THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

# Energy efficiency improvements in logistics as a means to environmental sustainability:

## The case of capacity utilisation in road freight transportation

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Division of Service Management and Logistics

CHALMERS UNIVERSITY OF TECHNOLOGY
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# Energy efficiency improvements in logistics as a means to environmental sustainability:

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## Abstract

The energy consumption in logistics, and especially in road freight transportation, is steadily increasing and with that the greenhouse gas emissions which have a negative impact on the environment. In order to improve environmental sustainability of logistics, a change in the actors' behaviour and policies is needed since the development of technology alone is not sufficient. This thesis addresses energy efficiency improvements in logistics by using unutilised capacity as a means to environmental sustainability. This way, energy which has been untapped can finally be utilised. A framework of energy efficiency and its building blocks is developed. Causes of unutilised capacity are identified and countermeasures proposed. Further, the logistics fulfilment in the last leg of the supply chain is analysed with focus on the role of the end consumer in order to reach energy efficiency.

This thesis is a compilation of three papers based on a literature review, secondary evidence and two interview studies. First, literature within freight transportation, logistics and supply chain management that focuses on the energy-logistics domain and environmental sustainability was reviewed. Second, secondary evidence from logistics service providers and their customers was analysed in order to outline current practices and activities in the industry. Third, the first interview study was conducted with logistics service providers and their customers and focused on *where* unutilised capacity is available and *how* it can be utilised. And fourth, the second interview study with actors who work within the last mile focused on logistics fulfilment and identified energy efficiency characteristics of different fulfilment options as well as assigning the end consumer a distinct role in the logistics system.

The thesis contributes to the fields of road freight transportation and logistics at a cross-section with sustainability. Its contribution to management includes a framework on where the potential for improvement of energy efficiency is and how it can be exploited as well as a framework for logistics fulfilment with a focus on energy efficiency.

**Key words:** Capacity utilisation, distribution structure, energy efficiency, household logistics capability, last-mile fulfilment, logistics system, overcapacity, road freight transportation, system boundaries, system levels.

# List of appended papers

## Paper I:

Wehner, J., Halldórsson, Á. & Lumsden K. (2015), 'Energy Efficiency by Utilising Overcapacity in the Logistics System?'.

*An earlier version of this paper was published in the proceedings of the 20$^{th}$ Annual Conference Logistics Research Network Conference (LRN 2015), 9-11 September 2015, Derby, United Kingdom.*

*The first author was responsible for the data collection under advisement of the other authors. The paper's planning, data analysis and writing was equally shared among the first and second authors. The theoretical framework was developed by all authors.*

## Paper II:

Wehner, J. (2017), 'Increasing energy efficiency in road freight transportation: Analysing causes and countermeasures of unutilised capacity'.

*This paper has been sent in to an international journal. An earlier version with the title 'Improving Energy Efficiency in Supply Chains: The Case of Overcapacity in Road Freight Transportation' was presented as a work-in-progress at the 28$^{th}$ Annual Nordic Logistics Research Network Conference (NOFOMA 2016), 8-10 June 2016, Turku, Finland.*

## Paper III:

Halldórsson, Á. & Wehner, J. (2017), 'Sustainable Development of Logistics: The Case of Energy Efficiency in Last-Mile Fulfillment'.

*This paper has was published in the Proceedings of the 29$^{th}$ Annual Nordic Logistics Research Network Conference (NOFOMA 2017), 8-9 June 2017, Lund, Sweden.*

*The paper's planning, data collection, analysis and writing were equally shared among the authors.*

# Acknowledgements

Around two and a half years ago, I started my journey as a PhD student. This time has taught me a lot and I have had many great experiences, for which I would like to thank my colleagues, friends and family.

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Jessica Wehner

Gothenburg, July 2017

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# 1 Introduction

This chapter will present the introduction to the research, starting with the background, problem area and research setting and continuing with the purpose and research questions.

## 1.1 Background

Energy is needed when operating logistics and especially for the transportation of goods and humans. Further, energy is both a cost and a key resource to time-based, flexible and reliant deliveries. Especially transportation is depending upon the use of fossil fuel as key energy source (OECD/IEA, 2015b). Fossil fuels emit greenhouse gases (GHGs), which in turn intensify global warming. Average temperatures have been rising around 0.70-0.75° Celsius during 1910-2009 (Wen *et al.*, 2011). The European Union (EU) wants to keep climate change below 2° Celsius (European Commission, 2011c). The international community has agreed and adopted in December 2015 the Paris Agreement, a long-term goal to keep an increase of global temperature below 2° Celsius above pre-industrial levels (European Commission, 2016b). The development towards environmental sustainability and a reduction of GHG is also reflected in the sustainable development agenda on 'climate actions' and 'responsible consumption and production' set by the United Nations to ensure access to affordable, reliable, sustainable and modern energy for all humans by 2030 at the latest (United Nation, 2017). Against this background, this thesis investigates the potential for improvement of energy efficiency in logistics as means to environmental sustainability.

The thesis is part of a research project called 'The Fifth Fuel – Energy Efficiency through Effective Freight Transport in Sustainable Urban Areas' and funded by the Swedish Energy Agency. The concept of the 'The Fifth Fuel' calls for innovative thinking, applicable knowledge and a methodology to achieve the vision of 'energy-efficient freight transportation', where value is created through the availability of integrating unutilised capacity as a part of urban areas – the transportation of goods in the down-stream part of the supply chain. This thesis, in particular, focusses on road freight transportation because this is the most common transport mode for freight transportation into and within urban areas, and accounts for over 70% of all transport GHG emissions (European Commission, 2016a).

By conducting interviews to investigate improvement efforts taken by logistics managers both from shippers and logistics service providers (LSPs) during the last legs in the supply chain, this thesis takes a multi-actor approach. This approach helps to map current activities taken in industry and to propose opportunities in regard to improving energy efficiency in logistics. Such an improvement, especially in freight transportation, is of high importance in order to reduce the total energy consumption and GHGs. By applying the systems view as the theoretical lens, the logistics system is viewed as in steady interaction with its environment and among its components (Arbnor and Bjerke, 2009).

This thesis is a compilation of three papers based on a literature review, secondary evidence and two interview studies. The research contributes to the fields of road freight transportation and logistics at a cross-section with sustainability.

## 1.2 Problem area

In order to minimize the global impact from GHG emissions, all EU member countries committed themselves to reduce GHG emissions by 80-95% by 2050 compared to 1990 (European Commission, 2011b; European Commission, 2011c). This requires a reduction of GHG emissions of at least 60% in the transport sector, a sector which is emitting a still growing amount of GHG emissions (European Commission, 2011c).

Freight transportation is an energy intensive operation and mainly powered by fossil fuels, which comes from a time when these fuels were generally considered to be inexpensive and plentiful (Rogers *et al.*, 2007). In 2013, transportation was responsible for over 63% of the world's oil consumption (OECD/IEA, 2015b). For the future, the International Energy Agency expects energy consumption in transportation to increase even further by almost 30% by 2030 and 80% by 2050 and the transported volume to nearly double by 2050 compared to 2006 (OECD/IEA, 2009). The Swedish Transport Administration foresees a 50% increase in freight transport (exclusive of air freight) by 2030 compared to 2006, whereof road freight transportation will grow the most (Trafikanalys, 2016). Because road transportation is congested in urban areas, emissions are much higher in the same areas (OECD/IEA, 2015a). In total, transportation in urban areas is responsible for around one fourth of all GHG emissions from transport (European Commission, 2011c). Besides greenhouse gases other substances are also emitted from transportation which are dangerous to the environment and to humans.

New technologies and a shift to fossil free fuels are moves in the right direction but not enough. Even electric driven vehicles are not free of GHG emissions. Depending on the primary energy source, GHG emissions can be generated when the electricity is produced (Piecyk *et al.*, 2015). In order to reduce the energy consumption in road freight transportation, a change in the management and organisation of logistics is suggested. In Europe, the load factor of road freight vehicles was on average under 50% by weight for the time period from 1997 to 2007 (European Environment Agency, 2017). Differences amongst countries show there is potential for improvement. By using unutilised capacity in the road freight transport sector and adjacent logistics activities, energy efficiency in logistics as a means to environmental sustainability can be improved. Identifying where this unused potential is and how it can be utilised in order to reduce the energy consumption and improve energy efficiency in freight transportation and adjacent logistics activities, is the aim of this thesis. Especially, the question of how this potential can be exploited needs detailed investigation, and ongoing changes in logistics such as the growth of e-commerce need to be considered. A behavioural change by logistics customers as well as by LSPs is needed to create energy-efficient supply chains and to utilise unused capacity (McKinnon and Ge, 2006; Rizet *et al.*, 2012b). According to Marchet *et al.* (2014), environmental sustainability in logistics and freight transportation is a topic of increasing interest, but the need for further investigation of environmental sustainability in connection with LSPs is pointed out by Centobelli *et al.* (2017).

Changes in management and behaviour pattern are needed because development in technology alone is an insufficient solution (Aronsson and Huge-Brodin, 2006; Chapman, 2007) in order to stop the development of increasing energy consumption and to meet the governmental goals set for the future. Decreasing consumption of fossil fuels not only promotes independency from fluctuating oil prices, but also encourages competitive and resource-efficient freight transportation. Energy-efficiency is, therefore, the most cost-effective way and promotes security in the energy supply at the same time (European Commission, 2011a).

## 1.3 Research setting and delimitations

This research is bedded in various fields. The starting point of the research is located in the fields of 'Freight transportation' and 'Sustainability'. However, by choosing an energy-centric approach, the focus lies only on one of the three pillars of sustainability, i.e. environmental sustainability. In a broader picture, the research also touches on the fields of 'Logistics' and 'Supply Chain Management'. The overlap of all these fields allows studying road freight transportation from a perspective of energy efficiency.

The composition of these various fields also reflects the development of logistics – starting off in the 1960s as merely physical distribution, developing to time-dependent just-in-time (JIT) systems in the 1980s and to a focus of supply chain management (SCM) including e-logistics in the 2000s (Klaus, 2009). Stock *et al.* (2010) also emphasize that SCM is about achieving benefits through adding value, creating efficiencies and increasing customer satisfaction through service offers. Today, logistics are characterised through e-commerce, energy scarcity and sustainability. New business models have to be developed to guide the needed changes. Bocken *et al.* (2014), for example, suggest sustainable business model archetypes that include maximisation of energy efficiency, creation of value from waste, change from non-renewable to renewable energy sources and consumer education in order to prepare businesses and society for a sustainable future.

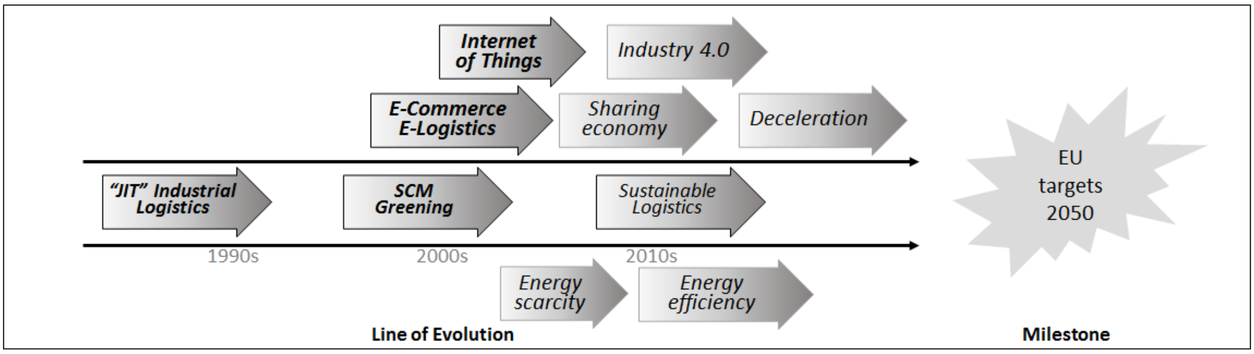


*Figure 1.1: Logistics' line of evolution [bold-printed terms are adopted from Klaus (2009), the other terms are added by the author]*

The most environmental-friendly way of using energy is to utilise it efficiently and not to waste it. This way, energy which is available but has been untapped can finally be used. This research takes an energy-centric perspective and focusses therefore on contributing to an energy-efficient solution to decrease the energy consumption in road freight transportation and adjacent logistics activities. The scope of the research begins with road freight transportation, the mode which is most common in the downstream part of the supply chain, into and within urban areas, but goes beyond pure transport activities to include the behaviour and capabilities of actors as well as the structure of the logistics system. Figure 1.2 visualises the scope which includes the last two legs in the supply chain.

