as part of the freight transport activities or not. Also, there may be other logistics activities that can be related to these areas, perhaps on a more detailed level, than those activities mentioned here. The abovementioned activities should therefore be seen as examples of activities related to these areas of influence. The logistics activities that influence load factor are illustrated in Figure 26, and further descriptions of the interdependencies between activities within these areas are provided in section 5.3.3.

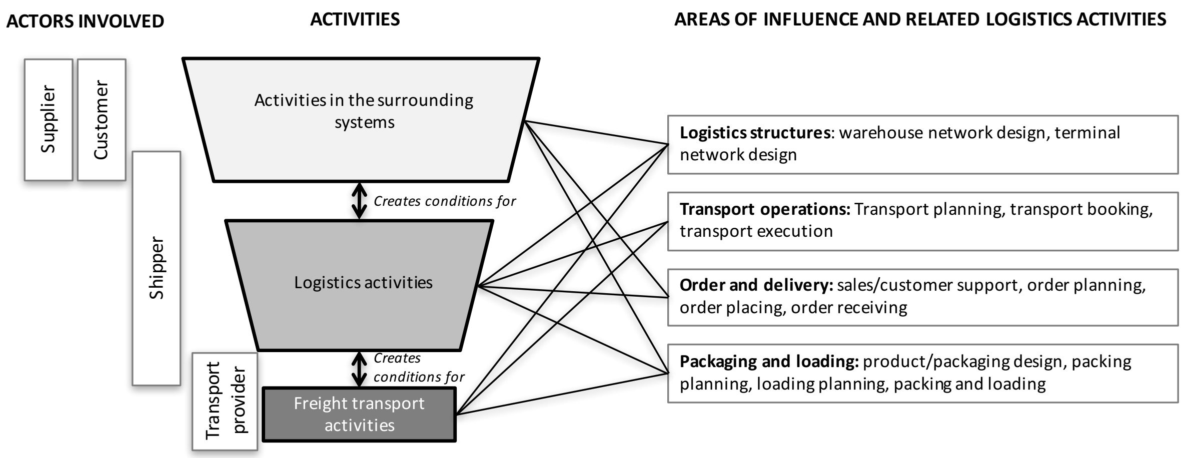


Figure 26: Examples of logistics activities that influence load factor performance, connected to shippers' logistics activities, freight transport activities and activities in the surrounding systems

5.3.2 Conditions created by logistics activities influencing load factor performance

The abovementioned logistics activities, freight transport activities and activities in the surrounding systems influence one another and shippers' load factor performance. The load factor performance is defined, based on the definition in Paper 5, as the ratio of the load carried (required capacity) and the maximum load that could have been carried (available capacity). The load factor model described in Paper 5 identifies aspects that determine the required and available capacity on each load factor level (see Figure 27). These aspects are conditions created as outputs from logistics activities, transport activities and/or activities in the surrounding systems and are inputs to other activities. Conditions that are created from logistics activities and thus influence the load factor performance relate to a) required capacity: item characteristics, number of items and how to consolidate items (referred to as 'how to pack' on the packaging level and 'how to load' on the shipping level) and b) available capacity: type of units and number of units. Conditions related to order details, which also influence load factor performance are: order size, delivery time, delivery address and delivery frequency.

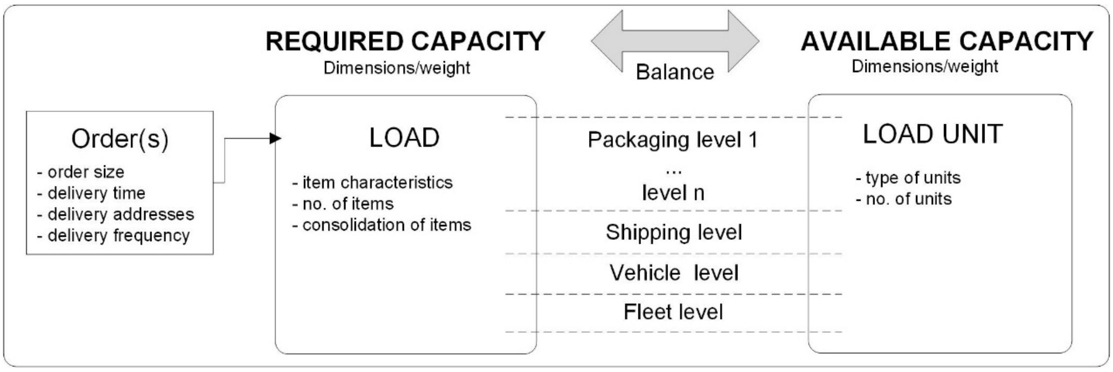


Figure 27: The determining aspects in the load factor model (Paper 5)

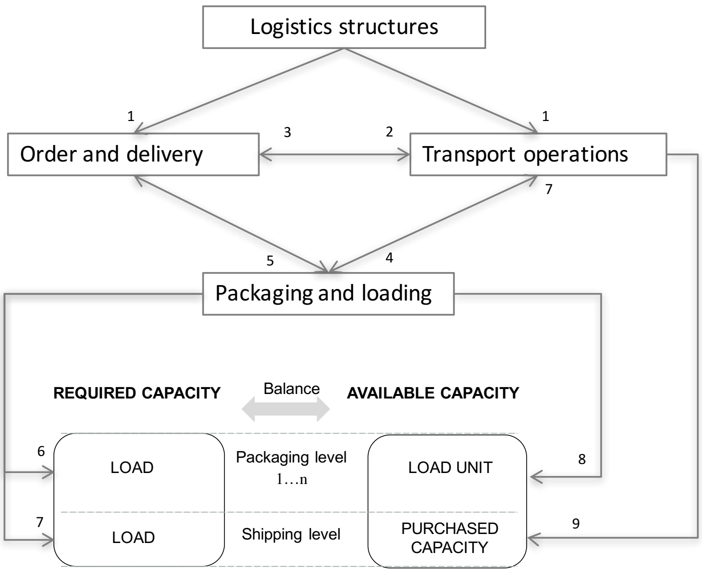
These conditions are used as a starting point for the analysis, and are identified within the logistics activities taking place in the cases. An overview of logistics activities and the conditions created from such activities is provided in Table 17, which also includes conditions related to order details. In the next section, these conditions are further detailed in relation to how they serve as inputs to other activities, that is, the interdependencies between different areas of influence are highlighted and their influence on load factor performance explained.

Table 17: Conditions created from different types of logistics activities (based on cases)

Area of influence	**Activities in the surrounding systems**	**Shippers' logistics activities**	**Freight transport activities**	**Conditions created**	**Case example**
Logistics structure	Location of facilities, e.g. warehouse network design	Location of facilities, e.g. warehouse network design	Terminal network design (transport provider)	Where goods are sent to and from (delivery address and sender address)	Fast Response
Transport operations		Transport planning, transport booking.	Transport planning (transport provider), transport execution (shipper/transport provider)	Which customers to deliver to (delivery address), when to deliver (delivery time), speed of delivery (transport lead time), what mode to use (type of unit), what capacity is planned/booked (number of units and type of units), order of delivery.	All cases
Order and delivery	Order planning (customer), order placing (customer), delivery	Sales/customer support, order planning		Order size, delivery frequency, delivery time, delivery address, delivery restrictions, order lead time, order variation	Distribution Round, Fast Response
Packaging and loading	Packaging design (supplier/shipper),	Packing planning, loading planning, packing, loading		Number of items, item characteristics, how to pack/load items (consolidate), type of load unit, number of load units	Fast Response, Project Delivery

5.3.3 Cases exemplifying how logistics activities influence load factor performance

An overview of the interdependencies between areas of influence and load factor performance is provided in Figure 28. These interdependencies are a compilation of the identified links between the four areas of influence and load factor performance, as exemplified in the cases. Using each area of influence as a starting point, examples of the conditions created from different logistics activities are provided and influences on other logistics activities described.



Conditions created:
1. Where from/to
2. Order size, delivery frequency, delivery time, delivery address, order lead time, order variation
3. Delivery address, delivery time, transport lead time
4. Which customer orders to pack/load, transport lead time, unloading order, number of units and characteristics of units booked/selected
5. Order size (number of items and their characteristics), order lead time, delivery restrictions
6. Number of items, item characteristics, how to pack
7. Number of items, item characteristics, how to load
8. Type of load units, number of load units
9. Type of units purchased, number of units purchased

Figure 28: Direct and indirect influences on load factor, based on the conditions created from activities that serve as inputs to others

Logistics structures concern conditions created by designing where facilities should be located, such as the warehousing and terminal networks within shippers', their customers' and the transport providers' logistics systems. These network designs create conditions for transport concerning where goods are sent from and to within the networks. For a shipper, contracting a third party to carry out transport activities within the transport provider's terminal network means that the transport provider's terminal locations create conditions for the *transport operations* (transport planning), since those locations determine what customer orders can be consolidated (for distribution via the terminals). In the Fast Response case, all customer orders were consolidated within the geographical area for each terminal district of the transport provider, which was decided when planning the transport. Also, the customer's location of their shops in the Distribution Round case created conditions for both the *order and delivery* (sales/customer support) and *transport operations* (transport planning). The agreed delivery time with the customer (which involves sales/customer support) needs to be set in relation to the customer's location and the planned delivery round (which involves transport planning).