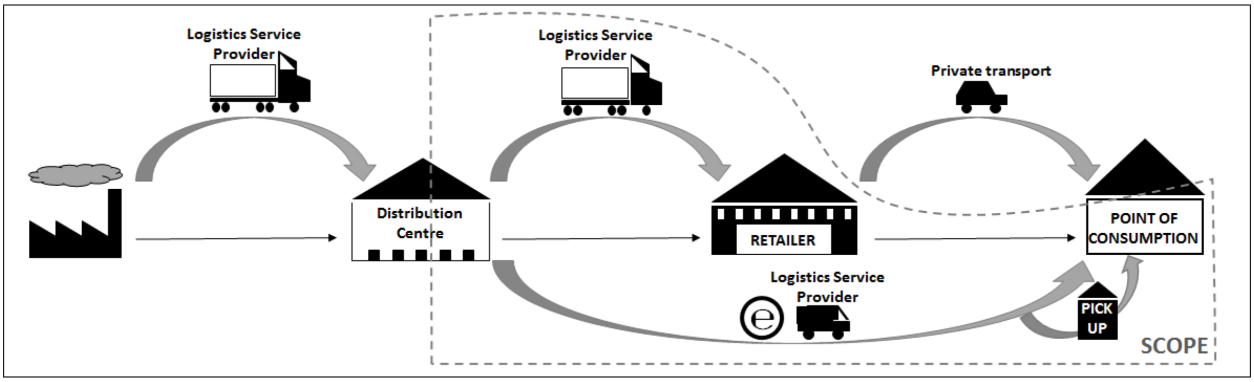


*Figure 1.2: Scope of the research*

Delimitations are found within the empirical data which is only collected within Sweden and from professionals (i.e. logistics managers from LSPs and shippers) but not from the private end consumer.

## 1.4 Purpose and research questions

The research is based on the pursuit of energy efficiency in logistics as a means to environmental sustainability in order to reduce energy consumption. In clear terms, the purpose is formulated as the following:

> *The purpose of this research is to identify the potential for improvement of energy efficiency in logistics through the utilisation of capacity in road freight transportation in order to enhance environmental sustainability.*

The starting point for this research is to focus on unutilised capacity in freight transportation within the traditional logistics system boundaries. In the next step, the perspective is broadened by extending the traditional system boundaries to also include the logistics fulfilment and explore further opportunities.

The road freight transport sector is associated with an excessive use of fossil fuels. It is suggested that the total energy consumption can be reduced when capacity is fully utilised. This thesis suggests that capturing and fully utilising capacity contributes to improving energy efficiency in road freight transportation. Unutilised capacity is synonymous with overcapacity and is explained in more detail in Chapter 2.3. The developed research questions (RQs) investigate overcapacity and examine separately *where* in the logistics system overcapacity can be identified and *how* it can be released. A further distinction is made regarding the system boundaries, examining what other opportunities emerge when the system boundaries are extended.

Road freight transportation is the focal point of this licentiate thesis and one of the most energy intensive logistics activities; therefore, the RQs focus upon this transportation mode. To examine overcapacity, the system boundaries have to include adjacent logistics activities, such as other transport, warehouses, manufacturing and distribution activities (Bottani *et al.*, 2014). This approach is originated in the systems view where a part of a system cannot be understood by solely focusing on its individual components (Arbnor and Bjerke, 2009). In this broad approach by including road freight transportation and adjacent logistics activities, it is possible to examine the full potential of energy efficiency improvements in road freight transportation.

The first research question is supported by an exploratory approach examining *where* in the logistics system overcapacity is available. It serves as a foundation for all further research, maps available potential and is therefore called the ‘identification question’.

> **RQ 1 – ‘Identification question’:**
>
> *Where* in the logistics system is unutilised capacity available that can be exploited in order to improve energy efficiency in road freight transportation?

After identifying the locality of unutilised capacity in the logistics system, the second research question, which builds on the first one, helps to identify ways of how this potential can be released respectively utilised in order to achieve energy efficiency improvements. This knowledge should help researchers as well as logistics service providers to create an energy-efficient logistics system with the focus on road freight transportation. The second research question centres on *how* unutilised capacity can be released and is called the ‘utilisation question’.

> **RQ 2 – ‘Utilisation question’:**
>
> *How* can unutilised capacity be used in order to release the potential for improvement of energy efficiency in logistics?

The third research question lifts itself from the initial system setting of the traditional logistics boundaries and tries to include other opportunities for energy efficiency improvements. It does this by expanding its traditional system boundaries to include distant activities or actors which are not normally associated with road freight transportation. It serves as an entry for further research after the licentiate and therefore is referred to as the ‘exploration question’. The question is stated as the following.

**RQ 3 – ‘Exploration question’:**

*What other opportunities* in regard to energy efficiency emerge when the traditional system boundaries of logistics are extended?

The research questions are answered through different studies. The first two research questions are set within the initial system boundaries, whereas the third question regards opportunities within extended system boundaries. The main focus before the licentiate degree is set on the first two research questions.

## 1.5 Outline of thesis

Based on the background, the problem area and the research setting, this chapter introduced the research topic of the licentiate thesis. Further, it presented the purpose and motivated the research questions. Chapter 2 presents the frames of reference. Next, in Chapter 3 the research approach is presented, including the research design, methods, quality and the process. Chapter 4 summaries all appended papers and Chapter 5 reveals the result and analysis of the three research questions. In Chapter 6, the discussion is provided, followed in Chapter 7 by the conclusion of the thesis and proposed future research.

# 2 Frame of reference

This chapter discusses different theoretical concepts which are needed to answer the research question. The research draws upon concepts, frameworks and theories from the energy-logistics domain.

## 2.1 Energy efficiency

Energy efficiency in logistics helps to decrease the total energy consumption and contributes to the EU target set for 2050 aiming to reduce total GHG emissions by 80-95% compared to the level of 1990 (European Commission, 2011b) and in the transport sector in particular by at least 60% (European Commission, 2011c). Energy efficiency is defined in the Directive 2012/27/EU of the European Parliament and the Council of the EU (2011a) as 'the ratio of output of performance, service, goods or energy, to input of energy' and energy efficiency improvement as 'an increase in energy efficiency as a result of technological, behavioural and/or economic changes'. The International Energy Agency applies the term energy efficiency when something 'delivers more services for the same energy input, or the same services for less energy input' (OECD/IEA, 2014). This research approaches energy efficiency in qualitative terms and assesses energy efficiency improvements through a decrease of energy consumption or an increase in the output of transportation or other adjacent logistics activities with the emphases on quality, reliability and flexibility.

To rely solely on the development of an advanced technology to tackle the increasing energy consumption is too risky, but rather behavioural changes and new policies are needed (Johansson, 2009). Technological developments like renewable energy and better vehicle technology (Léonardi and Baumgartner, 2004; McKinnon and Ge, 2004), as well as policies (Lindholm and Blinge, 2014), as approaches to tackle high energy consumption in freight transportation have been the focus of different research. However, this research suggests that energy efficiency improvement can be reached by the utilisation of capacity through behavioural and managerial changes of different actors in the logistics system. Changes in behaviour of different actors can decrease the demand for products and thus reduce the demand for transportation. Managerial changes can lead to better collaboration and coordination among actors and reduce the energy consumption of transportation.

The difficulty with energy efficiency is to measure it. Kalenoja *et al.* (2011) point out that the ability to assess energy efficiency is essential in order to implement and plan energy efficiency measures in logistics. Additionally, qualitative and quantitative  the supply chain information is required to calculate and measure its energy efficiency (Kalenoja *et al.*, 2011). Indicators like vehicle fill, empty running, fuel efficiency, vehicle time utilisation and deviations from schedule have been used in past studies to monitor efficiency in transportation (McKinnon and Ge, 2004). Operating principles in logistics such as flexibility, cost-efficiency, speed and reliability stand in direct contrast to energy efficiency. McKinnon (2016b) points out that agile supply chains and just-in-time deliveries are difficult to combine with energy efficiency.

Energy efficiency in freight transportation depends on the structure of the whole supply chain, such as on choices in product demand, production and the purchasing process (Kalenoja *et al.*, 2011; Aronsson and Huge-Brodin, 2006), therefore a systems view is chosen (see Chapter 2.4.1). Since energy efficiency can be viewed relative to its energy input, energy consumption will be discussed in Chapter 2.2. Capacity utilisation as a means to energy efficiency in road freight transportation is examined in Chapter 2.3.

## 2.2 Energy consumption

The high energy consumption, especially of fossil fuels, in transportation counteracts the ambitious emission targets set for the future. Especially the downstream of the transportation chain operates on a high energy level because of the small number of products carried per vehicle, empty running, redundant trips and the return of goods. The smaller the vehicle and the less goods being transported, the higher the energy consumption per transported unit (Browne *et al.*, 2006). In particular, the consumer transportation, from store to household, has a huge impact on the total transportation energy consumption (Browne *et al.*, 2005). In an example of the transportation of yoghurt, the consumer transportation from supermarket to household consumed almost as much energy as all upstream transportation activities, from farm to store, together (Browne *et al.*, 2006; Rizet *et al.*, 2012a).

Different transportation modes have different effects on the total energy consumption. But as Lindholm and Behrends (2012) point out, it is not always an option to switch to a more energy-efficient transportation mode, especially not in urban areas which mostly rely on road freight transportation. In addition, the consumer transportation which operates on a high energy level has to be included in the consideration about how energy consumption can be reduced and energy efficiency reached. As Browne *et al.* (2005) show in their case study, the consumer transport has to be viewed by companies as an integral part of the supply chain and included in freight transport research.

In short, energy consumption needs to be reduced throughout all logistics activities with a focus on transportation, although there is an increasing demand for transportation triggered by end consumers' demand for more products.

## 2.3 Capacity utilisation

Utilising overcapacity in freight transportation and logistics reduces energy consumption. From an energy-centric perspective, capacity is seen as an energy consuming unit and its availability in freight transportation constitutes both an environmental and economical challenge.

In its basics, capacity is often associated with loading capacity, the physical ability of a vehicle to carry freight during a certain time (Konings *et al.*, 2008). In this, a truck is often referred to as the key unit in road freight transportation. But capacity describes so much more and is therefore often difficult to measure. Hayes et al. (2005), who have a background in manufacturing and operations, describe capacity as a representation of 'a complex interaction of physical space, equipment, operating rates, human resources, system capabilities, company policies, and the rate and dependability of suppliers' (2005:77). Unutilised capacity in the system can have two reasons – an unwanted overcapacity or a planned spare capacity (Kalantari, 2012). While spare capacity exists to manage fluctuations in demand, Kalantari (2012) writes that 'overcapacity denotes the operational underutilisation of resources. It is an indication that efficiency improvements are possible' (2012:xii).

Taking the example of the truck, overcapacity and spare capacity can be visualised as shown in Figure 2.1. Additionally, overcapacity can be divided in system loss capacity and operation lost capacity. System loss capacity is evoked by parcels which are too big to fill up the last space in the truck. On the contrary, operation lost capacity is generated by discrepancies in the operational process, like trucks which have to leave the logistics centre because they have to meet delivery times, but run with unutilised space.

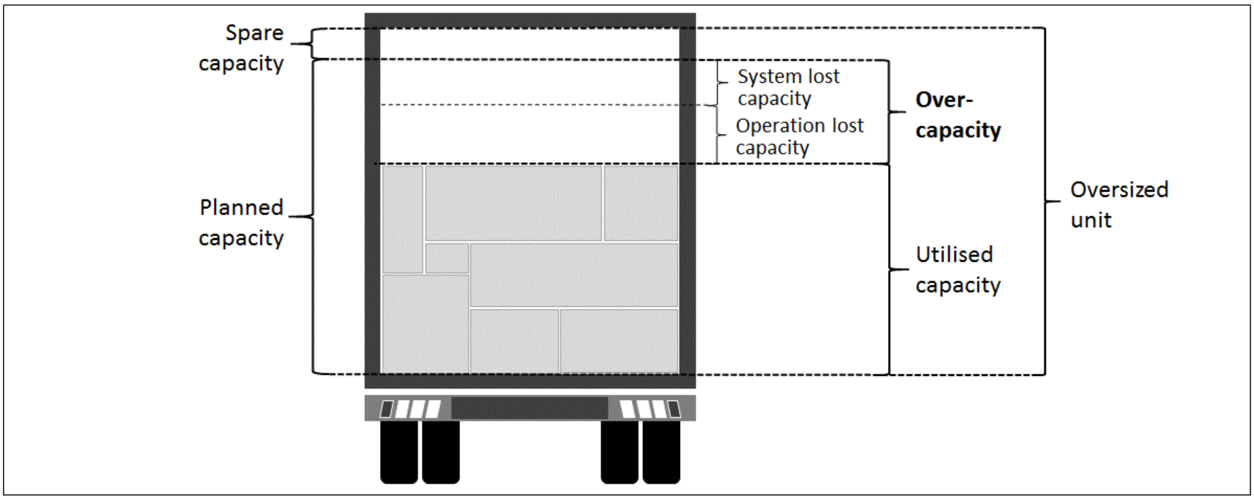

*Figure 2.1: Truck as key unit of capacity in road freight transportation*

Overcapacity within the logistics system boundaries cannot only be detected in unused vehicle space because of limited interaction between suppliers and carriers, but also in form of insufficient homogeneity between products and markets. According to Pfohl and Zöllner (1997) an increasing homogeneity between products and markets leads to a better usage of the existing capacity in logistics. Indicators for overcapacity in the logistics system are a low price for transportation services, low fill rates, an increasing number of insolvency among LSPs and decreasing earnings.[1]

The application and understanding of capacity in literature has developed with time. Over the years, the perception of capacity developed from an understanding of a pure physical space (Browne *et al.*, 2006; Chapman, 2007) to an indicator of energy efficiency (Kalenoja *et al.*, 2011) to a factor of a wider system (Brown and Guiffrida, 2014). Wu and Dunn (1995) were ahead of their time and early viewed capacity as an factor which directly influences the environmental impact of the transportation system. Capacity is, furthermore, viewed as an essential factor of the energy supply chain (Halldórsson and Svanberg, 2013).

## 2.4 Logistics' system and structure

Although this research focusses on the potential for improvements of energy efficiency in road freight transportation, potential in road freight transportation cannot be viewed without its environment and adjacent logistics activities. Throughout the whole thesis the theme of 'systems' is drawn – as the theoretical lenses and as a structure. Besides the theoretical perspective, the following subchapters the potential for improvements of energy efficiency will be explained from a horizontal perspective (system boundaries) and a vertical perspective (system levels).

### 2.4.1 Systems view on logistics

The research is influenced by the systems view and approaches energy efficiency as an integrated part of logistics operations. The systems view is a common approach in the logistics research and a 'softer' school is applied recognising purposeful human activities as part of the system (Lindskog, 2012). Arbnor and Bjerke (2009) use the systems view by creating a model of the real world while stressing the totality of a complicated world in which all the parts are more or less depended on each other (Arbnor and Bjerke, 2009:112). Energy efficiency is, therefore, viewed as a phenomenon that is a result of a 'web of relationships among its components' (Arbnor

[1] For more information see Automotive Logistics (2015), ABB (2015), and Boston Consulting Group (2015).

and Bjerke, 2009:103) and this research seeks to understand what ‘common patterns, behaviour, and properties’ (Arbnor and Bjerke, 2009:103) in the logistics system constitute energy efficiency.

The logistics system can be viewed as an open system in constant interaction with its environment (Arbnor and Bjerke, 2009:108). Reactions from the system to the environment can be summarised in three kinds: variation, structural change and paradigmatic shift. Temporary variation from the normal state implies that the environment will eventually return to its point of departure. Structural change describes an irreversible change from a previous state and the paradigmatic shift explains where radical changes lead to a new state and only a completely new model can picture the real world (Arbnor and Bjerke, 2009).

In brief, the systems view shapes this energy-centric research by approaching energy in constant interchange with its surrounding components such as the environment, different actors, transportation vehicles and policies. This perspective highlights the need for a structural change or even a paradigmatic shift of the transport sector in order to reach a high level of energy efficiency as a means to environmental sustainability.

### 2.4.2 System boundaries in logistics

In order to measure energy efficiency in transportation, system boundaries have to be defined. The setting of system boundaries influences substantially the result of the assessment of the energy consumption and efficiency (Reap *et al.*, 2008).

The example of system boundaries for measuring energy efficiency in logistics by Kalenoja *et al.* (2011) shows clearly the scope of different system boundaries in which a company can operate, plan and manage their business. The system boundaries can be extended horizontally and the figure depicts the various differences in the assessment of energy efficiency (Figure 2.2). While ‘System boundary A’ includes activities, their energy consumption, and emissions from production and outbound logistics, the ‘System boundary B’ adds further energy and emission flows from inbound logistics, such as warehousing, raw material acquisition from the supplier to the system, and waste. The ‘System boundary C’ covers the whole supply chain, including logistics to retailer and end consumer as well as reverse logistics. This system boundary also contains the logistics fulfilment of the last mile. The last mile describes the transportation activity during the last leg of the supply chain, i.e. the transfer of goods from the retailer to the end consumer. In ‘System boundary D’ the whole life cycle of a product is assessed including the recycling of a product.

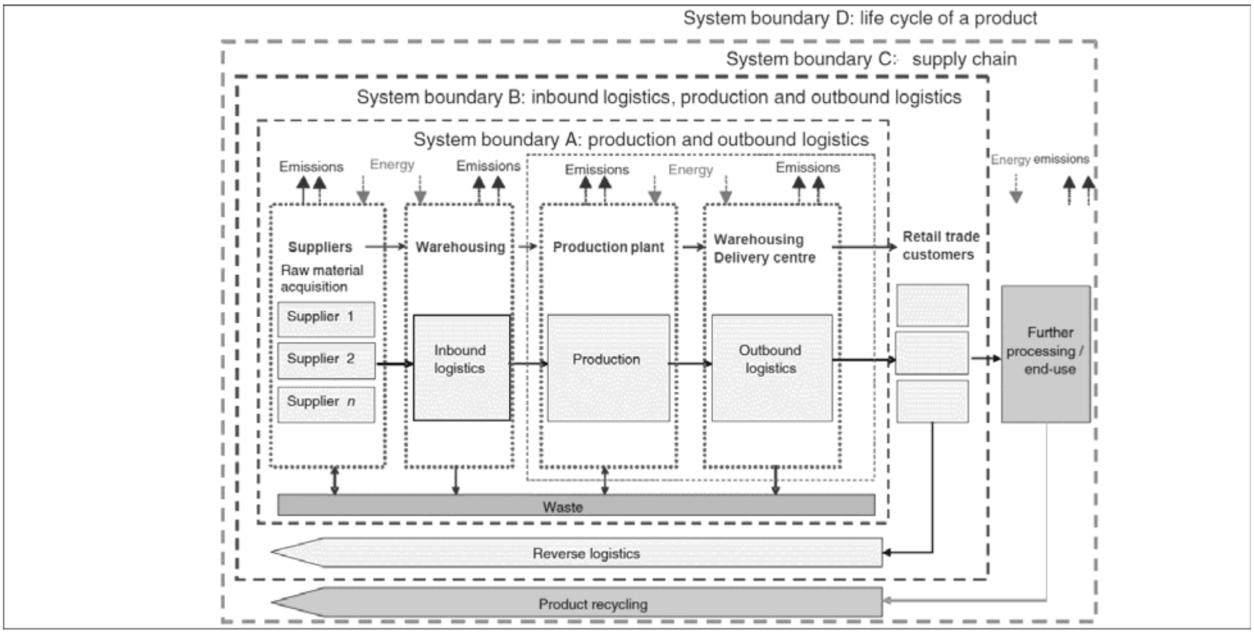


*Figure 2.2: System boundaries for measuring the energy efficiency in logistics [Kalenoja et al., 2011]*

Each system contains a finite number of activities as well as actors. By expanding horizontally the system boundaries it is possible to find new unutilised capacity among those activities and actors. The extended system boundaries expose new intersections of actors and unused potential, for example, in a limited interaction and collaboration, in unutilised vehicles and requirements.

Logistics flows are powered by energy (Halldórsson and Svanberg, 2013). To minimise the environmental impact of logistics, every element in the supply chain has to be included in the management and planning process (Wu and Dunn, 1995). Browne *et al.* (2005) extent the tradition system boundaries of freight transportation to include the end consumer because of the high energy consumption form transportation during that last mile. Because of the trend of increasing e-commerce, and the higher volume of online-ordered goods and services (Piecyk and McKinnon, 2010), it becomes even more important to examine this last mile for potential for improvements of energy efficiency. Furthermore, good information sharing systems help to manage the physical flows along the supply chain (Aronsson and Huge-Brodin, 2006).

In brief, the concept of system boundaries in logistics shapes the research by broadening the angle of view from one single company to its bordering operations and actors. This concept is closely connected to the systems view.

### 2.4.3 System levels of logistical activities

The scope of energy efficiency in the logistics system cannot only be determined through a horizontal differentiation of different system boundaries, but in addition also through a vertical differentiation of system levels. Aronsson and Huge-Brodin (2006) suggest vertical levels for a model describing overall, strategic, tactical and operational decisions in regard to environmental consequences. Work by McKinnon and Bilski (2014) and McKinnon (2016a) suggest system levels as scope of innovation and decarbonisation. Figure 2.3 shows eight different system levels, starting with technical dimensions until the overall structure of the supply chain.

The first two levels focus on technical dimensions such vehicle technology, alternative fuels and vehicle maintenance. These dimensions have been in the centre of numerous research (Léonardi and Baumgartner, 2004; McKinnon and Ge, 2004; Liimatainen *et al.*, 2012). The operational levels (level 3 to 5) such as driving, vehicle loading, and vehicle routing and scheduling are the business of logistic service providers (LSPs) (McKinnon and Bilski, 2014). On the sixth level a differentiation between modes is made such as, road, rails, sea and air transportation. The logistics system design is carried out by individual shippers while the supply chain structure is influenced by other supply chain partners who set conditions.

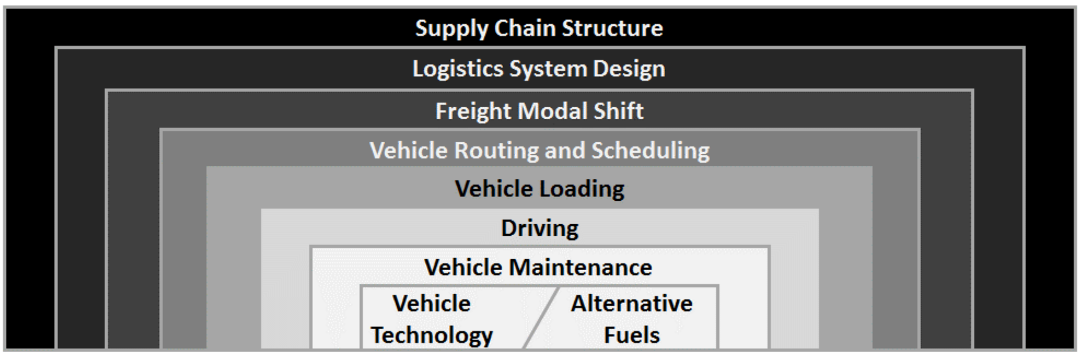


*Figure 2.3: System levels of the logistical activity and innovation after McKinnon and Bilski (2014) and McKinnon (2016a)*

In short, the concept of system levels informs the research by providing a structured overview of different logistical activities which can improve energy efficiency. This vertical differentiation makes it possible to identify potential of energy efficiency on different levels system. The focus of this research is set on system levels 4 to 8.

## 2.5 Summary and synthesis

As stated, energy efficiency is the ratio of output of performance or service, to the input of energy. The output in this research is road freight transportation with requirements on quality, reliability and flexibility. In order to improve energy efficiency which leads in turn to sustainable logistics, unutilised capacity can be used. The overall structure of the system sets conditions on the energy efficiency in road freight transportation. The attributions of energy efficiency, which are guiding the research, are the need of reducing the energy consumption from freight transportation while continuously providing the service of freight transportation, all under the consideration that the organisation of the logistics system and the behaviour of actors needs to change. In the following figure, the frame of reference is summarised in a conceptual model.