Order to delivery concerns conditions created when agreeing the order and delivery details with the customer, the sales/customer support, the customer's order placing and the order planning (both at the shipper and the customer). The conditions created relate to the order, including: what to send (order size), how often to deliver goods (frequency), when to deliver (delivery time) and where to deliver the goods (delivery address). The cases provided several examples of how order and delivery create conditions for other activities, in the area of *transport operations* and *packaging and loading*. Order variations are the result of an order pattern from one or several customers. In Distribution Round, the sizes of the orders from customers within one distribution round varied between weekdays and created conditions for the *transport operations* (transport planning and transport booking), in the form of booking extra capacity on high volume days, because the order sizes exceeded the available capacity of one vehicle. Also, the agreed delivery time, frequency and delivery address created conditions for the transport planning, in terms of scheduling the vehicle in the distribution round each weekday. In the Fast Response case, the order sizes, which also fluctuated between days, and the order lead time created conditions for the *transport operations* (transport planning and transport booking), in terms of how to predict the total order stock, what capacity to purchase for each weekday and scheduling the vehicles' pick-up times. The short order lead time also created conditions for *packaging and loading* in terms of how much time can be taken to load goods onto the purchased capacity. Also, the order sizes, in terms of number of items and the characteristics of the items ordered, created conditions for how to pack and load the items, in both the Fast Response and Distribution Round cases. Moreover, delivery requirements were agreed with the customers, which created conditions for *packaging and loading*. For example, in the Distribution Round case, a certain height and length of vehicle was preferred for unloading pallets at the customer's site. In the Project Delivery case, a specific unloading order was preferred to facilitate mounting of the products at the customer's site, which created conditions for how items should be combined in each box. However, a particular unloading order was not always agreed beforehand and, in those cases, the packing activity created conditions for how to unload the items instead.

Transport operations concern conditions created by planning or executing transport or (if performed by a third party) booking the purchased capacity. Transport booking purchases the available capacity for transport; which is done in terms of type of units and number of units for executing the actual delivery. Figure 28 shows that the available capacity on the shipping level results from the transport operations in terms of purchased capacity; for shippers organising the transport themselves (which was partly done in the Distribution Round case) the same link applies, even though the available capacity in terms of allocated space on vehicles is the result of planning the transport. For a shipper organising the scheduling of the distribution rounds (as in the Distribution Round case), transport planning creates conditions for *order and delivery* (sales/customer support) in terms of which customers can be delivered to within a distribution round, the scheduled delivery time and the order in which they should be delivered. When the shipper agrees the order details with the customers, consideration is given to how the distribution round can be scheduled (in the Distribution Round case). Also, the transport operations create conditions for *packaging and loading*. The purchased capacity (number of load metres purchased) creates conditions for loading, in terms of how much to compress the items when loading. Loading by height is done only if there are enough orders and then items to fill the truck; otherwise, the floor is utilised first. Also, the type of vehicle that is allocated for the load (as in the Distribution Round case) creates conditions for how to pack and load the items; for example, if equipment such as bars is available, pallets can be packed without having to make allowance to stack another pallet directly on top. Activities within the transport operations also create conditions for one another; in the Fast Response case, the transport planning, particularly concerning the results of the forecast of ordered stock, was input for the transport booking, in terms of the capacity that had to be booked from the transport provider. Owing to the short order lead time (13 to 18 hours), incoming orders arrived until 6 p.m. and the transport was booked in advance based on the forecast need. By contrast, in the Project Delivery case the capacity that had to be booked from the transport provider was based on input from the packaging and loading activities, regarding number of items, item characteristics and how to load. Thus the transport booking was made after all items were packed in boxes and the purchased capacity could be matched to the required capacity at the shipping level.

Packaging and loading concerns conditions that are created by designing the load unit, designing the packaging system, planning packing and loading, packing items onto the load unit and loading items onto the purchased capacity. As described above, both activities in the area of *order and delivery* and *transport operations* create conditions for *packaging and loading* and *packaging and loading* creates conditions for *order and delivery* and *transport operations*. Further, the activities related to *packaging and loading* create conditions for one another and for load factor performance. As in the Fast Response case, the design and choice of load units (in terms of their shape and size) result in the available capacity on the packaging level. Further, the type of load units creates conditions for how to pack items in the load unit (which results in required capacity on the packaging level). Moreover, the packing activity results in packed load units and creates conditions for how to combine these load units when loading them onto the purchased capacity in the vehicle, in terms of number of items and their characteristics (e.g. if it is possible to stack them on top of one another or not), which results in the required capacity on the shipping level. In the Project Delivery case, the design of the packaging (i.e. the shape of the boxes) also produced the available capacity on the packaging level. Moreover, planning the way in which the items are packed in the boxes determines the required capacity on the packaging level. The way in which the items are packed can create conditions for the design of the boxes that are chosen (in terms of required capacity of items to be packed), while the design of the boxes can create conditions for the way in which items should be packed (in terms of available capacity for items). Designing boxes and planning how to combine items in boxes thus create conditions for one another (as exemplified in the Project Delivery case after changes).

5.3.4 Discussion: How logistics activities influence load factor performance

The areas of influence described above were identified in Paper 3, based on the review of previous literature, and the cases provided examples of the interdependencies between logistics activities related to each area and its link to load factor. Such an overview of influences on load factor performance, including the detailed examples from the cases, contributes to a holistic understanding of the role of logistics for the shippers' load factor performance. There is no overview in the literature such as is provided in this thesis of the different influences on load factor. Instead, most articles focus on one aspect at a time, such as logistics structures (Kohn and Brodin, 2008), order and delivery – in terms of demand fluctuations and customer service agreements (Bø and Hammervoll, 2010) – and packaging selection (Pålsson *et al.*, 2013). Piecyk and McKinnon (2010) indicate links between load factor and a number of determinants as part of the larger system of key variables that influence CO_2 emissions, although not all the relations identified in the present research are part of their framework. Also, Aronsson and Huge-Brodin (2006) provide several examples of influences on load factor (centralisation, delivery frequency, load unit selection, route planning), although details about their interrelations and link to load factor performance are missing. In addition, McKinnon (2015b) recently presented a fivefold classification scheme of the constraints on vehicle utilisation: market-related, regulatory, inter-functional, infrastructural and equipment-related. This classification scheme also captures several of the factors that are mentioned in this research as influencing load factor performance, although the main difference with this thesis is that McKinnon focuses only on the vehicle level and does not provide details and structures explaining in what way these factors influence load factor performance on different levels, as well as their mutual interdependencies. This thesis therefore adds to previous research by providing more detail on (a) which logistics activities that create conditions for load factor performance, (b) their interdependencies and (c) the ways in which they influence load factor. There are, however, previous studies on the interdependencies between activities in other contexts, for example the construction industry (Segerstedt *et al*., 2010), but not in terms of influences on shippers' load factor performance.

The cases studied illustrate the interdependencies among activities. The area of packaging and loading is central for load factor; the required capacity on the packaging and shipping level results from packing and loading, and the available capacity on the packaging level results from packaging design. Other activities in other areas influence load factor by creating conditions for packaging and loading. Further, available capacity on the shipping level (purchased capacity) results from activities in the area of transport operations, which in turn are influenced by conditions created within activities in the other areas. An activity can create a condition for another, or two activities can create conditions for one another; there are several examples of the latter. For instance, scheduling the distribution round (in the area of transport operations) creates conditions for the order agreements (in the area of order and delivery) concerning frequency and delivery times. Also, the order agreements create conditions for the distribution round, order sizes, delivery frequency, delivery addresses and agreed delivery times. Other examples of activities creating conditions for one another occur when packaging design creates conditions for the type of load unit (e.g. regarding size) or when the way in which items are packed creates conditions for the size of the combined items, which affects the required size of the load unit. Exactly which interdependencies exist in each shipper's context may vary, given that activities can be performed in a different order, which is the case when the transport booking occurs in the Fast Response and Project Delivery cases. However, because of the interdependencies between activities, adapting the activities to one another may be necessary to achieve a high load factor. The next question further considers what logistics actions can be taken and how these actions change the conditions created among the logistics activities to achieve improved load factor performance.

5.4 Logistics actions that improve shippers' load factor performance

As shown in the previous section, logistics activities create conditions that determine the load factor performance (i.e. the balance between required and available capacity). For shippers to take action, two important issues must be considered: (1) motivation to take action stems from an understanding of the imbalances between required and available capacity, and (2) to take action implies changing logistics activities so that new conditions are created that support improved load factor performance. Figure 29 shows the link between a shipper's actions, logistics activities and load factor performance. Also, freight transport activities and activities in the surrounding systems need to be taken into account, since they indirectly influence load factor performance through the conditions that are created, which serve as inputs to other activities.

The developed framework for increasing load factor (described in Paper 4), shown in Figure 5.15, and the framework for opportunities to increase load factor (described in Paper 6), shown in Figure 31, illustrate how shippers' opportunities to take action are linked to load factor performance. In the next section (5.4.1), these two frameworks are briefly described. The way in which shippers' logistics actions change logistics activities and create conditions for improving load factor performance is further analysed in subsection 5.4.2.

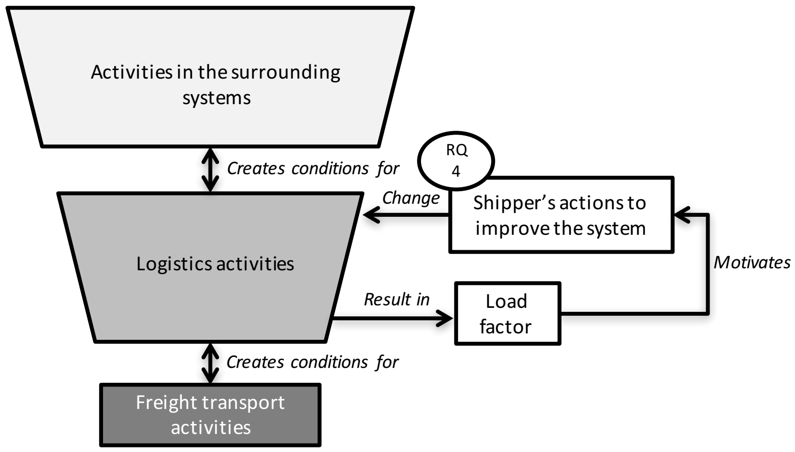


Figure 29: To improve the load factor performance, shippers need to make changes to their logistics activities by taking action

5.4.1 Overview of shippers' opportunities to take action to improve load factor performance

The framework for increasing load factor at Wholesale Alpha, shown in Figure 30, combines three indicators – packaging, loading and booking – into one measure of load factor. Each indicator is directly linked to an action area; Wholesale Alpha provides examples of actions that were taken (further described in Paper 4). The actions implemented in the Wholesale Alpha case that relate to packaging, loading and booking create new conditions for how logistics activities are carried out, which will be further discussed in section 5.4.2. These actions are related to the framework of opportunities in order to understand the link to load factor performance (see the Fast Response case in Paper 6).

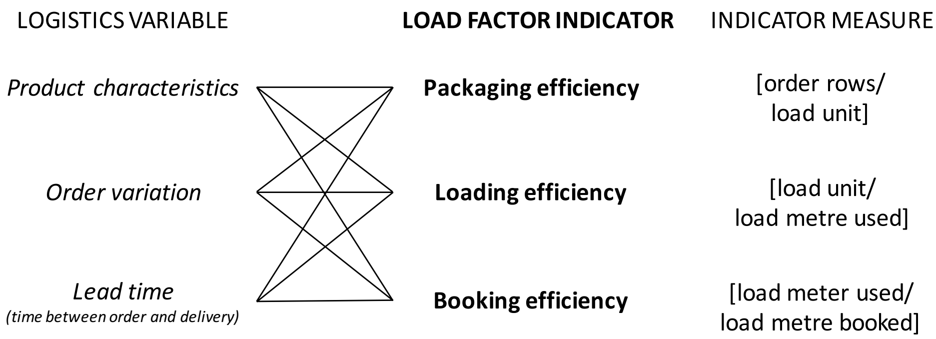


Figure 30: Framework for increasing load factor at Wholesale Alpha (Paper 4)

The framework of opportunities, shown in Figure 31, structures shippers' opportunities to take action depending on whether the required or the available capacity is changed. Two approaches are distinguished in the framework: to reduce or increase the capacity and to reallocate capacity between time periods. Each opportunity is then related to the required capacity (number of items, item characteristics or consolidation of items) or the available capacity (number of units and type of unit). By structuring the opportunities in this way, the connection to aspects determining the required and available capacity is clear and builds on the same logic as the load factor model (Paper 5). The aspects determining the required and available capacity are conditions created by logistics activities, freight transport activities and activities in the surrounding systems, as described in section 5.3.

	Required capacity			Available capacity	
	No. of items	Item characteristics	How to consolidate	No. of units	Type of unit
Reduce/ increase capacity	• Change what orders/ items to consolidate • Change no. to match available capacity	• Change size • Change characteristics to support loading	• Loading and packing method	• Buy, sell or contract • Improve forecasting of required capacity	• Change type • Change design
Reallocate capacity	• Change order agreements • Change pricing			• Postpone/advance maintenance • Change time for utilizing load units	

Figure 31: The framework of opportunities, that provides an overview of actions to improve load factor performance (Paper 6). Underlined actions are exemplified in the cases studied

For more detailed descriptions of all the actions that can be taken (based on the framework of opportunities), see Paper 6. In the cases studied, a number of actions were taken, underlined in Figure 31. Below, actions taken to improve the load factor performance in these cases are explained, detailing how logistics activities were changed and new conditions created.

5.4.2 Clarifying how actions change logistics activities to create conditions for improved load factor performance

Section 5.3 explained that load factor performance is influenced by the conditions created by different logistics activities within the areas of **logistics structures**, **order and delivery**, **transport operations** and **packaging and loading**. The framework of opportunities (Paper 6) suggests a number of changes that shippers can make to improve their load factor performance. To clarify how actions change logistics activities, the actions implemented in the three cases, Fast Distribution (described in Papers 4 and 6), Project Delivery (described in Paper 6) and Distribution Round (described in Paper 6), are analysed. The description clarifies the changes that were made, which activities the changes concerned and the new conditions that were created for improving load factor performance.

Table 18 provides an overview of the actions that were taken in the cases studied, in what way the action changed the logistics activities, which new conditions were created and what logistics activities the changes concerned. As the table shows, it was not just one action that was taken in the cases to improve the load factor performance but rather a number of actions. The actions are numbered in the order in which they were implemented in each case. There are examples of both single actions (that could be taken independently of the others) and actions that needed to be taken in a sequence in order to achieve the desired results. These interdependencies are explained in more detail based on each case below. The types of action, that is, in what way the action changed the logistics activities, are highlighted. It should be noted that these actions concern a wide range of logistics activities, some of which are tactical, such as design or planning activities. In such cases, operational activities are indirectly influenced by the conditions created from tactical activities, which serve as an input to the daily operations. The resulting load factor performance from actions taken is described for each case below, with details relating to load factor level and whether required or available capacity was changed.

Table 18: Actions taken in the cases studied

Case	Actions taken	Changes of the logistics activities: 'the change concerns…'	New conditions created	Which activity the change concerned
Fast Response	1. More detailed forecast of required capacity	How an activity is performed, the condition created	Forecast amount of order rows	Transport planning (shipper)
	2. Differentiated booking (changes to purchased quantity)	How an activity is performed, the condition created	Number of load metres booked	Transport booking (shipper)
	3. New types of load units added	The condition created	Type of load units, characteristics of load units	Transport planning (shipper), transport planning (transport provider)
	4. Changes to loading method, introducing pre-loading	Which activities were performed, when an activity was performed, who performed the activity, the condition created	Load units combined for each load metre, number of load metres required	Pre-loading goods (transport provider)
Project Delivery	1. Changes to supplier's scope	How and when an activity was performed, which activities were performed, who performed the activity, the condition created	Purchasing of packing planning, purchasing of new packaging design, new packaging design and packing planning	Packaging purchasing
	1. New design (size and packaging material) and packaging material in boxes	The condition created	Number, type and characteristics of boxes (e.g. stackability)	Packaging design (shipper)
	2. New packing method (modelling)	How and when an activity was performed and the condition created	Required number of boxes, characteristics of boxes, which items to combine in each box, order of packing	Packaging planning (shipper)

Table 18 (cont.). Actions taken in the cases studied

Case	Actions taken	Changes of the logistics activities: 'the change concerns…'	New conditions created	Which activity the change concerned
Distribution Round	1. Changes to order agreements	The condition created	Order size, delivery frequency and delivery time	Order planning (customer) and customer support (shipper)
	2. Change what orders to consolidate	The condition created	Number of orders to consolidate, number of items to pack and their characteristics, number of pallets and their characteristics	Transport planning (shipper)
	3. Change number of vehicles for distributing goods	The condition created	Number and type of vehicles, amount of extra booked capacity, distribution order, delivery address, delivery time, loading order	Transport planning (shipper)

Figure 32–Figure 34 link the actions to the logistics activities that were changed and lists the new conditions created in each case (described in Papers 4 and 6). They also show how load factor is influenced in terms of the required or available capacity and load factor level. These figures demonstrate how actions in different areas support one another to improve load factor performance and how changes create new conditions for logistics activities that in turn create new conditions for other logistics activities, before measuring the resulting load factor performance. In the figures, black arrows represent new conditions created in one activity that form the input to another. Grey arrows represent input to an activity that is not part of the change. Only new conditions created from changes are specifically pointed out. The numberings of the new conditions created as input to another activity follow the action number only if linked to a specific action, for example action 1 creates conditions numbered 1a, 1b, if new conditions can be derived from a specific action. If new conditions cannot be derived from a single action but from a combination of several, new numbering, separated from the action number, is used.

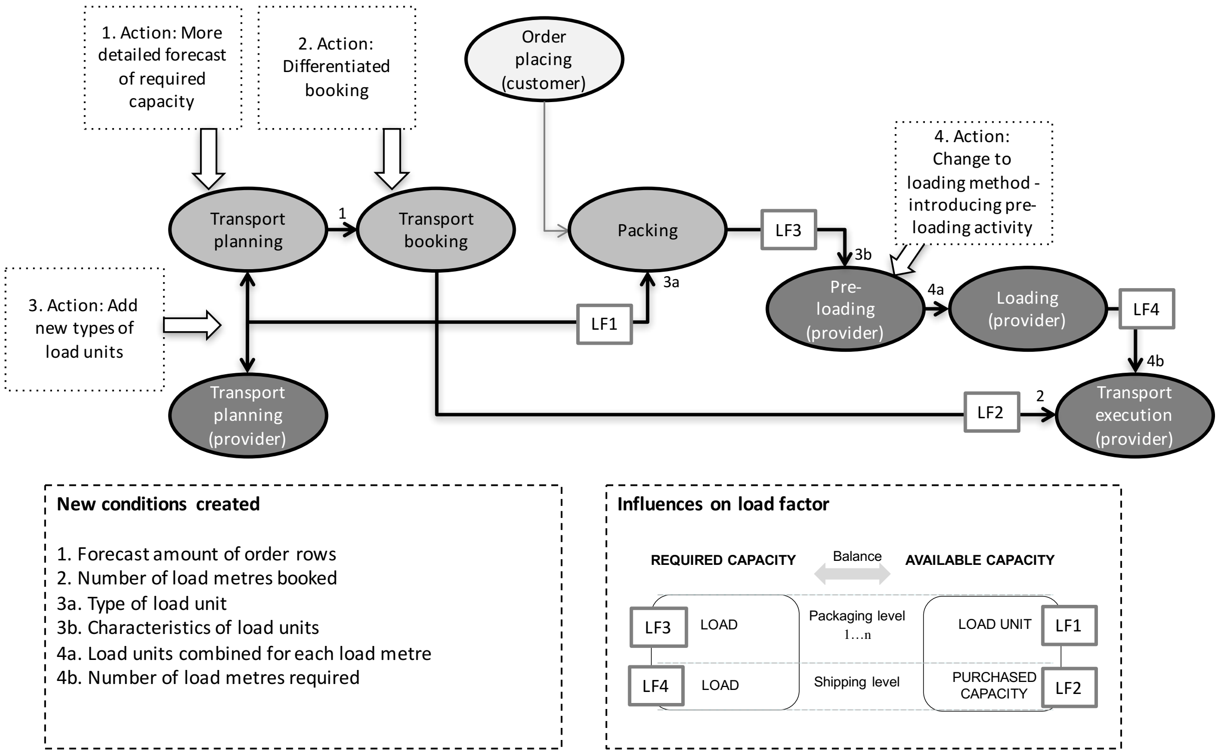


Figure 32: Actions taken, new conditions created and influences on load factor performance (LF) in the Fast Response case