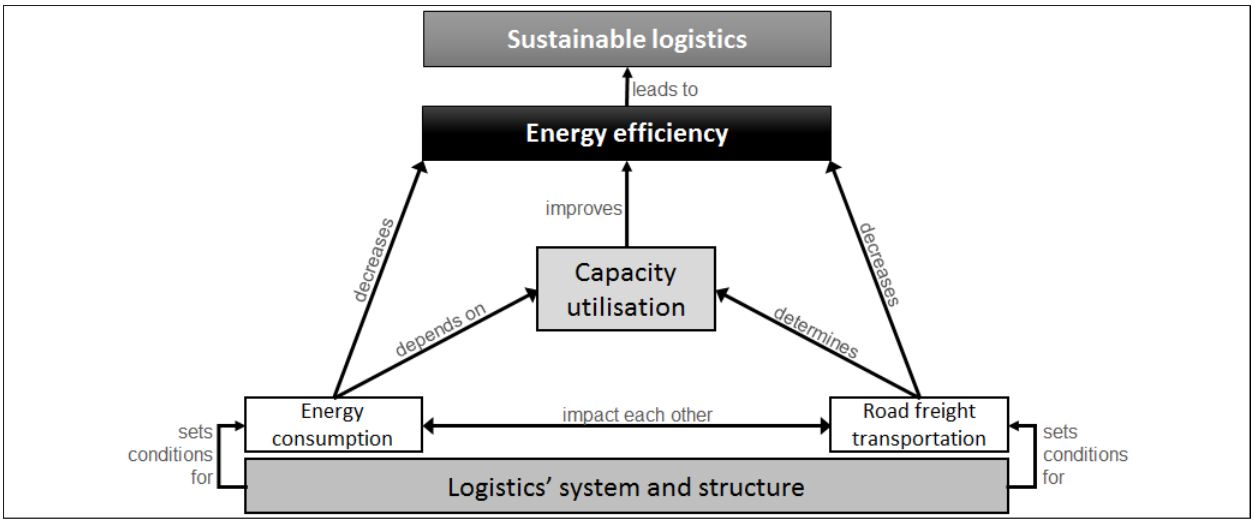


*Figure 2.4: Frame of reference (conceptual model 1)*

# 3 Research approach

This chapter presents the research approach, including the research design and methods for the different studies, the research quality and process.

## 3.1 Research design

The framework of research questions, planned methods and studies, such as literature review, secondary evidence and interviews, while simultaneously ensuring research quality, can be described by a research design (Bryman and Bell, 2011). Influenced by the research design, this research follows a qualitative research approach. Concerning qualitative research, Flick (2014) states that the process presents a sequence of decisions about such matters as the research questions, the goal, the theoretical framework, and the selection of empirical material in light of the available resources. Maxwell (2013) sees the research questions not as the starting point but as the centre which connects directly to all other components of the research design. The interactive model of a research design by Maxwell has the research questions in the centre and the conceptual framework, goals, methods and validity influencing and being influenced by them.

This research follows an abductive research approach that is characterised by an alternation between practices and theory (Spens and Kovács, 2006; Kovács and Spens, 2005), which is reflected for example in the alternation of developing an interview guide from literature and through feedback from the industry. The research questions developed with time and were in constant exchange with the research design, the methods, the purpose and the theoretical frame of reference.

Figure 3.1 visualises which study informed which paper and which paper helped answer which research question. The literature review served as a foundation for all further studies and papers. Studies 3 and 4 were interviews and streamed into Paper 1 and Paper 2, respectively.

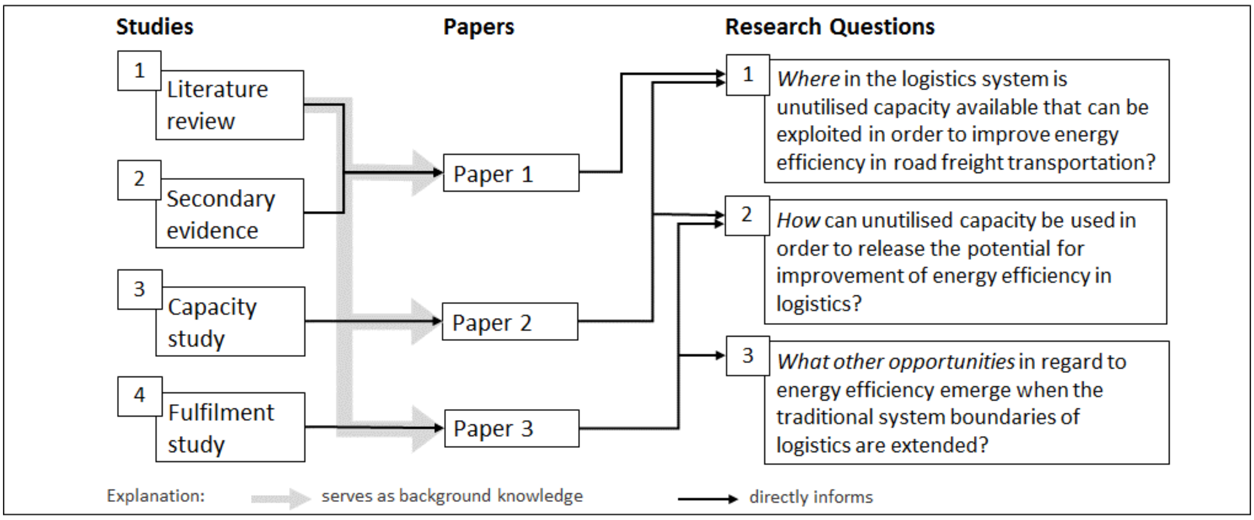


*Figure 3.1: The research design*

In addition to the three papers, a book chapter was also developed. The book chapter was an opportunity to combine studies 1, 3 and 4 together with additional material. Because of copyright concerns, the book chapter is not appended to the licentiate thesis in its full version, but a summary is presented in Chapter 4.4.

In the following subchapters, first the research questions and then each study is explained.

### 3.1.1 Research questions

The first research question calls for an exploratory study in order to identify the locality of energy efficiency and to answer *where* the potential is. The collected data streams from a literature review, secondary evidence from publicly-accessible sources, and partly through interviews on capacity.

The second research question of *how* the potential can be released is answered through two interview studies, one on capacity and the other on fulfilment. By interviewing several actors in the supply chain who work, buy and/or are dependent on road freight transportation, the potential for improvement of energy efficiency can be identified. Further, by focusing on the downstream part of the supply chain, potential energy improvements can be pointed out in that highly energy intensive part of the supply chain.

The third research question calls for innovation and opens ways for new opportunities. It includes new actors, and in doing so, the system boundaries are expanded with the focus on the last mile. The research questions, their data and the contributions are illustrated in Table 3.1.

*Table 3.1: Research questions and data*

| Research questions | Data collection | Data analysis | Contribution |
|---|---|---|---|
| RQ 1 – 'Identification question' | Literature review, secondary evidence (impact cases), *capacity* study (interviews) | Structured literature review, screening of impact cases, content analysis of interview data | Identify where in the logistics system the potential for improvement of energy efficiency (i.e. overcapacity) can be found, categorise causes |
| RQ 2 – 'Utilisation question' | Literature review, *capacity* study and *fulfilment* study (interviews), secondary evidence (benchmark) | Structured literature review, content analysis of interview data, benchmark of delivery services | Map causes of unutilised capacity and propose countermeasures |
| RQ 3 – 'Exploration question' | Literature review, *fulfilment* study (interviews) | Structured literature review, content analysis of interview data | Expand system boundaries, assign distinctive role to end consumer |

A qualitative research strategy is chosen which is in line with the research questions which ask *where* the potential for improvements in energy efficiency is and *how* it can be released. To map the locality of the potential for improvement of energy efficiency, semi-structured interviews are conducted with different individuals working with road freight transportation and logistics as this qualitative research gives the opportunity to understand the social world by examining the participants' perception of that world (Bryman & Bell, 2011:410).

### 3.1.2 Research studies

In the following table, all four studies are outlined in regard to their research design. Table 3.2 gives an overview of research studies.

*Table 3.2: Overview of research studies*

| | **Study 1:** Literature review | **Study: 2** Secondary evidence | **Study: 3** Capacity study | **Study 4:** Fulfilment study |
|---|---|---|---|---|
| Research design | Literature study | Analysis of impact cases<br>Benchmarking | Semi-structured interviews<br>Multi-actor approach | Semi-structured interviews<br>Multi-actor approach |
| Empirical data | Literature within freight transport, logistics and SCM that focuses on the logistics-energy domain and environmental sustainability | Publicly available data from the companies' websites and sustainability reports | Interviews with logistics managers from ten companies (LSPs and shippers) | Interviews with logistics managers from six companies (LSPs and shippers) |

#### 3.1.2.1 Study 1: Literature review

The literature review helped to build up a strong foundation in the research field. The approach was narrative and had the means of gaining an initial impression of the field (Bryman and Bell, 2011:101). Initially, this study was supposed to help answer the first research question, but by streaming into all papers, it gave insights into all three research questions. Nonetheless, the strongest influence was on Paper 1, and, therefore, it helped answering the first research question. The literature review provided the foundation in order to conceptualise capacity in literature (i) as an interactive concept, (ii) through the interplay of components and (iii) by adjustment of the system boundaries. These three propositions were derived from literature. MacInnis (2011) describes conceptualisation as the understanding of something abstract and highlights its importance in laying out new areas in which empirical research is needed.

#### 3.1.2.2 Study 2: Secondary evidence

Secondary evidence from logistics service providers and their customers has been analysed in order to outline current practices and activities in the industry. Three reasons why secondary evidence is used are: (a) *timeliness* – to capture the contemporary; (b) *relatedness* – to compare the framework and ideas with realities; (c) *mapping* – to understand the range of methods of improving energy efficiency already used in the industry. Secondary evidence from company homepages and reports is a self-portrayal of the company's social world and communicative devices that construct a subjective version of the company (Flick, 2014). This dimension has to be taken into consideration when analysing the data.

#### 3.1.2.3 Study 3: Capacity study

Study 3 was an interview study that focused on *where* overcapacity is available and *how* it can be utilised. Causes as well as countermeasures of unutilised capacity, i.e. initiatives to improve inefficiencies, were identified and presented in a framework. Semi-structured interviews were conducted with different actors in the supply chain, mainly logistics managers from LSPs and shippers in the downstream part of the supply chain in order to identify the potential of energy efficiency. One of the findings identified the last mile as a cause for overcapacity. This finding led to Study 4.

#### 3.1.2.4 Study 4: Fulfilment study

The second interview study focuses on last-mile fulfilment and identified energy efficiency characteristics of different last-mile fulfilment options. For this study, different options were mapped and were validated in several interviews with the interviewees. Because this interview study started while the previous one was still ongoing, new questions were added to the original interview guide. In several cases, interview participants were interviewed for both studies.

## 3.2 Research methods

In the following chapter, the research methods for all studies are explained. The interview studies share one subchapter, while similarities and differences in regard to case sampling, data collection and analysis are highlighted.

### 3.2.1 Study 1: Literature review

A literature review was conducted early in the process to serve as background information. Literature within freight transportation, logistics and SCM that focuses on the logistics-energy domain and environmental sustainability was reviewed. A combination of three search strategies was used: (a) databases, (b) journals and (c) snowballing and recommendations. At first, different databases (i.e. Business Source Premier, Web of Science, ABI/INFORM Collection) were searched using different keywords. Secondly, a number of academic journals were structurally reviewed. For that review, the top ten ranked journals of logistics and SCM in the Nordic countries were chosen (Kovács *et al.*, 2008) and additionally two journals focusing on the energy domain: *Energy*, *European Journal of Purchasing and Supply Management*, *International Journal of Logistics Management*, *International Journal of Logistics: Research and Applications*, *International Journal of Physical Distribution and Logistics Management*, *International Journal of Retail & Distribution Management*, *Journal of Business Logistics*, *Journal of Cleaner Production*, *Journal of Supply Chain Management*, *Supply Chain Management: An International Journal, Logistics Management* and *Supply Chain Management Review*. Depending on the database and journal, keywords that were searched differed as well as if they were searched for alone or as strings. The searched keywords were mainly the following ones: logistics, energy logistics, sustainable logistics, supply chain, supply chain management, freight transport, energy efficiency, energy and sustainability. In a third step, this approach was supplemented through snowballing and by adding recommended articles from other researchers in the field. This resulted in a list of more than 250 papers that are seen as part of the energy-logistics domain. The papers were first screened by scanning their abstracts. The resulting reduced number of papers were read, and out of these, 23 papers were identified as 'core literature', i.e. having a strong profile on capacity utilisation in road freight transportation. The papers span the time period from 1995 to 2016. The literature review was updated repeatedly during the research process. The core literature is presented in Appendix A.