In the Fast Response case, actions regarding packaging, loading and booking were taken (see Papers 4 and 6 for detailed descriptions). Each area independently improved the load factor performance. However, with regards to booking, two actions were needed. Differentiated booking was introduced (action 2 in Figure 32) to better match the order variations. The change concerned the conditions resulting from booking (that is, the number of load metres booked), which influenced available capacity on the shipping level (LF2). In order to match the booked capacity to the order variations, a more detailed prediction of the order pattern needed to be made before performing differentiated bookings (action 1 in Figure 32) and predicting the number of order rows to deliver. Moreover, new types of load units were introduced (action 3 in Figure 32) to better match the varying characteristics in the assortment of products offered to customers. The new type of load units influenced the available capacity on the packaging level (LF1): plastic boxes, steel racks and parcel cages. This action involved transport planning for both the shipper and the transport provider, since the reverse flow of load units needed to be planned for. Further, the parcel cages were owned by the transport provider and the shipper's outgoing flow was used to distribute the cages back into the transport provider's terminal network, which was a win–win situation for both parties. The new load units created new conditions for packing because items could be packed in a smarter way in the load unit, which influenced the required capacity on the packaging level (LF3). Further, the packing of items in the new load units created conditions for ways of loading the items on the booked vehicle, and the new characteristics of the load units made it possible to combine them (e.g. double-stacking), which influenced the required capacity on the shipping level. A change in loading method was implemented by introducing a pre-loading activity (action 4 in Figure 32). This change was introduced because the short lead time restricted the time for loading of goods onto the vehicle, making it difficult to find the best combination of load units for the purchased capacity. By introducing pre-loading activities, loading onto the vehicle took less time and load units could be combined to save space. The pre-loading activities took place at the shipper's warehouse, where it was performed by loading staff from the transport provider, a result of their close dialogue about how to improve the load factor. Introducing pre-loading activities reduced the required capacity on the shipping level (LF4). In the Fast Response case, the load factor on each load factor level was not measured; instead, the order rows/load metre booked were compared, with the result that it was possible to load nearly 7% more order rows/load metre booked after the actions were taken.

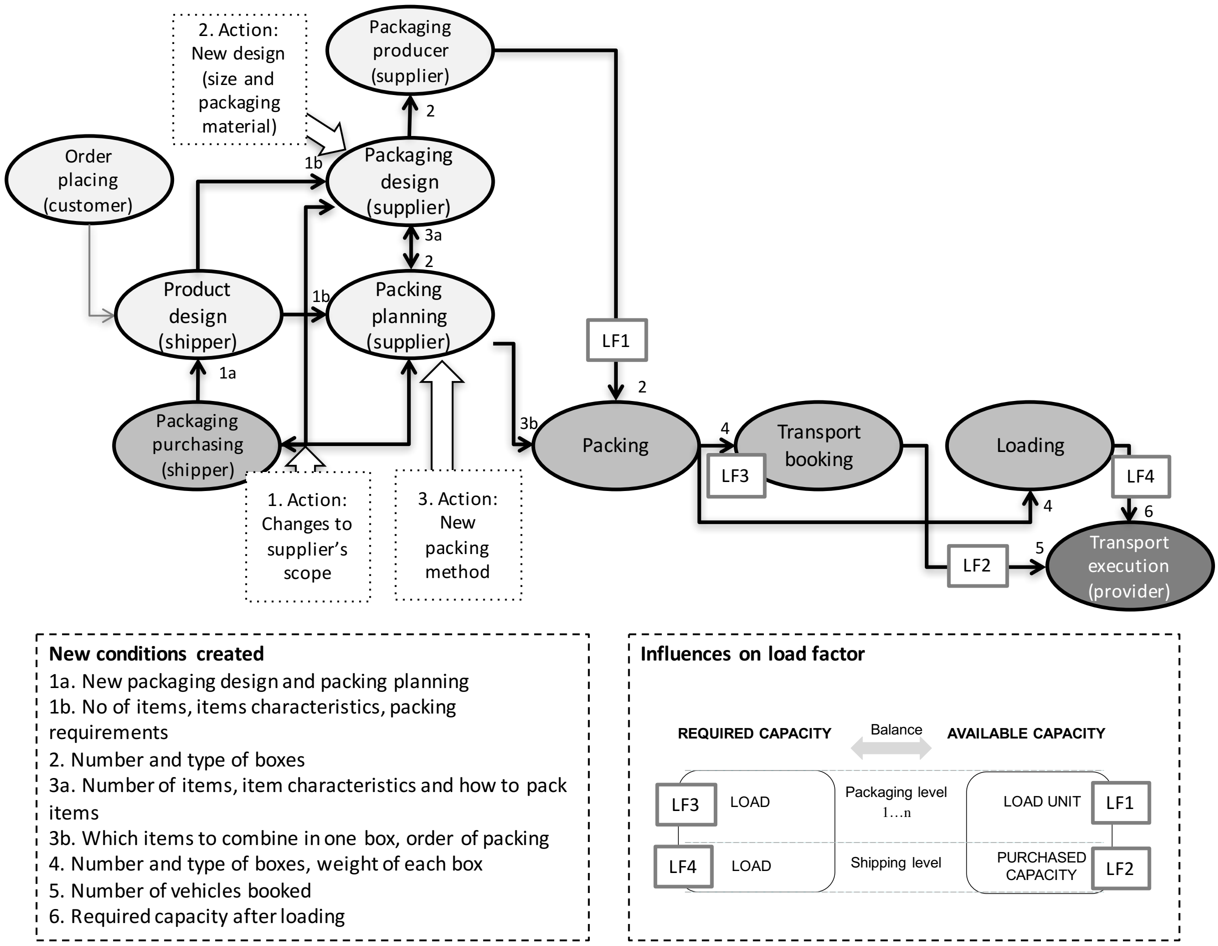


Figure 33: Actions taken, new conditions created and influences on load factor performance (LF) in the Project Delivery case

In the Project Delivery case, three actions were taken with regards to packaging and packing methods. For a more detailed description of the case, see Paper 6. The first action was to change the scope of the packaging supplier (action 1 in Figure 33). This change was made when purchasing packaging, the packaging supplier having been involved in a close dialogue about appropriate actions to improve the load factor in the packaging. New activities were introduced (planning packing), as well as designing a new packaging (box), which should match the items to be packed. Also, the new scope of the packaging supplier required the product design team to deliver information regarding the designed product: number of items, their characteristics and packing requirements. With regards to packing requirements, it was important to take into account the order of unpacking needed when mounting the product at the customer's site after delivery. Thereafter, the second and third actions were realised: 2. new packaging design and 3. new packing method (actions 2 and 3 in Figure 33), which created conditions for each other. These actions were taken to produce packaging (boxes) that matched the characteristics of the items to be packed. Before the changes, there were imbalances between required and available capacity owing to a large amount of unused space in the boxes (the boxes were too large). Each box was designed for each customer's order and was based on the products being packed.

Changing the design of the packaging (boxes) created conditions for planning packing in terms of the number and type (e.g. size) of the boxes. Changes to the packing method, that is, modelling the items and possible combinations to determine the required number of boxes and characteristics (e.g. shape and sensitivity) of the items to be combined created conditions for the packaging design. The new packaging design created new conditions for the packaging producer, which in turn created new conditions for packing in terms of the number, type and characteristics of boxes. The available capacity on the packaging level was determined based on the new type of boxes (LF1). The new packing plan created new conditions for packing regarding which items to combine and the order in which to pack items. The packing created new conditions regarding the weight of each box, since additional material might be needed to fix and/or protect the items in the boxes. The required capacity after packing the items was determined based on how the items were packed, number of items and their characteristics (LF3). The resulting number of boxes and their type and weight were input to the transport booking and loading. When booking the transport, the number, shape and weight of boxes to ship and how they could be combined on the booked vehicles determined the capacity to be purchased (LF2). This required capacity was determined based on how the boxes were loaded on each vehicle (LF4). The resulting load factor performance was improved on the packaging level (from 74% to 83%), as well on the overall level (from 49% to 56%). On the shipping level, the load factor was reduced (from 84% to 81%), since the required capacity was reduced more than the available capacity.

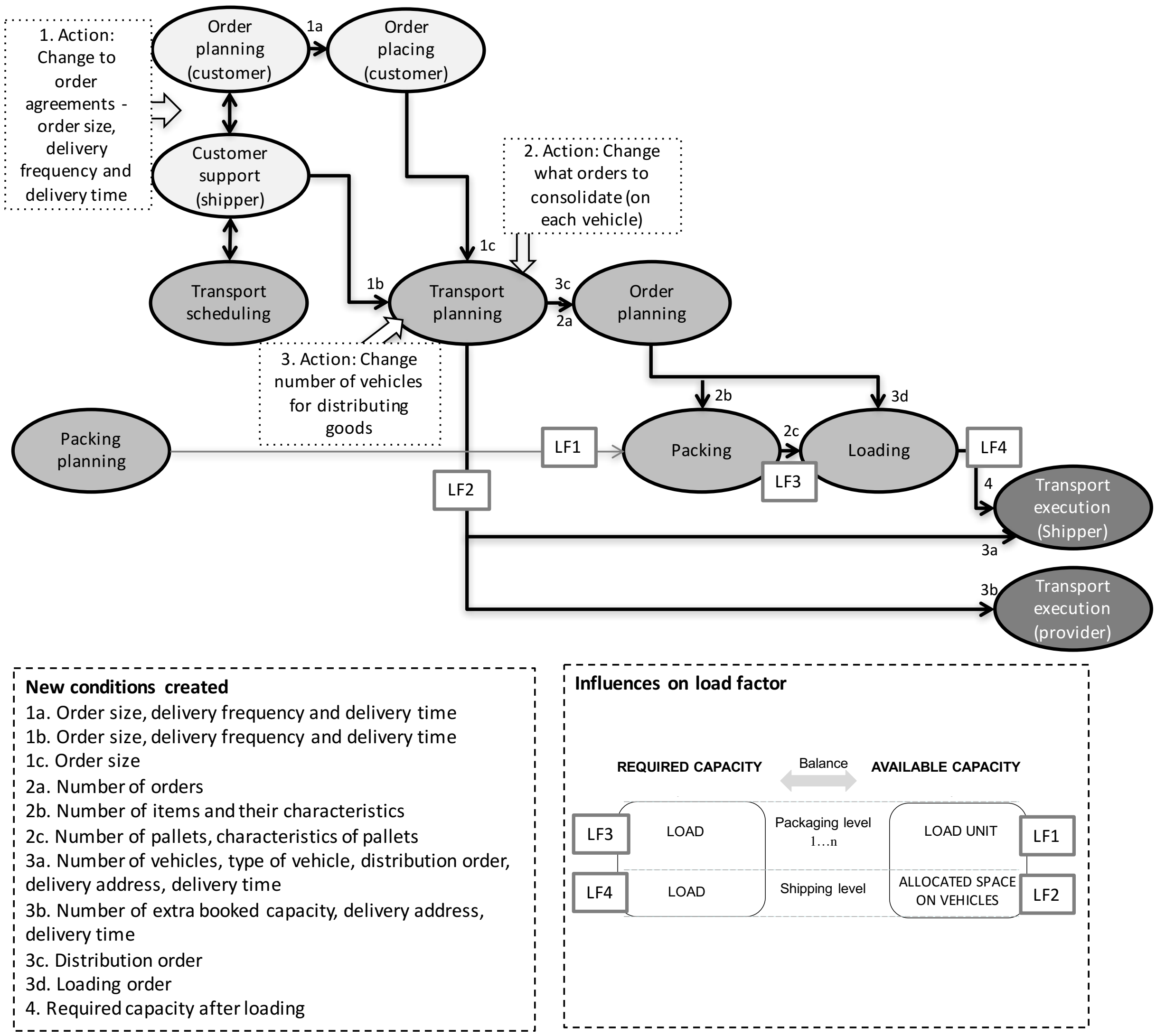


Figure 34: Actions taken, new conditions created and influences on load factor performance (LF) in the Distribution Round case

In the Distribution Round case, three actions were taken that supported one another to improve the load factor performance (see Paper 6 for details). The changes were made to ensure that the goods flowed, levelled out on weekdays, since order variations made it difficult to match the load with the available capacity on one vehicle in the distribution round each day. On high volume days, one vehicle was not enough and extra capacity had to be purchased, and on low volume days, the load factor was low. To even the flow, three interdependent actions were taken. First, close dialogue with the customer was necessary to achieve new order agreements (action 1 in Figure 34) that resulted in changes in the order sizes, delivery time and delivery frequency. Transport scheduling was closely involved in this dialogue, so that the agreements could be adapted to the schedule of the distribution round. When this change was made, it was possible to implement actions 2 and 3. New conditions relevant to transport planning were created from the order agreement and the customer's order regarding delivery frequency, delivery time and order size. These new conditions made it possible to take two additional actions. First, reducing the number of vehicles distributing goods to one (action 2 in Figure 34) resulted in the same available capacity each weekday and made it necessary to plan the distribution round differently; new conditions that were relevant for executing transport (i.e. which type of vehicle to use (LF2), delivery addresses and delivery time) were created. No extra capacity was purchased from external transport providers. As a result of the new transport planning, the distribution order created conditions for the order planning regarding the order in which to load packed items. Second, changing what orders to consolidate (action 3 in Figure 34) created new conditions for order planning with respect to the number of orders to consolidate on each vehicle. Further, the order planning created conditions for packing (number of items to pack and their characteristics) and loading (loading order). The result of the packing activity was the required capacity on the packaging level (LF3). As before, pallets were used to load goods onto vehicles, and they determined the available capacity on the packaging level (LF1). The packing created conditions for loading (number of pallets and their characteristics), resulting in the required capacity on the shipping level (LF4). The load factor performance was improved on the shipping level on low volume days owing to increased required capacity. On high volume days, the available capacity was reduced so that no extra capacity was needed. Thus, both required and available capacity were changed to achieve an improved load factor on the shipping level (since the load factor on the packaging level was not affected by the changes). On the shipping level, the load factor was improved from 38% to 57% on Tuesdays and Saturdays (the low volume days), whereas for Mondays and Fridays the load factor was reduced from 80% to 66%. On average, the load factor on the vehicle level was increased from 60% to 63%.

5.4.3 Discussion: What logistics actions improve the shipper's load factor performance

Previous studies mostly discuss improvements of load factor performance as one way (among several) to reduce the environmental impacts of freight transport (Léonardi and Baumgartner, 2004; Piecyk and McKinnon, 2010) or improve transport efficiency by means of transport costs savings (Bø and Hammervoll, 2010; Lumsden *et al.*, 1999). The two suggested frameworks, a framework for increasing load factor (Paper 4) and a framework of opportunities (Paper 6), link actions to load factor performance. In particular, the framework of opportunities contributes to previous research by providing an overview of actions that shippers can take to improve their load factor performance, and relates each action to the required and available capacity, respectively, as well as to information on how capacity is reduced/increased or reallocated between time periods.

Actions involve changing logistics activities so that new conditions are created to improve load factor performance, as the studied cases exemplify. Actions taken on a tactical level create conditions for the operational logistics activities. On an operational level, actions create new conditions by changing logistics activities in terms of:

1. **how** an activity is performed, for example how to load the goods onto the vehicle;
2. **when** in the process the activity is performed, for example packing the goods on the vehicle after all customer orders are in place (sequential) or while customer orders are being placed (parallel);
3. **which** activities are performed (activities can be added or removed from the process), for example, the goods can be pre-loaded on the warehouse floor before loading onto the vehicle instead of loading directly onto the vehicle, as in the Fast Response case;
4. **who** is involved in performing the activity, for example if the shipper or the transport provider is pre-loading goods.

The cases illustrate actions that are taken to manage imbalances by changing either required or available capacity, or both. To increase load factor, one action may not be enough, since there are interdependencies between activities. As the Distribution Round case shows, changes may occur stepwise (reducing the number of vehicles needed for distributing goods, changes to the order agreements). In the Project Delivery case, changes to two activities were necessary, since they created conditions for each other (packing planning created conditions for packaging design, and vice versa).

The shippers' logistics activities, freight transport activities and activities in the surrounding system influence load factor performance and hence are part of the changes to shippers' actions. Consequently, different actors are involved in the changes, as the studied cases show. Figure 35 provides an overview of actors' involvement in changes, as well as the activities that the changes affected.

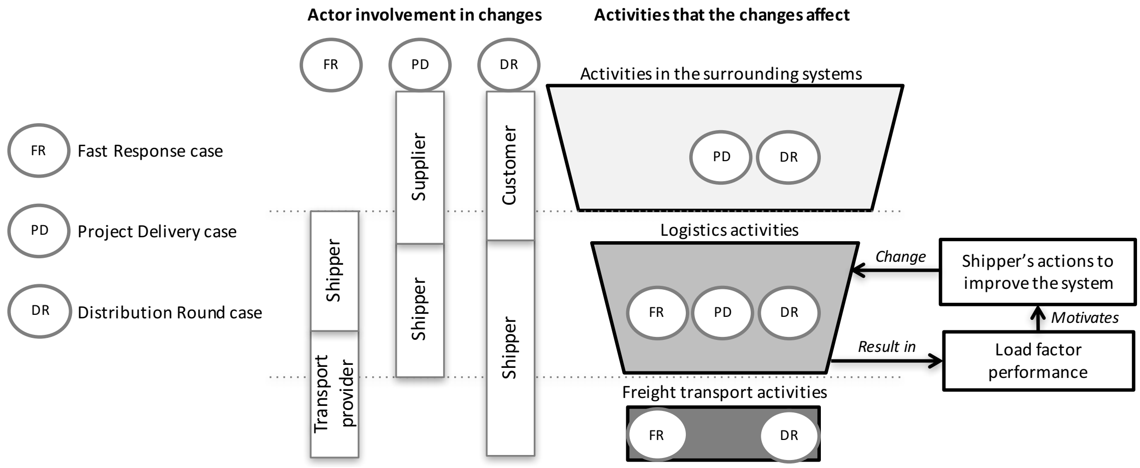


Figure 35: The differences in actor involvement in the activities that the changes affect (in the cases studied), related to different parts of the system

As shown in the cases, the load factor performance and the actions they took differed, for example regarding where imbalances between the required and available capacity occurred in the load factor model, which conditions influenced the load factor, which logistics activities took place and the order in which activities were performed. The 'framework of opportunities' provides a structure and overview of actions and their link to load factor performance. The shippers studied have adopted a number of such actions. What can be concluded from the cases is that the actions that were relevant and possible to implement, as well as the role of the shipper and those with whom they collaborated, varied depending on the situation of the shippers, for example with regards to what activities were part of their logistics system and the characteristics of their goods flow.

As also mentioned in 5.3, McKinnon (2015b) describes a fivefold classification of the constraints on vehicle utilisation and discusses opportunities to improve it. Several of the logistics actions identified and described in this thesis are also briefly described by McKinnon (2015b), such as the design of the packaging, in terms of shape, dimensions and stackability, which influence the use of vehicle capacity (although the focus is only on the vehicle level and does not include other load factor levels). McKinnon (2015b) also identifies other opportunities, such as geographical imbalances and priority given to outbound deliveries, which the research in this thesis does not cover, because the present focus is on the load factor performance in the shippers' outgoing goods flow. In particular, this thesis adds to previous research by providing details and structure about which logistics actions shippers can take to improve load factor, what changes such action concern, which new conditions are created and the interdependencies between such actions.