### 3.2.2 Study 2: Secondary evidence

The study of secondary evidence can be separated into two parts. In the first part, several impact cases were analysed to validate the model of system levels. The second part was a benchmark of different garment retailers and focused on delivery services in e-commerce.

The first part of the secondary evidence study served as an entry study to see what efforts are already taken by industry in order to increase energy efficiency in logistics, and focused on 14 examples of secondary evidence in which energy efficiency played an important role in transportation and logistics activities in industry. The 14 impact cases originated from another pilot study within the research project 'The Fifth Fuel'. The examples were used to validate the model of system levels (see Chapter 2.4.3). This secondary material was collected from company reports (e.g. sustainability reports) and companies' online representation (e.g. home pages), reports from trade organisations and consultancies.

*Table* 3.3: Cases from secondary evidence

| No. | Secondary evidence | Industry/ Context | System level |
|---|---|---|---|
| 1 | DB (DB Schenker, 2013) | Logistics Service Provider | 1-8 |
| 2 | DHL (DHL, 2015) | Logistics Service Provider | 1-8 |
| 3 | McKinsey (McKinsey & Company, 2010) | Consultancy | 1-8 |
| 4 | Iea (International Energy Agency, 2010) | Intergovernmental organisation | 1-4 |
| 5 | IKEA (IKEA, 2014) | Furniture industry | 1, 3-8 |
| 6 | Intel (Intel, 2014) | Technology company | 1-7 |
| 7 | ODYSSEE-MURE project (ODYSSEE-MURE, 2013) | Monitors energy efficiency trends and policies in Europe | 1-8 |
| 8 | P&G (P&G, 2014) | Consumer goods industry | 1-7 |
| 9 | PostNord (PostNord, 2014) | Logistics Service Provider | 1-8 |
| 10 | Uber (The Economist, 2015) | Passenger transportation Service | 2-4, 8 |
| 11 | Unilever (Unilever, 2015) | Consumer goods industry | 1-7 |
| 12 | UPS (UPS, 2013) | Logistics Service Provider | 1-8 |
| 13 | Volvo (Volvo Group, 2014) | Automotive industry | 1-8 |
| 14 | Walmart (Walmart, 2015) | Consumer goods industry | 1-8 |

The second part of the secondary evidence study was a benchmark of 11 different garment retailers and their delivery services in e-commerce. All data was publicly available on the companies' websites. The sampling started with different garment retailers which sell their products on the Swedish market and was widened by including retailers with a similar but extended product variety (i.e. Hemtex) and international competitors (i.e. Amazon) for comparison. But not all companies offered the same level of information on their websites. Therefore, if a service was not mentioned on the website, it was assumed that the service was not offered to the customer base. This assumption limited the results, but if customers do not know about a service, their purchase decisions will also not be led by it. The data was analysed in regard to pickup in store, pickup at a pickup station, home delivery and return. These companies were compared: Amazon, Dressman, Ellos, H&M, Hemtex, Kappahl, Lindex, MQ, Nelly, Stadium and Zalando.[2]

### 3.2.3 Studies 3 and 4: Interviews

Both interview studies followed a qualitative approach. Their strength is based on the possibility of obtaining the experts' complex stock of knowledge (Flick, 2014:217), and their point of views on the topic of study. This helped to get a direct inside view from industry while directly getting feedback from the interviewee by testing the results. In the following subchapters, the research method for each interview study is explained, pointing out similarities and differences in regard to case sampling, data collection and analysis.

#### 3.2.3.1 Sampling

The sampling process started with convenient sampling (Flick, 2014:175) by choosing interviewees who were involved with the research project. Further interviewees from different companies were added in order to represent different actors from industry. By interviewing different individuals who work professionally with logistics (retail managers and managers of LSPs) and also an expert in implementing LEAN, an approach that seeks to reduce waste and improve services, a broad picture of the current situation could be painted. This diversity of the sample, by following a multi-actor approach, is seen as an opportunity, and this approach was chosen for both interview studies. The multi-actor approach was chosen to broaden the perspective by collecting data from different actors in the supply chain to map efforts taken in industry. Further, by following this approach, different logistical activities on different system levels could be pointed out and analysed. Following the idea of theoretical sampling (Flick, 2014:172), the sample size was not defined up front, but the sampling process was finished when theoretical saturation was reached and enough data was collected to answer the given aim. Mostly, several interviews with participants from one company were conducted.

Table 3.4 lists all sample companies, giving a brief description of each company and its size. In connection with Figure 3.2, it is illustrated where in the supply chain the companies operate. Both interview studies focus on the flow of goods during the downstream part of the supply chain with the scope on road freight transportation and adjacent logistics operations into and within urban areas. Transportation from foreign countries to Sweden is excluded.

[2] For more information see Amazon (2017), Dressman (2017), Ellos (2017), H&M (2017), Hemtex (2017), Kappahl (2017), Lindex (2017), MQ (2017), Nelly (2017), Stadium (2017), Zalando (2017).

*Table 3.4: Sampled companies*

| No. | Brief description of sampled companies | Size of company* | Number of conducted interviews | Operation in supply chain segments | Included in Capacity study | Included in Fulfilment study |
|---|---|---|---|---|---|---|
| 1 | Manufacture for bearings and logistics service provider | Large | 1 | (0,) 1, 2, 3 | x | |
| 2 | Manufacturer for packaging, processing and distribution solutions | Large | 1 | (0,) 2 | x | |
| 3 | Manufacturer for paper and tissues | Large | 1 | (0,) 1, 2, 3 | x | |
| 4 | Garment retailer with physical stores and e-commerce representation | Medium | 3 + site visit (same interviewee) | (0,) 2, 4, 6 | x | x |
| 5 | E-grocery retailer in Sweden | Small | 1 + site visit | 2, 6 | x | x |
| 6 | World leading logistics service provider | Large | 4 (same interviewee) | 1, 2, 3, 5, 6 | x | x |
| 7 | World leading logistics service provider | Large | 1 | 1, 2, 3, 5, 6 | x | |
| 8 | Nordic logistics service provider | Large | 3 (different interviewees) | 1, 2, 3, 5, 6 | x | x |
| 9 | Nordic logistics service provider | Medium | 1 | 1, 2, 3, 5 | x | x |
| 10 | LEAN energy consultancy | Small | 3 (same interviewee) | n/a | x | |

**Note. Small: <1.000 employees, medium: 1.000-9.999, large: >10.000 employees*

The following figure visualizes the downstream part of the supply chain and shows in which segment each company operates.

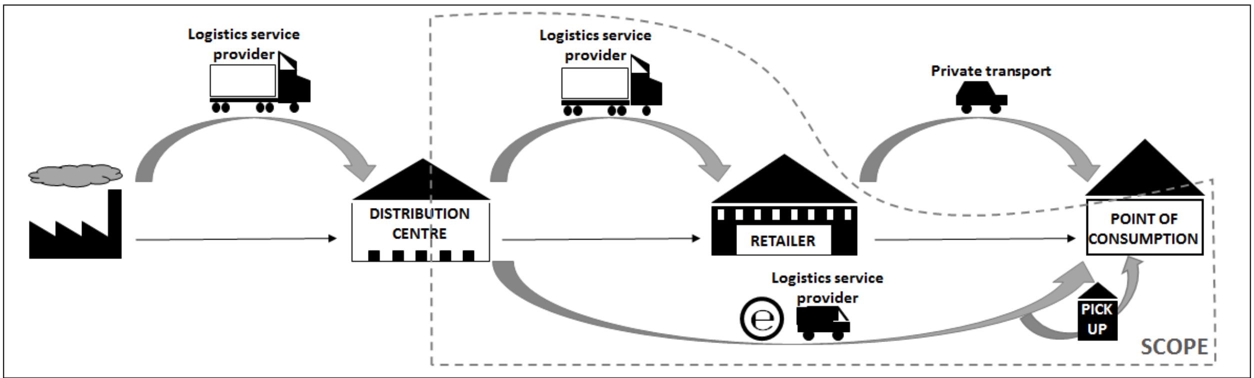


*Figure 3.2: Illustration of supply chain showing in which segment sampled companies operate*

### *3.2.3.1.1 Capacity study*

The interview study on capacity included 19 interviews with participants from 10 companies. Companies were selected on criteria such as industry, size and logistics strategy. To draw a broad picture, different companies were chosen operating in segments 2, 3, 4, 5 and 6 of the supply chain (see Figure 3.2), with a focus on road freight transportation between distribution centre and retail store.

### *3.2.3.1.2 Fulfilment study*

In the second interview study, several interview participants from the previous interview study were interviewed again but this time with a focus on the transportation during the last mile. Therefore, a selection criterion was that the case companies have contact with the end consumer (B2C), such as through e-commerce. Goods that are bought through e-commerce are either shipped to the retailer's store where the products are picked up by the end consumer or directly to the point of reception (i.e. the end consumer's home or a pickup point close to the end consumer's home) (Hübner *et al.*, 2016a). This study does not include data on private transportation during the last leg in the supply chain, i.e. transportation from store or terminal to household, from the end consumer but only from individuals who work professionally with this downstream part of the supply chain.

#### 3.2.3.2 Data collection

The identified literature, in combination with the aim of the studies, led to several themes which guided the formulation of the interview questions. The themes emerged from literature in relation to the field of energy-logistics and capacity as well as last-mile fulfilment. The themes are: energy consumption, energy efficiency, capacity, collaboration, logistics system, consumer, e-commerce, last-mile fulfilment and services. In regard to each theme, interview questions were developed. The following table shows from which literature each theme emerged and exemplifies building blocks for the interview guide.

*Table 3.5: Relevant literature, emerged themes and building blocks*

| Relevant literature | Emerged themes | Building blocks for interview guide |
|---|---|---|
| Piecyk and McKinnon (2010), Browne *et al.* (2006), Browne *et al.* (2005) | *Energy consumption* | – Measuring energy consumption of transportation<br>– Influencing energy consumption; examples of how to reduce fuel/energy consumption<br>– Energy as essential cost driver |
| Liimatainen *et al.* (2015), Kalenoja *et al.* (2011), Liimatainen and Pöllänen (2010), McKinnon and Ge (2004), Wu and Dunn (1995) | *Energy efficiency* | – Measuring energy efficiency<br>– Goals in regard to energy efficiency<br>– Trade-offs of energy efficiency |
| Rizet *et al.* (2012b), Kalenoja *et al.* (2011), Chapman (2007), Browne *et al.* (2006), Hayes *et al.* (2005) | *Capacity* | – Potential / unutilised capacity in the transportation system<br>– Ability to adapt to time slots and its effect on capacity |
| Bottani *et al.* (2014), Plambeck (2012), Björklund (2011), Wolf and Seuring (2010) | *Collaboration* | – Collaboration with other actors in the supply chain<br>– Connection between collaboration and energy efficiency |
| McKinnon (2016b), Kalenoja *et al.* (2011), Aronsson and Huge-Brodin (2006), Pfohl and Zöllner (1997) | *Logistics system* | – Placing company in the logistics system<br>– Responsibilities on the environment and the transported products<br>– Speed and just-in-time deliveries<br>– Returns<br>– Description of the company's operations and processes when handling freight |
| Brown and Guiffrida (2014), Browne *et al.* (2006) | *Consumer* | – The end-consumer's role in regard to energy efficiency<br>– Consumer's awareness of his impact on energy consumption<br>– Behaviour in the last-mile delivery |
| Brown and Guiffrida (2014), Rizet *et al.* (2012a) | *E-commerce* | – E-commerce as an opportunity or a drawback<br>– Handling last-mile delivery<br>– Challenges |
| Liimatainen *et al.* (2015), Hübner *et al.* (2016a), Hübner *et al.* (2016b) | *Last-mile fulfilment* | – Consequences of increasing demand for parcel distribution<br>– Last-mile fulfilment options (e.g. home delivery, pickup stations, locker stations)<br>– Integration of the return flow<br>– Planning routing |
| McKinnon (2016b) | *Services* | – Express delivery<br>– Overdelivery of services |

On the basis of these themes and building blocks for the interview guide, exploratory interviews were conducted. The interviews started with a focus on capacity to identify causes for unutilised capacity in the logistics system and to discuss countermeasures in order to utilise this potential. Questions addressing e-commerce, last-mile fulfilment and services were soon added for the fulfilment study. Each interview took between 60 and 120 minutes. In cases when several interview rounds were conducted with one company, predominantly the same persons were interviewed.