5.5 Conclusions relating to the research questions

The four research questions and their main results are illustrated in the conceptual framework for this thesis (see Figure 36). Below, the main conclusions for each research question are summarised.

The analysis of RQ1 provides an overview of action areas related to three approaches to reducing environmental impact. The action areas are linked to shippers' logistics activities and thereby provide a holistic understanding of ways to improve environmental performance for shippers. Among identified action areas, shown in relation to RQ1 in Figure 36, improving the load factor was found to be particularly relevant for shippers, first, because of its potential in reducing environmental impact by diminishing the need for traffic, second, owing to the apparent links between shippers' logistics activities and load factor performance, and third, because the actors themselves showed interest in improving the load factor as an important way to further improve the environmental performance of their transport activities.

The results of RQ2 show that the load factor could be measured overall, as well as on each individual level, namely packaging, shipping, vehicles and fleet, based on the balance between required and available capacity (see the load factor model in relation to RQ2 in Figure 36). The packaging(s) and the load factor on the shipping level result from shippers' logistics activities, while the load factor on the vehicle and fleet level result from transport activities (which can be part of the shippers' logistics activities if purchasing full truck loads. Such detailed measures yield a better understanding of the potential for improvements and what further actions might be taken on each of these levels, related to required and available capacity.

According to the results of RQ3, logistics activities in the areas of order and delivery, transport operations and packaging and loading are identified as influencing load factor performance, in terms of creating conditions from one to another or for one another (see the areas of influence for load factor in relation to RQ3 in Figure 36). The areas of influence includes logistics activities of the shippers, as well as of the transport providers and the surrounding systems (suppliers and customers). Conditions that determine the required capacity (number of items, item characteristics and how to pack/load) and conditions that determine available capacity on the packaging(s) level (number of units and type of units) are created in packaging and loading, which in turn are influenced by conditions created in order and delivery, transport operations and logistics structures. The available capacity on the shipping level is determined by conditions created in transport operations, which in turn are influenced by conditions created in the other areas of activity.

As concluded in relation to RQ4, actions can be taken that reduce/increase required and/or available capacity or that reallocate required and/or available capacity (see Figure 36), by changing logistics activities so that new conditions are created to support an improved load factor performance. Further, on an operational level, *which* activities are performed, *how* the activity is performed, *when* the activity is performed and *who* performs the activity can indirectly or directly improve the load factor performance as a result of the new conditions created from such changes. The results of RQ4 show that one action alone may not be enough to achieve an improvement in load factor performance; rather, several actions may be needed, related to more than one area of influence, requiring the involvement of several actors internally as well as externally, such as the transport provider, customers and suppliers.

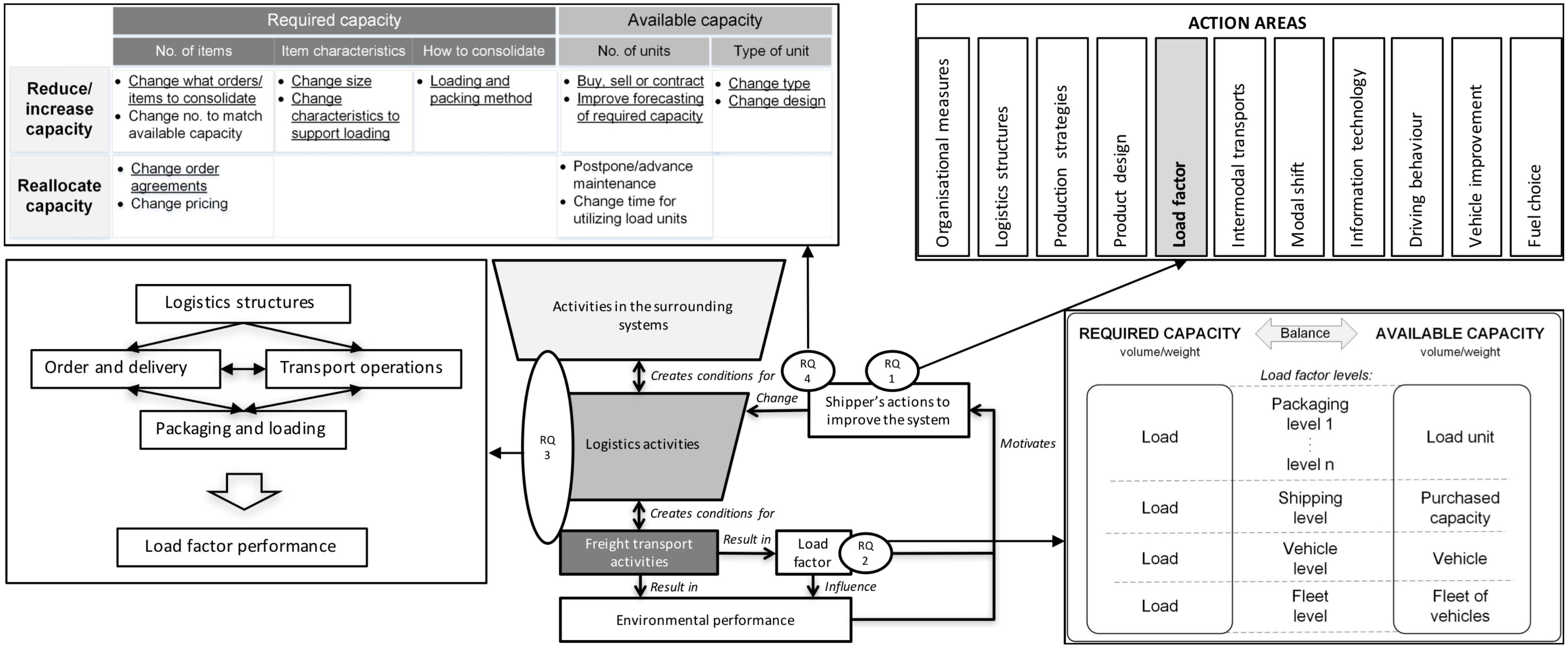


Figure 36: The research questions and the main results in relation to the key concepts relevant to the purpose of this thesis

6 Discussion

This chapter discusses the findings in relation to the purpose of the thesis and also describes the research contributions and practical implications. The chapter ends with suggestions for possible future research directions.

This thesis applies a systems approach to explain how shippers' logistics actions contribute to environmentally sustainable freight transport, inspired by Checkland (1999) (described in section 2.2). The results of each question is a building block that, in total, provides a broad picture of how shippers' logistics actions contribute to environmentally sustainable freight transport, in particular the resulting load factor performance, as shown in Figure 36. This chapter does not discuss the results from each research question (which can be found in chapter 5) but rather discusses the findings in relation to the overall purpose; to explain how shippers' logistics actions contribute to environmentally sustainable freight transport by clarifying the link between logistics activities and the resulting load factor performance. Two topics are raised that are relevant for the purpose: identifying actions that are relevant depending on the situation, and the importance of systems thinking when performing actions.

The results from each research question support the overall view of the system, in which the shippers' logistics activities are performed in relation to continuously changing circumstances (within the system as well as in the surrounding systems). This thesis explains how logistics actions can improve load factor performance and in what way such actions change the logistics activities and influence the resulting load factor performance. As concluded in section 5.4, however, the actions relevant to take differing according to the shippers' specific situations. In order to understand what actions may be applicable for other shippers, it is essential to discuss what makes actions relevant for the shippers studied. This issue is addressed in section 6.1.

Further, although this thesis identifies load factor as one important action for shippers aiming to contribute to environmentally sustainable freight transport (as also supported by previous research, e.g. Léonardi and Baumgartner, 2004; Aronsson and Huge-Brodin, 2006; McKinnon, 2015b), it is essential to be aware of how the actions taken to improve load factor performance influence other parts of the system, for example other key performance variables and potential conflicts with other performance goals. In section 6.2, the importance of systems thinking when implementing actions is discussed.

After the broad discussion on the two topics mentioned above, the contributions of the thesis, in terms both of research and of practical implications, are described in sections 6.3 and 6.4. Suggestions for further research are outlined in 6.5.

6.1 Relevant actions depending on the situation

The actions that are most relevant for a shipper to take to improve the load factor performance will vary, depending on the situation in which the logistics activities take place. One way to describe this situation is by characterising the outgoing goods flow, for example in terms of product range (small or large), characteristics of goods (shape, sensitivity, stackability, density), order lead times (short or long), order variation (low or high), use of private fleets (use of the shipper's own fleet or the use of external vehicles), type of transport service purchased (full vehicles or a portion of vehicles), number of delivery addresses (few or several) and variations in delivery addresses (low or high). Depending on the situations of the shipper, different combinations of goods-flow characteristics may exist. Exemplifying some different situations based on these goods-flow characteristics, using the experiences in the cases studied, a better understanding can be achieved of what actions are of relevance when. Situations that differ with regards to order lead time and order variations are discussed below.

As noted in section 5.3, the activities in the area of order and delivery create conditions for other logistics activities, for example in terms of order lead time, which has an influence on the load factor. That order lead time has an influence on load factor is also supported by Piecyk and McKinnon (2010). Order lead time is one characteristic of the goods flow that differed in the cases studied. Adapting to a short order lead time (13–18 hours in the Fast Response case) can be challenging for achieving a high load factor, first, because of the short planning horizon for packing, loading and executing the transport and, second, because of the short time for performing the operations (packing and loading). In the Fast Response case, such challenges were handled by improving forecasting, so that purchased capacity could be better matched with actual order stock. Also, using the time before loading the items on to the vehicles to prepare the loading (by introducing pre-loading activities) made the actual loading proceed faster and resulted in better utilisation of the space. A further way of approaching the problem could be to be more flexible about order lead time, encouraging customers to place their orders in advance and/or stipulating a later delivery time to enable better planning. Similarly, McKinnon (2010) suggests adopting a nominated delivery day system as another way of improving the load factor, which relates to changes in the order lead time and to the service level provided. By contrast, the long order lead time of 1.5 to 2 years in the Project Delivery case made it possible to plan in detail how to pack and load the items to be shipped. Improvements to the load factor were thus focused on designing the packaging according to the specific items to be packed, as well as detailed planning of the packing of items, before performing the packing operation. Consequently, the length of order lead time was one characteristic in these cases that made different actions appropriate. A long lead time made it possible to plan the operational activities in detail for each specific delivery, while a short lead time moved the focus towards improving the forecasting and standardised/improved ways of performing the activities.

Handling a high level of order variation was a challenge for both the Fast Response and Delivery Round cases. Order variation influences load factor and is a constraint on vehicle utilisation, as identified by McKinnon (2015b) and Bø and Hammervoll (2010). As one option, McKinnon (2015b) states that when there is a fluctuation in demand that can be predicted, vehicle capacity can be planned to meet demand peaks. In Fast Response, order variation in combination with a large product range made it very challenging to forecast capacity and then to pack and load the different product combinations in the order stock. As mentioned above, forecasting could be improved, and also, similar to the suggestion of McKinnon mentioned above, order peaks could be met with additional vehicle capacity, agreed with the transport provider (extra capacity could be purchased at a late point in time before departure). Also, the introduction of new load units, better adapted to different combinations of products with different characteristics, improved the load factor in this case. In Distribution Round, the problem was not that the peak days could not be matched with extra vehicle capacity (as suggested by McKinnon, 2015b) but that there was a low load factor when there were few goods to carry on low volume days. Since the same customers were placing the orders from day to day (with the same delivery addresses), a dialogue with the customers was realisable, which made it possible to change the order agreements so that goods could be transferred from one day to another and a more even goods flow was achieved. Also, in Bø and Hammervoll (2010), it is stressed that one way of reducing such fluctuations is to encourage customers to order more volume of products on low volume days. In Distribution Round, as there were few delivery addresses and no variation in those delivery addresses between days, a long-term agreement could be reached. This was not manageable in the Fast Response case, since they had a large number of delivery addresses and also a high variation of these from day to day (involving several different customers). Hence, ways to deal with order variations differed between cases. If few customers were involved, it was possible to have a dialogue with the customers to agree on changes to even the flow, whereas if there were many and varying customers involved, the operations were instead adapted to handle the order variations more efficiently. In addition to such options, McKinnon (2015b) suggests dealing with demand fluctuations by introducing a nominated day delivery system and an order and delivery timetable (which also influence the frequency and order lead time, as mentioned above).

6.2 The importance of systems thinking to realise actions

Measuring the performance contributes to shippers' understanding about the output of the system at a specific point in time, and also motivates further actions. Evaluating environmental performance of shippers' freight transport (as illustrated in Paper 2) can yield a broad understanding of which action areas to apply, load factor improvements being one of several areas that can be identified from such an evaluation. With an understanding of which area to focus on, more detailed actions can be identified within each specific area. Evaluating the load factor performance based on the structure in the load factor model motivates actions that will increase, decrease or reallocate either required or available capacity by changing any of the determining aspects of that capacity. Since the load factor model can be described as causally oriented, it links load factor performance to activities that influence it on several levels, which also support one another. Still, other performance variables may be affected by changes related to promising logistics actions that are taken to improve load factor performance among shippers. Although increasing load factor is a key variable for improving the environmental performance from transport, actions taken to improve load factor alone may also involve changes in other key variables for environmental performance, such as vehicle type and routeing. The same reasoning would apply to logistics performance, if logistics actions to improve load factor imply changes to the customer service level. To avoid sub-optimising the system, actors must therefore take into account goals for other parts of the system as well, such as the transport system or larger systems goals.

6.2.1 Influencing environmental performance by improving the load factor

Although load factor is undoubtedly a key variable for environmentally sustainable freight transport, a high load factor is not always beneficial for the environmental performance of freight transport activities, as will be discussed below. Load factor is one among several variables, mode choice, routeing (e.g. distance) and vehicle type being examples of other key variables influencing the environmental performance of transport. In the cases studied, all examples of actions taken contributed to an improved load factor in their purchased transport share, saved vehicle-kms being identified in two of the cases (Project Delivery and Distribution Round) and released capacity for the transport provider in one case (Fast Response). When all variables are constant, a high load factor provides better environmental performance. Taking action to improve load factor may also involve other variables, however, thus influencing environmental performance as well.

As an example, one way to improve load factor is to switch from a larger to a smaller vehicle; full loads may then be delivered with higher frequency. As Gucwa and Schafer (2013) observed, however, using a larger vehicle may result in a less energy-intensive operation (as long as the shipper consolidates the goods to be delivered less frequently), even if the load factor is lower. This can be compared with the Fast Delivery case, where changes concerned purchasing LTL capacity instead of FTL. Another option would have been to execute the transport with a smaller and thus fuller vehicle. Nevertheless, for their purchased transport share, their load factor and environmental performance would be more improved by using the larger vehicle. As long as the transport provider can use the spare capacity by consolidating other customers' goods in the vehicle as well, the operation will be more energy-efficient.

Also, the order of deliveries in a distribution round is relevant for environmental performance. Arvidsson (2013) argued that, in order to minimise fuel consumption in a given distribution round, the heaviest goods should be delivered first; in this way, the vehicle is emptied as quickly as possible. During a delivery round, when measuring the load factor at each stop, the lowest load factor will thus generate the best environmental performance. Similarly, in the study by Glock and Kim (2015), in which emissions costs were considered when routeing vehicles in a supply chain, they concluded that 'routes should be restructured in such a way that vehicles drive long distances empty or with a lower vehicle load to reduce fuel consumption and therewith emissions' (p. 512). For Distribution Round, in which customer orders to four shops were consolidated in one distribution round, their environmental performance would be improved if they also took into account the delivery order to empty the vehicle as quickly as possible.

Another way to increase load factor is to change logistics structures. One example from the literature is to centralise warehouses to achieve main flow consolidation. This could make it possible to change to another mode of transport, for example from road to rail (Aronsson and Huge-Brodin, 2006), increasing the load factor and reducing the environmental impact compared to road transport.

6.2.2 Influencing logistics performance by improving load factor

Further, shippers must be aware of logistics performance goals. In order to avoid sub-optimisations, it is appropriate to view load factor as part of a larger logistics performance measurement system (Caplice and Sheffi, 1995; Holmberg, 2000). Common logistics performance measures related to transport (Fawcett and Cooper, 1998) include cost (transport cost), asset management (inventory level), customer service (average lead time) and quality (damages). How these performance measures are influenced will differ from one situation to another and will depend on which types of actions the change requires. There are, however, examples of how other performance measures influence the realisation of actions for improving load factor performance.

In terms of cost, reduced transport cost can be expected from increasing the load factor (as shown in all the cases); this also meshes with previous research, for example that of Bø and Hammervoll (2010). In terms of asset management, the inventory level can be influenced by several actions, including changing the number of items by reallocating capacity between time periods; this change was exemplified in the case of Distribution Round, where levelling the flow between days resulted in reduced order sizes on Mondays and increased sizes on Tuesdays. This change affected the inventory level on each day but did not limit the possibility for realising the changes. In terms of customer service, the lead time was shown to influence load factor, since that was one result from order agreements. In particular, in Fast Response, the company viewed lead time as an order winner, although it constrained the firm's possibilities for forecasting customer orders and planning how much transport capacity was needed. When considering quality, the risk of damage to goods can limit load factor performance. The results from this thesis showed that the items' characteristics create conditions for how to pack and/or load the items; for example, sensitive items cannot be double-stacked due to the risk of damage.

6.2.3 Involving other actors

Further, since the load factor performance is influenced by conditions that are created as an output from activities in the logistics system, the transport system and the surrounding system, the involvement of actors outside the shippers' logistics system is important for realising logistics actions. The three cases exemplify different actors' involvement in the shippers' efforts to improve: Fast Response collaborated with the transport provider, Project Delivery collaborated with the supplier of packaging and for Distribution Round dialogue with the customers was crucial for realising the relevant actions. The cases also illustrate the importance of involving actors related to different logistics functions internally, such as transport planning and packing. Collaboration between actors in order to increase load factor has been demonstrated in, for example, the work of McKinnon (2015b), by identifying a lack of inter-functional relationships as a constraint on vehicle utilisation, and Tacken *et al*. (2014), who identified inter-company collaboration as an influence on vehicle utilisation in the German logistics sector. In the cases, it was possible to find ways to improve the load factor that did not conflict with the other performance goals of the involved actors. Therefore, a dialogue with actors in the surrounding systems is crucial, not only for implementing actions but also to understand potential conflicts of goals and to discuss their respective priorities.

6.3 Research contributions

This study contributes to current knowledge within the discipline of green logistics research. By taking a phenomenon-driven stance and an explicit systems approach, frameworks are developed, in which links between logistics activities and load factor performance are clarified and conceptualised. Detailed descriptions from the perspective of shippers are provided, regarding how load factor can be evaluated, how logistics activities influence load factor performance and what actions can be taken to improve the load factor performance. Each part contributes to an overall understanding of how different elements in the system under study are linked.

The fact that logistics activities creates conditions for freight transport activities and the resulting environmental performance is an important consideration arising from previous studies within green logistics (Aronsson and Huge-Brodin, 2006, Piecyk and McKinnon, 2010). This research adds to previous work by clarifying the link between logistics activities and the resulting load factor performance as a way of explaining what actions improve such performance. This research also contributes to green logistics research by taking a clear shipper's perspective, which has been underrepresented in research to date (Marchet *et al*., 2014). Such a perspective enables an in-depth understanding of how shippers can improve their load factor performance.