#### 3.2.3.3 Data analysis

During the interviews, comprehensive notes were taken and in three cases the interviews were recorded and afterwards transcribed. The qualitative data analysis software NVivo was used as a tool for the data analysis. The notes and transcripts were coded according to different nodes. As a start, the emerged themes from literature which helped to construct the interview guide were used as nodes. But further nodes were added during the analysis process when needed. The data was repeatedly analysed and sorted under the nodes. In the next step the nodes were reduced to overall categories in order to obtain a good overview of the problem areas (Ellram and Tate, 2015).

##### 3.2.3.3.1 *Capacity study*

From the first interview study, three categories were derived, helping to sort causes of unutilised capacity in one of the categories of actors, activity and areas in the logistics system. These three categories were chosen, since they explained *who* (actor) and *what* (activity) creates unutilised capacity and *where* (areas in the logistics system) it is created. Causes of unutilised capacity were extracted from the interview data and collected under each of the three categories. This separation into three categories also helped the process of identifying countermeasures. In addition to the causes, examples from the interviews were collected for better illustration. Next, the causes were linked with corresponding countermeasures which also were derived from the empirical data. A framework was developed based on the idea of Lee *et al.* (1997a). The framework addresses the overall problem of high energy consumption in road freight transportation by focusing on its symptom of unutilised capacity, identifying causes and linking them with countermeasures in order to mitigate the symptom and reach high energy efficiency.

##### *3.2.3.3.2 Fulfilment study*

The second interview study focused on e-commerce, last-mile fulfilment options and their energy consumption, involvement of the end consumer in last-mile distribution, and related challenges. The interview data was analysed in regard to different key terms such as e-commerce, end consumer, speed, energy consumption, energy efficiency, collaboration, capacity, home delivery and pickup. The last-mile fulfilment options and their characteristics were mapped and validated with the interviewees in several interview rounds.

## 3.3 Research quality

Research quality was ensured through a careful construct of the research design. The literature review gives not only an overview of the logistics-energy domain and environmental sustainability but also informs all other studies, including the papers and the book chapter. The literature review helped to provide a theoretical perspective with the systems view. Furthermore, from the literature, the themes for the interview guide emerged which ensures high relevance of the interview questions in regard to the studied topic. The secondary evidence was carefully analysed since it only expresses a subjective view of and by the companies.

The quality of research is often judged with quantitative measurements, although more and more research is qualitative. Thus, research is often evaluated improperly. Yin (2014) suggests judging the quality of a research design of a case study by using the following tests: construct validity, internal validity, external validity, reliability. Bryman and Bell (2011:394) discuss the relevance of the criteria reliability and validity for assessing the research quality of qualitative data. Halldórsson and Aastrup (2003) suggest an alternative criterion to judge especially logistics research and by using trustworthiness with the dimensions of credibility, transferability, dependability and confirmability. The latter criterion is chosen because of its link to the field.

Credibility means to accept that there is no single objective reality but that reality exists only in the minds of the participants (Erlandson *et al.* 1993). Therefore, the research findings are validated with the studies' participants by discussing the findings to ensure correction of the understood world. The second dimension is transferability which describes the general application of the findings (Halldórsson and Aastrup, 2003). To ensure transferability, richness of detail is needed. Therefore, interviews were repeated with several interviewees of the 10 companies in order to provide a thick description. The third dimension is dependability and it is ensured by keeping records of all phases of the research process and documentation of all methodological decisions (Halldórsson and Aastrup, 2003). Furthermore, peers have viewed and discussed this material with the author. Finally, confirmability is reached by ensuring that the findings represent the results and are free of bias on the part of the researcher (Halldórsson and Aastrup, 2003). This was ensured by comparing the data within itself and comparing it with the current body of knowledge. Table 3.6 summarises the criteria for research quality and their application.

*Table 3.6: Research quality – Ensuring trustworthiness*

| Criteria | Meaning | Application |
|---|---|---|
| Credibility | Reality is a construct of the individual | – Interview guide emerged from literature review<br>– Findings are validated by discussing them with study participants<br>– Review of findings by participants<br>– Validation to theory |
| Transferability | General application of findings | – Interviews with multiple respondents<br>– Multiple rounds of interviews<br>– Richness of detail |
| Dependability | Possibility of replication | – Records of all phases of the research process<br>– Documentation of all methodological decisions<br>– Review of findings by peers |
| Confirmability | Findings represent the results | – Discussion of findings with peers<br>– Comparison of data within itself<br>– Comparison of data with literature |

## 3.4 Research process

All research is part of a research project called 'The Fifth Fuel – Energy Efficiency through Effective Freight Transport in Sustainable Urban Areas'. The research project started in June 2014, and the author entered the project at the end of January 2015 with the employment as a PhD student. The author started with a literature review in order to get familiar with the research field but also to build a foundation for all papers, the book chapter and this licentiate thesis. The study on secondary evidence helped to outline current practices and activities in the industry. The interview studies focused on different issues, set on different system levels. Both interview studies, together with the literature review, streamed into the book chapter. Figure 3.3 illustrates the time line of the research process.

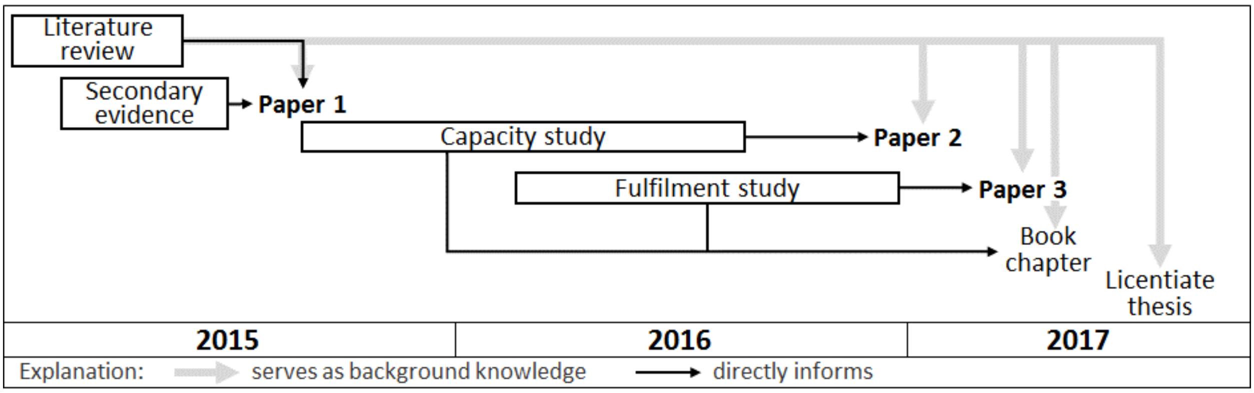


*Figure 3.3: The research process*

# 4 Summary of appended papers

This chapter summarises the three appended papers and presents their main contribution.

## 4.1 Paper 1 – Energy Efficiency by Utilising Overcapacity in the Logistics System?

### 4.1.1 Summary

Energy is both a cost and a key resource in time-based, flexible, reliable deliveries. In this paper, the energy intensity of freight transport and its dependence upon the use of fossil fuel as an energy source are addressed in terms of the interaction of three components: (1) the flow of goods, conditions which are created by customers of logistics providers; (2) capacity utilisation, in which the key task for logistics service providers is to manage capacity to meet the demand of flow and protect margins; and (3) increased energy consumption, which is strongly influenced by growing demand for freight transport services and shippers' supply chain strategies, but which also conflicts with EU emissions targets set for 2050. Since new technologies and policies are insufficient for addressing the energy-transport dilemma, any overcapacity available in the freight transport system has to be identified and utilised until it constitutes an energy resource. Against that backdrop, the purposes of this paper are to identify areas in the logistics systems with unutilised freight transport capacity and to explore pathways for utilising that capacity in order to improve the energy efficiency of logistics providers. A review of the literature on energy and logistics, identified by searching journals with keywords and snowballing, was performed to develop a framework to clarify the interplay of the requirements of the flow of goods, capacity availability and energy consumption.

### 4.1.2 Contribution

This paper provides an overview of the current body of knowledge on energy efficiency, logistics and freight transportation and suggests that capturing and using overcapacity in the logistics systems can contribute to reducing the energy intensity of freight transport. To achieve this aim, it points out different system boundaries in logistics and highlights pathways for improving energy efficiency in regard to available and unavailable capacity and current and new system boundaries.

## 4.2 Paper 2 – Increasing energy efficiency in road freight transportation: Analysing causes and countermeasures of unutilised capacity

### 4.2.1 Summary

Decreasing energy consumption in road freight transportation and adjacent logistics operations is crucial to environmental sustainability. The purpose of this paper is thus to identify and conceptualise causes of unutilised capacity in road freight transportation and adjacent logistics operations, and to link them with corresponding countermeasures, all in order to improve energy efficiency in road freight transportation.

By collecting and analysing 18 interviews with representatives of 10 companies (five shippers, four logistics service providers and one expert in lean energy), the causes of unutilised capacity in road freight transportation are mapped and a framework is developed. Thus, ways are suggested to overcome the problem of high energy consumption and to achieve energy efficiency by addressing the symptom of unutilised capacity grouping the causes and countermeasures in three categories and pinpointing *who* (actors) and *what* (activities) causes unutilised capacity and *where* (areas in the logistics system) it is caused. The countermeasures derived from the data include better visualisation of performance, the education of different actors, the management of expectations, the standardisation of material handling and procedures, off-peak delivery, planning ahead, better information sharing, deceleration, reduction, tracking and a new cost structure.

### 4.2.2 Contribution

The paper contributes to the understanding of how energy efficiency in freight transportation can be achieved in a broad, interactive system by identifying particular causes of unutilised capacity and countering them with countermeasures. By dividing causes into three categories – actors, activities and areas in the logistics system – the causes are highlighted and, as a result, the symptom of unutilised capacity can be mitigated toward improving energy efficiency.

## 4.3 Paper 3 – Sustainable Development of Logistics: The Case of Energy Efficiency in Last-Mile Fulfillment

### 4.3.1 Summary

The transportation during the last mile, the last leg in the supply chain before the good arrives at the point of consumption, is the most energy-consuming logistics operations in the supply chain. This paper presents an array of last-mile fulfilment options and relates them to energy efficiency. The energy efficiency of these fulfilment options is a result of the interaction between distribution structure, transportation execution and household logistics capability. This paper's purpose is to explore last-mile fulfilment options in regard to their energy consumption and identify propositions that make last-mile fulfilment more energy-efficient. The analysed last-mile fulfilment options are: (1) conventional shopping, (2) click and collect, (3) pickup point, (4) locker station, (5) home delivery and (6) in-car delivery.

Explorative, semi-structured interviews are conducted with Swedish retailers and their LSPs to collect empirical data and map the characteristics of the different options.

### 4.3.2 Contribution

This paper contributes with a sustainable-development perspective on last-mile logistics fulfilments based upon energy efficiency and can be summarised in four points. First, the paper complements the current body of knowledge on new and emerging last-mile fulfilment solutions with focus on energy. Second, the framework extends the system boundaries of energy efficiency from transportation execution and distribution structure to also include the attributes of household logistics capability. Third, this paper considers an array of last-mile fulfilment options and suggests that improving energy efficiency must focus on the interplay between distribution structure, transportation execution and household logistics capability. Fourth, integrating commercial and private transportation in the last mile by transporting goods with commercial vehicles in large quantities to a collection point and finalising the last mile by private transportation without a car, is the most energy efficient fulfilment option.

## 4.4 Additional publication

Additionally, a book chapter was written together with two other authors with the title 'Sustainable Supply Chains and Energy: Where "Planet" meets "Profit"' (Halldórsson, Sundgren and Wehner, forthcoming). This book chapter is part of a book called 'Handbook on Sustainable Supply Chains' edited by J. Sarkis and is expected to be published 2018. Because of copyright reasons, the chapter cannot be appended to this thesis. In the following paragraphs, a brief summary of the chapter is provided.

The book chapter conceptualises energy in supply chains as economic driver and environmental performance, because energy in the supply chain lies at the intersection where environmental sustainability meets economic performance. In other words, energy can be directly related to two dimensions of the triple bottom line, namely, profit and planet. Supply chains' underlying structures and strategic priorities are decisive in how much and what type of energy is used. Actions towards energy efficiency can be taken on different system levels. Developments in technology are not sufficient to improve energy efficiency in supply chains, but rather changes are needed in regard to supply chain activities such as transportation and warehousing, the actors' behaviour and the supply chain design, which sets conditions for the energy consumption.

Areas of improvement in the supply chain that can be identified at different system levels, are freight transport capacity, last-mile fulfilment options (downstream supply chain), sourcing (upstream supply chain) and reverse logistics and closed-loop supply chains. These four types of logistics situations are chosen and discussed in detail in the book chapter in relation to the conditions they set on supply chains.

The energy consumption in the supply chain is directly influenced by the chosen logistics situation, and therefore the causal relationship between the design of the supply chain and the amount and type of energy has to be acknowledged. The chapter explains how to release the potential of energy efficiency embedded in a supply chain perspective, under consideration of the four distinct areas of improvements in the supply chain: freight capacity utilisation, last-mile logistics fulfilment mode, sourcing, and reverse logistics and closed-loop supply chains. The book chapter highlights the importance for logistics managers to move across system levels to improve the energy efficiency in the supply chain.

# 5 Results and analysis

This chapter provides answers to the three research questions proposed in Chapter 1.4. The analysis is based on the results from the three appended papers. The following model shows how the frame of reference, the research questions, and the papers mesh with each other.

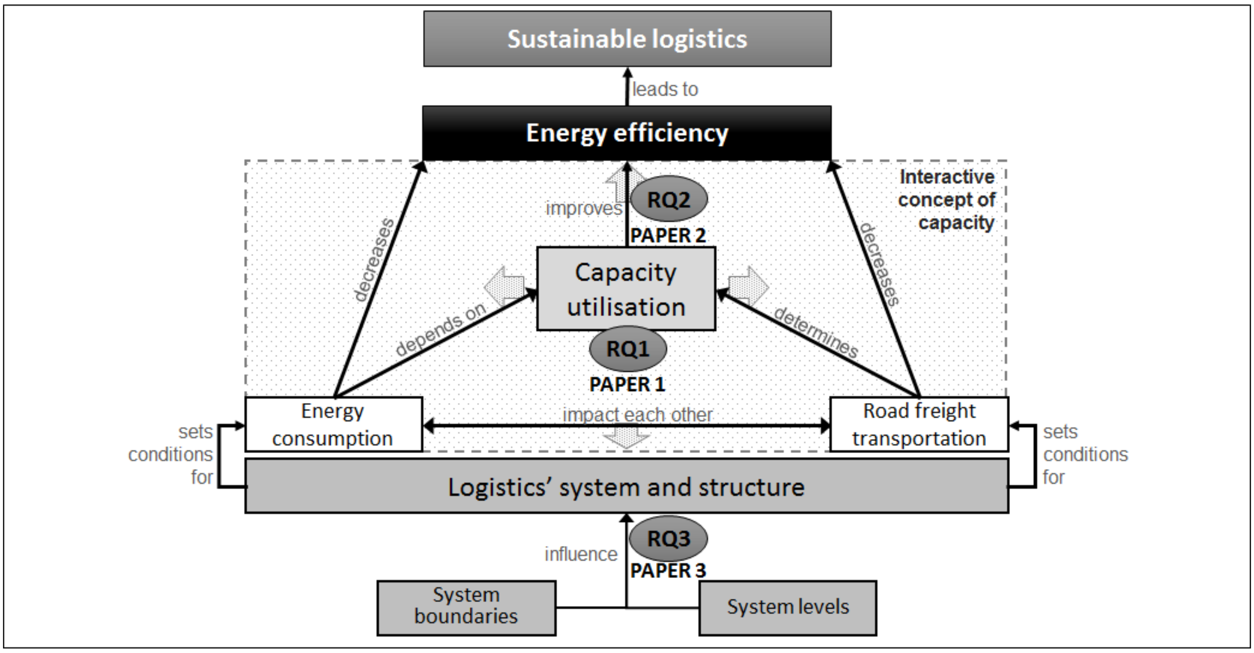


*Figure 5.1: The overall research (conceptual model* 2)

## 5.1 RQ1: Identification question

The first research question aims to identify *where* unutilised capacity can be found in the logistics system in order to improve energy efficiency in road freight transportation. But before this RQ is answered, two other important results are pointed out; the difficulties with energy efficiency (Chapter 5.1.1) and capacity as an interactive concept (Chapter 5.1.2). In the third subsection, system levels are presented (Chapter 5.1.3), showing where capacity can be found, not only in road freight transportation but also in adjacent logistics activities on different system levels.

### 5.1.1 Difficulty measuring energy efficiency

As discussed earlier, energy efficiency in freight transportation helps to decrease energy consumption and contributes to EU targets on reducing GHG emissions, but working with energy efficiency also evokes difficulties, which are summarized in Paper 2. The empirical data from the interviews showed that companies often experience problems when trying to improve energy efficiency in road freight transportation because they have difficulties measuring energy efficiency. The difficulties in measuring energy efficiency are based on (a) difficulty in collecting the right data, (b) the multiplicity of indicators that are collected and (c) difficulty in defining system boundaries.

First, many companies experience difficulties collecting and/or receiving the right data. Often numbers are rounded off, based on assumptions, such as a certain fuel consumption for a given distance, and standard values are applied. Therefore, calculations of consumed energy are far from exact. Second, when energy efficiency is assessed through the consumption of fossil fuels, difficulties arise because of the variety of fuel types, so that first an energy unit needs to be calculated. In addition, companies often prefer to assess energy efficiency by measuring other units of improvement, such as $CO_2$ emissions. But, as an interviewee pointed out, $CO_2$ emissions are not comparable between different LSPs. Further, another indicator used by companies to track energy efficiency is costs for transportation. This is done in the belief that lower costs for freight transportation often coincide with lower emissions (Aronsson and Huge-Brodin, 2006). But the cost driver for freight transportation is often not the consumed energy; rather costs are driven by salary for employees, products and the equipment used. Third, companies have difficulty defining the system boundaries in which they operate and mapping an overview of all the transportation activities connected to their business. Supply chains are complex and often not all up- and downstream transportation activities are considered. When shippers outsource their transportation to LSPs who in turn outsource their work to transportation providers, the first two actors cannot neglect their accountability for the consumed energy. Further, the sheer number of subcontractors often makes it difficult to keep track of the consumed energy.

These three difficulties in measuring energy efficiency show that, even if companies have an agenda for improving energy efficiency, they often have difficulties in following it. A standardised approach with more exact data is needed so results can be compared between companies. If a comparable system of figures could be established, for example, shippers could use the results when choosing a LSP which could lead in turn to increased competition to lower energy consumption even more and boost energy efficiency further.

### 5.1.2 Capacity as an interactive concept

The term ‘capacity’ has been applied differently in literature. This variety of application in connection with the systems view points towards the *interactive nature of capacity*. The goal should be to conceptualise capacity as interactive in regard to a theoretical dimension and strengthen the concept through empirical results. A systemic and interactive view on capacity is required to identify and release the potential of overcapacity. The following three propositions are observed within the literature and are supported through empirical evidence:

i. Capacity in the logistics system should be regarded as an *interactive concept* with several components, e.g. equipment, operating rates, human resources, system capabilities and policies (Hayes *et al.*, 2005). In this view, overcapacity arises when components do not harmonize or are not well coordinated, e.g. limited interaction between suppliers and carriers and insufficient homogeneity between products and markets (Pfohl and Zöllner, 1997).

   Examples from empirical evidence:
   - The boxes in which goods are carried need to be designed in cooperation with several actors in the supply chain so the goods fit well in the boxes, the boxes fit well on pallets, and a certain number of pallets exactly fill one truck.
   - Capacity utilisation of a single box is influenced through the size and type of products and operations in the terminal.
   - Capacity utilisation in the terminal depends on the type of product and the process characteristics in the terminal (e.g. automation, technology, standardization, time constrains and return policies).
   - Capacity utilisation of a truck depends not only on the volume and weight of products but also on where the delivery stops are located (density and distance).
   - Capacity utilisation in the store depends on how often new products are delivered and if the boxes are foldable in order to reduce their size when emptied.
   - Capacity utilisation during the return flow is influenced by whether or not boxes can be folded (and how) and stacked and on the amount of returned products.

ii. Accordingly, the ability to *manage the interplay* between the components that constitute capacity must focus on utilisation of overcapacity and a reduction in energy use – or the replacement of fossil fuels altogether – by altering the requirements of the flow (e.g. slow-steaming and abandoning just-in-time deliveries) is aimed for.

Examples from empirical evidence:

- Route planning for home deliveries provides exact delivery times.
- In the terminal, when employees pack goods for customers, a program calculates how many products (by weight and volume) need to fit in one transport unit.
- Allocation of products and replenishments to stores is performed.
- Products from different shippers are consolidated on one truck.

iii. By adjusting the *system boundaries*, new forms of capacity can be made available. New actors (e.g. taxi services, bicyclists) can be included as part of the logistics system, exchange between consumer and commercial transport can be supported, and new business models can be applied because more ‘shared economy’ or ‘open economy’ approaches are emerging (Pan *et al.*, 2015).

Examples from empirical evidence:

- Certain roles for end consumers in last-mile logistics fulfilment can be set.
- Responsibility can be delegated to the end consumer to track the delivery of a product and be home and available as the receiver (tracking of goods is possible through smartphone applications).
- The trunk of a car can be used not only as a means of delivery but also as a pickup point.

The result from the literature review and how the term ‘capacity’ is applied in literature is summarized in Appendix A. The papers are presented in chronological order to display the evolution of sustainability issues in logistics and transportation (Marchet *et al.*, 2014).

The following figure shows the conceptualisation of capacity as an interactive concept derived from literature and empirical analysis. Capacity utilisation can be expressed in its most simple terms as a load factor (McKinnon and Ge, 2004; Browne *et al.*, 2006) with the truck as the core unit of transportation (see a in Figure 5.2). But the literature review shows further that capacity is an interactive concept where different components have to be considered simultaneously. Capacity utilisation in a system is surrounded by different components (see b in Figure 5.2). This was also shown in the empirical evidence through the interaction between the material handling system (i.e. human resources, warehouse layout and technology) and the transportation (i.e. trucks, delivery times and receiving capability) which illustrates the interactive nature of capacity and is demonstrated through the interaction of several components. Those components include the surrounding equipment, human resources, the process characteristics, the product, operating rates and technology. The literature provides different tools to manage the interplay of these components and to measure energy efficiency (e.g. frameworks, key performance indicators, life cycle assessment and balanced score card) (McKinnon and Ge, 2004; Browne *et al.*, 2005; Kalenoja *et al.*, 2011). An adjustment of the system boundaries is suggested in several papers (Wu and Dunn, 1995; Browne *et al.*, 2005; Aronsson and Huge-Brodin, 2006; Wolf and Seuring, 2010; Brown and Guiffrida, 2014; Bottani *et al.*, 2014) by including new actors, strengthening their roles and widening their scope. The wider structure in which transport is operated also depends on the design of the supply chain and the location of terminals (see c in Figure 5.2). In this case, capacity is also viewed as an interactive concept but one influenced additionally by the structure it operates in. Changes in the structure to increase capacity utilisation are suggested to take place on a higher system level (addressed in the following chapter).