Previous studies have stressed the importance of load factor as a key variable for improving the environmental performance of transport (McKinnon, 2015b; Léonardi and Baumgartner, 2004) or transport efficiency (Samuelsson and Tilanus, 1997b; McKinnon and Ge, 2004). However, load factor is mostly treated as one aspect among many, for example by Samuelsson and Tilanus (1997b), Léonardi and Baumgartner (2004) and Piecyk and McKinnon (2010), and few details about load factor are provided. The focus in this thesis on load factor performance contributes to both the green logistics and transport efficiency literature by providing details about how to evaluate the load factor, how logistics activities influence the load factor and what logistics actions a shipper can take to improve the load factor.

A systems approach is applied throughout this thesis, permeating the logic in the resulting frameworks. Though systems approaches are generally thought to significantly influence logistics research, such influences are seldom explicitly described (Lindskog, 2012). This thesis thus contributes to the logistics research discipline by explicitly describing the view of the system, inspired in part by Checkland (1999). The system under study is taking into account interdependencies between shippers' logistics activities, freight transport activities and activities in the surrounding systems, as well as the resulting performance and its motivation of actions to improve the performance of the system.

6.4 Practical implications

In essence, the results contribute to an increased ability for shippers to structure their improvement work towards environmentally sustainable freight transport. The results from the research questions provide an overall understanding of the ways in which shippers can take action and point out that the actions that will improve load factor performance in shippers' specific situations will vary. The results of this thesis can be applied to shippers in other situations by understanding the logic between the building blocks in the conceptual model of the system studied (Figure 13). Figure 37 proposes a number of steps that a shipper can take in order to gain an understanding of how to improve load factor performance.

Step	Relevant question	Details	Results from this thesis to apply
1. Evaluate the resulting performance	What is the resulting load factor performance?	– Describe load factor as the balance between required and available capacity at each load factor level – Calculate load factor (at each level and overall) – Identify if imbalances exist, and on which level(s)	See RQ2: Load factor model (Paper 5)
2. Identify causes for imbalances	Why are there imbalances?	– Where imbalances exist, identify which conditions influence required vs. available capacity – Identify any activities that create such conditions	See RQ3: Figure 28, overview of influences on load factor, load factor model (Paper 5), framework for increasing load factor (Paper 4)
3. Identify relevant actions	Which actions could improve load factor?	– Identify actions, in terms of changes of relevant activities (which, how, when, who and the conditions created) – Identify interdependencies—is more than one action necessary?	See RQ4: Framework of opportunities (Paper 6), detailed descriptions from cases (papers 4 & 6), and figures 32-24
4. Realise actions	Which actions are realisable?	– Identify other actors that need to be involved (internal/external) – Identify conflicts with other performance goals	See RQ4: Detailed descriptions from cases (papers 4 & 6) and figures 32-34

Figure 37: A stepwise guide for shippers regarding how to improve their load factor performance

The results from this thesis can be applied to each step detailed in Figure 37. The first step is to evaluate the current load factor performance in order to gain knowledge about any imbalances and potential for improvement. Next, any causes of imbalances need to be understood in terms of which conditions have an influence on required and available capacity in this particular situation and which activities currently cause such conditions. In order to identify relevant actions, existing imbalances – and their causes – need to be taken into account. With this knowledge, shippers can determine which activities should be changed and which new conditions can be created from possible actions to improve the load factor performance. In order to realise relevant actions, shippers must also decide if other actors need to be involved and if there are any conflicts with other performance goals from the relevant actions. Additional causes of imbalances, as well as relevant actions arising from additional interdependencies between activities, may be identified from such discussions; thus, decision making and action may be an iterative process, shown in Figure 37 by the arrows going back from step 4 to steps 2 and 3. Finally, an evaluation of improvements needs to be undertaken after the changes have been implemented (arrow back to step 1 from step 4) to provide information and motivating further actions. This is equally a process of continuous learning and evaluation to improve the system.

6.5 Further research

This thesis studies how logistics actions can improve load factor performance in shippers' outgoing goods flow. The load factor model (Paper 5) measures load factor in the outgoing goods flow at the point of departure from the shipper, while the opportunity framework addresses how different logistics actions influence load factor performance at this point. In order to improve the load factor, it is necessary to be aware about other parts of the system, so that sub-optimisations are not created there, such as in the transport system. For example, the load factor will vary within a distribution round and the total environmental performance of the round trip will depend on the order of delivery and total distance driven. Further research could therefore benefit from broadening the scope of the model, for example linking the model to key variables of larger performance measuring systems, such as load factor in relation to distance driven for each delivery/pick-up point. It would also be interesting to include the incoming goods flow in a future study, to measure the load factor at the point of delivery and study opportunities for such improvements, for example by consolidating different suppliers' goods.

The current findings show that not only shippers' logistics activities but also freight-transport activities and activities in the surrounding systems influence load factor, and therefore the involvement of other actors is crucial for improving the load factor performance. Future research could broaden the scope to involve transport providers and customers, for example, and could take a triadic or supply-chain perspective. This would illuminate how different actors can be involved when improving load factor performance and how such collaboration or coordination can be achieved when taking action. The starting point for further research could therefore be a specific theory to explain how actor involvement can be enhanced when improving load factor performance, such as by means of collaboration, coordination mechanisms and understanding the power balances between actors. As an example, Martinsen (2014) studied how to achieve greener supply chains, taking into account power balances and coordination mechanisms, in order to understand how environmental activities could be included in the relationship between shippers and transport providers. Future research could provide more details with regards to different actor constellations in the specific case of improving load factor as one environmental activity in the supply chain.

As discussed in the thesis, which actions are the most relevant in order to increase load factor will differ between companies' situations, regarding, for example, length of order lead time, level of order variation and product characteristics. Future research could study the differences between shippers' situations on a larger scale to provide guidance for increasing the load factor, for example based on characteristics of the goods flow. For such a study, a survey could be a suitable data collection method, and propositions derived from this thesis could be tested in a statistical analysis.

Moreover, this research also focuses on road freight transport. Although the results show a promising ability to be applicable to other transport modes, further research could test and develop the frameworks by adapting them to specific situations; for example, will the same logic apply for measuring load factor in rail or sea transport? What actions are applicable to improving load factor in different transport modes?

Finally, as a way to explain how shippers can take actions to improve their load factor performance, this thesis suggests a stepwise guide for the shipper to take in order to identify any promising actions for improving load factor performance. The suggested guide could be tested among other shippers to validate the relevance of the questions and to develop it further. It would benefit from more detail about the realisation of actions. More detail about what exactly makes an action realisable in a shipper's situation would facilitate our understanding of which actions to apply in each specific context and how to apply them. As pointed out by Rogerson and Sallnäs (2015), coordination of the internal logistics activities is important for improving load factor performance, and further research could explore this issue in more depth. As also mentioned above, the relationships with other actors, such as the transport provider or the customer, is also relevant for improving load factor performance, which means that understanding their perspectives may be valuable in finding ways to involve them in such improvement work. In addition, in terms of other performance goals that may constrain or limit the possibilities for implementing a specific logistics action, further research is needed about the conflicts that exist between load factor goals and other performance goals, as well as the ways in which shippers can handle these conflicts. For example, customer service (order lead time) has been shown to place a limitation on load factor, but it is not certain that all customers need such fast delivery (as described in Paper 4). Thus, it is important for shippers to conduct a dialogue internally and externally about the importance and priority of different goals. Action research should then be considered for approaching such managerial and organisational problems, with a view to obtaining in-depth understanding about how actors can handle specific trade-offs in different parts of the system.

7 Conclusions

This thesis explains how shippers' logistics actions contribute to environmentally sustainable freight transport, by clarifying the link between logistics activities and load factor performance.

An overview of actions that can contribute to environmentally sustainable freight transport are provided and linked to actors' perceptions of their importance and to shippers' logistics activities. This thesis concludes that, for shippers, reducing the amount of traffic by improving the load factor is of high relevance to improve their environmental performance in transport.

In particular, the imbalances between required and available capacity (which defines the load factor) need to be understood for each load factor level. For shippers, it is suggested that the load factor can be measured overall and on the packaging and shipping levels, which is a result of the shippers' logistics activities. If the shipper purchases less than truckload (LTL) capacity, the load factor can also be measured as a result of the providers' transport activities, on the vehicle and fleet level.

This research shows that logistics activities within the areas of *order and delivery*, *transport operations* and *packaging and loading* can influence load factor performance, directly or indirectly, by creating conditions for one another. Conditions that determine the required capacity (number of items, item characteristics and how to pack/load) and conditions that determine available capacity on the packaging level (number of units and type of units) are created in packaging and loading, which in turn are influenced by conditions created in order and delivery, transport operations and logistics structures. The available capacity at the shipping level is determined by conditions created in the transport operations, which in turn are influenced by conditions created in the other areas of logistics activities.

Actions can be taken that reduce/increase or reallocate required and/or available capacity, by changing logistics activities so that new conditions are created to support an improved load factor performance. On an operational level, changes to *which* activities are performed, as well as *how*, *when* and *by whom*, can indirectly or directly improve load factor performance by the new conditions that are created by such changes. Because of the interdependencies between logistics activities, several actions may be needed, related to more than one area of influence, and additionally the involvement of several actors, internally and externally. Moreover, influences on other parts of the system must be considered, so that sub-optimisations are not created by the logistics actions undertaken.

Finally, what actions are most relevant for a shipper to take will differ depending on the situation in which they operate, such as which logistics activities are performed and the characteristics of the goods flow. The results of this thesis will help shippers to determine how to improve their load factor performance and hence contribute to environmentally sustainability freight transport, specifically by 1) evaluating their current load factor performance, 2) identifying the causes of any imbalances, 3) identifying relevant actions, 4) implementing these actions, and 5) evaluating the improvements after changes have been made.

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