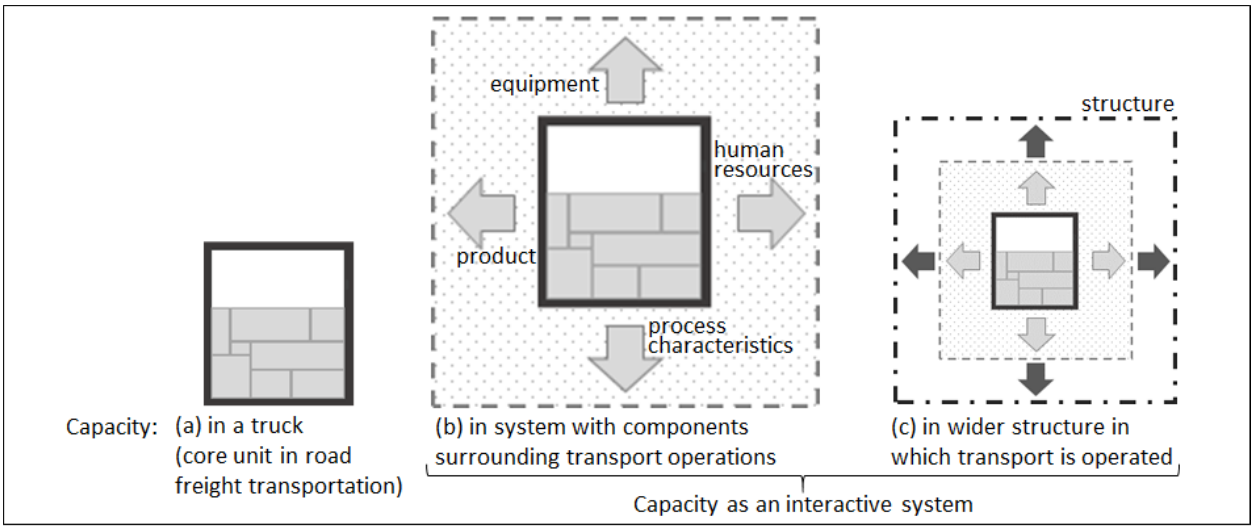


*Figure 5.2: Capacity as an interactive concept*

### 5.1.3 System levels

While companies operate within their system boundaries, capacity can be found on different levels. The model of system level emerged while work was being done on Paper 1 and was finalised for Paper 2, although it has not been included there. A similar model is included in the book chapter.

Viewing capacity on these different system levels facilitates the potential for improvement of energy efficiency. The levels were validated through the empirical evidence, i.e. interviewees pointing out on which level they operate and how they approach the potential. Figure 5.3 illustrates the different levels on which capacity can be found and categorises them in the categories *activities*, *actors* and *areas*.

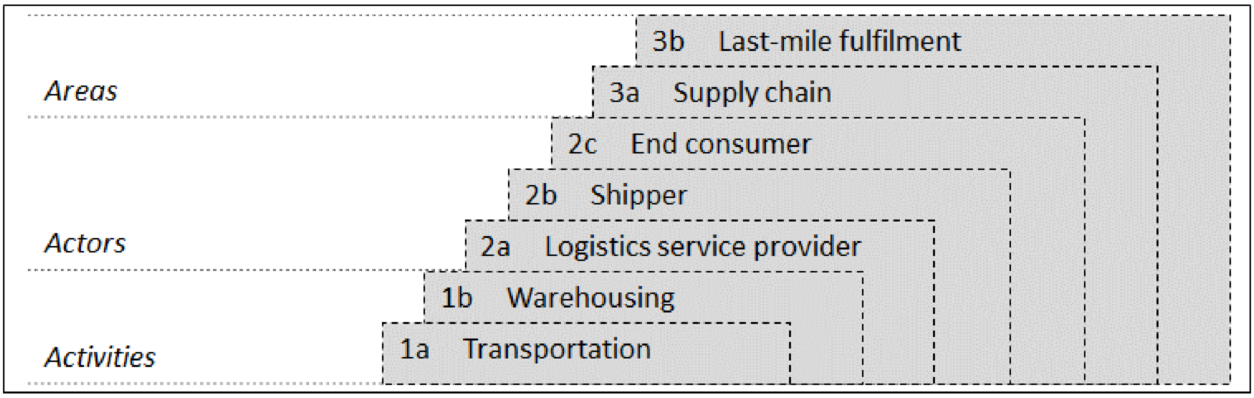


*Figure 5.3: Capacity on different system levels*

Capacity in *transportation (1a)* depends on the physical ability of a vehicle to carry freight during a certain time (Konings *et al.*, 2008). It is directly influenced by the size and shape of the packaging because reduced packaging requires fewer vehicles (Wu and Dunn, 1995; Kalenoja *et al.*, 2011). Capacity in *warehousing (1b)* is affected by, for example, the filling of boxes, their arrangement on pallets, the ability of loading and receiving goods and the adaption to time slots. Both these levels are summarized in the category *activities*. Capacity on those two levels became apparent during the visit to a retailer's terminal through the relationship between the components 'warehouse', 'boxes' and 'truck'. The way that products are stacked on a pallet is relevant for all following logistics activities. In this context, the retailer stated that when the boxes, which are stacked on pallets, are not completely filled and every time 1 cm of space would be left the unused capacity would add up to an extra cost of transportation activities of 1 million Swedish Krona per year.

In the category *actors*, capacity is influenced by the intensity of collaboration of *LSP (2a)* but also with other actors in the supply chain by sharing know-how and expertise (Plambeck, 2012). At the same time, *shippers (2b)* who purchase logistics services set demands for the LSP in regard to delivery windows as well as lead times. These demands often lead to an increased energy consumption and create overcapacity in the logistics system. Further demands are set by the end consumer, who demands express deliveries and a steady supply of goods. Most often during the interviewees, it was pointed out by LSPs as well as shippers that the highest goal for them is to minimize costs. However, it was also highlighted that reduced energy consumption in transportation does not always lead to reduced total costs, because there are much more crucial cost drivers, such as human resources, products and equipment.

The system levels under the category *areas* open up potential for improvement along the whole *supply chain (3a)* by applying a holistic view (Bottani *et al.*, 2014). One potential for improvement can be the deceleration of logistics operations (McKinnon, 2016b). This stands in direct contrast with the just-in-time principles often applied today. *Last-mile fulfilment (3b)* as a subform of the supply chain is highlighted in detail because it holds great potential for improvement of energy efficiency based on the highly energy-intensive transport during this last leg of the supply chain. Several interviewees pointed out that, although e-commerce and home delivery of goods are still a very energy intensive fulfilment solution, the increasing use of electric vehicles, more dense delivery nets and high fill rates of the delivery trucks are making this leg more energy efficient in comparison to consumer transportation.

In order to localise where in the logistics system unutilised capacity is available that can be exploited to improve energy efficiency in road freight transportation, it is necessary first to discuss energy efficiency and clarify what the logistics system is about. At the beginning of the chapter, the problem of energy efficiency was expounded and the interactive nature of capacity explained (i.e. the system with components surrounding transport operations as well as the wider structure in which transport is operated). After the conceptualisation of capacity, different system levels were depicted and discussed in relation to where unutilised capacity can be found. Unutilised capacity is available in different activities, is created by different actors and is available in different areas.

## 5.2 RQ2: Utilisation question

After explaining the conceptual view on 'where' in the system overcapacity is available and illustrating this with empirical evidence, the second research questions evaluates *how* that capacity can be utilised to release the potential for improvement of energy efficiency in road freight transportation. Chapter 5.2.1 summarizes causes of unutilised capacity and Chapter 5.2.2 presents a framework proposing countermeasures which help to utilise that capacity, leading in turn to energy efficiency in road freight transportation.

### 5.2.1 Causes of unutilised capacity

The empirical data collected form LSPs and shippers revealed that unutilised capacity can be found within three categories. The categories were chosen, since they explain *who* (actor) and *what* (activity) creates unutilized capacity and *where* (areas in logistics system) it is created (see left column in Table 5.1). Further, they are divided into subcategories. The causes of unutilised capacity are summarized in the right column in Table 5.1. This finding was also presented in Paper 2.

*Table 5.1: Causes of unutilised capacity*

| Category | Subcategory | Causes |
|---|---|---|
| **Actor *(who)*** | Shippers | – Narrow delivery and pickup timeframes for LSP<br>– Requirements, inflexibility and lack of compromises<br>– Demands to receive goods early and post late |
| | Logistics service providers | – Overdelivery of services<br>– Incorrect price setting<br>– Priorities to fulfil customer demands<br>– Compromises and adaption of own logistics processes<br>– Offer broad range of services that is uncompetitive with niche actors<br>– Responsibilities for fill rates delegated to the transport provider<br>– Inflexibility with mixing certain shipments |
| | End-consumers | – Lack of awareness of consequences of own behaviour<br>– Lack of information available on $CO_2$ footprint of transportation<br>– Sales campaigns with free shipping and sending along retour papers increase shipments<br>– Increasing demands for express deliveries<br>– Increasing returns of goods<br>– Expectations for narrow timeframes for home deliveries<br>– High failure rate of home deliveries |
| **Activity *(what)*** | Handling and loading | – Utilisation of vehicles (i.e., fill rate)<br>– Product characteristics<br>– Labour regulations<br>– Loading by hand (i.e., similar to the game Tetris)<br>– Redundant transportation of air and shipping hanging garments<br>– Human error during order picking<br>– Automation and information technology<br>– Standardisation |
| | Driving | – Pressure of deadlines<br>– Delivery peaks during mornings and afternoons (i.e. rush hours)<br>– Last-minute changes in routing due to express deliveries<br>– Driving behaviour<br>– Compromised ability to load shipments |
| | Ordering volumes | – High volumes of parcels needed to fill the system<br>– Volumes from other systems<br>– Overordering capacity by shippers<br>– Imbalances in volume flows and empty running |
| | Consolidation | – Difficulty with sharing distribution capacity among shippers<br>– Simultaneous consideration of volume and weight |
| | Information flow | – Limited internal and external information sharing<br>– Divergent interests |
| | Actor interaction | – Rules set by stronger actor<br>– Prohibited collaboration of larger LSPs (i.e. anti-competition law) |
| **Areas in the logistics system *(where)*** | Just-in-time delivery | – Increased demand for short lead times and smaller batches<br>– High energy consumption due to many small shipments (i.e. no economy of scale) |
| | E-commerce and last-mile distribution | – Increasing number of small shipments instead of full pallets<br>– Higher demand for transportation<br>– Standardised boxes often larger than necessary |
| | Reverse logistics and returns | – Reverse logistics poorly integrated in flow to end consumers<br>– Unprofitable returns<br>– Consumers' using return service simply to test products<br>– Redundant transportation |
| | Cost | – Energy not a crucial cost driver<br>– Pricing model of LSP unaligned with real costs (e.g. 'round prices', home deliveries)<br>– Transportation costs not visible to consumers (i.e. hidden costs) |

These causes of unutilised capacity create inefficiencies in the logistics system. By addressing them, energy efficiency can be achieved and hence energy consumption can be reduced. The causes can also easily be placed into the model of system levels in Figure 5.3, sorted under the corresponding categories. What is more, the empirical evidence delivers further into the first question and helps to clarify more precisely where overcapacity is located. The countermeasures are described in the following chapter.

### 5.2.2 Countermeasures

In order to explain how the causes of unutilised capacity can be addressed and to reach a high level of energy efficiency in road freight transportation, a framework (see Figure 5.4) was developed for Paper 2. Starting with the problem of high energy consumption in road freight transportation, it shows how the objective of high energy efficiency can be reached. The idea behind the framework was introduced by Lee *et al*. (1997a; 1997b). By addressing the problem via the symptom of unutilised capacity, causes could be identified and accordingly countermeasures proposed. This approach mitigated the symptom and in turn is leading to high energy efficiency. The limitation of the framework lies within the non-illustration of the interconnectedness of different causes and countermeasures. By countering one cause, another cause – or even several other causes – most likely will be impacted, either positively or negatively, since all the causes and countermeasures are connected within a system.

Although this research has focussed foremost on energy efficiency through capacity utilisation in road freight transportation and therefore on changes in the management of the logistics system, the main objective is to achieve energy efficiency improvements in logistics as a means to environmental sustainability. Therefore, a reduction of fossil fuels by shifting to alternative fuels is also regarded as a step towards environmental sustainability because not only the amount of fuel is decisive but also the type of fuel used.

In summary, the countermeasures in the category *actor* include better visualisation of performance, education of different actors, management of expectations, outsourcing of tasks to other actors, and the use of fossil-free energy. The countermeasures in the category activity are the standardisation of material handling and procedures, training, off-peak delivery, better planning and information sharing. In the last category, the countermeasures can be summarized by deceleration, disconnection, reduction, tracking and a new cost structure of LSPs.

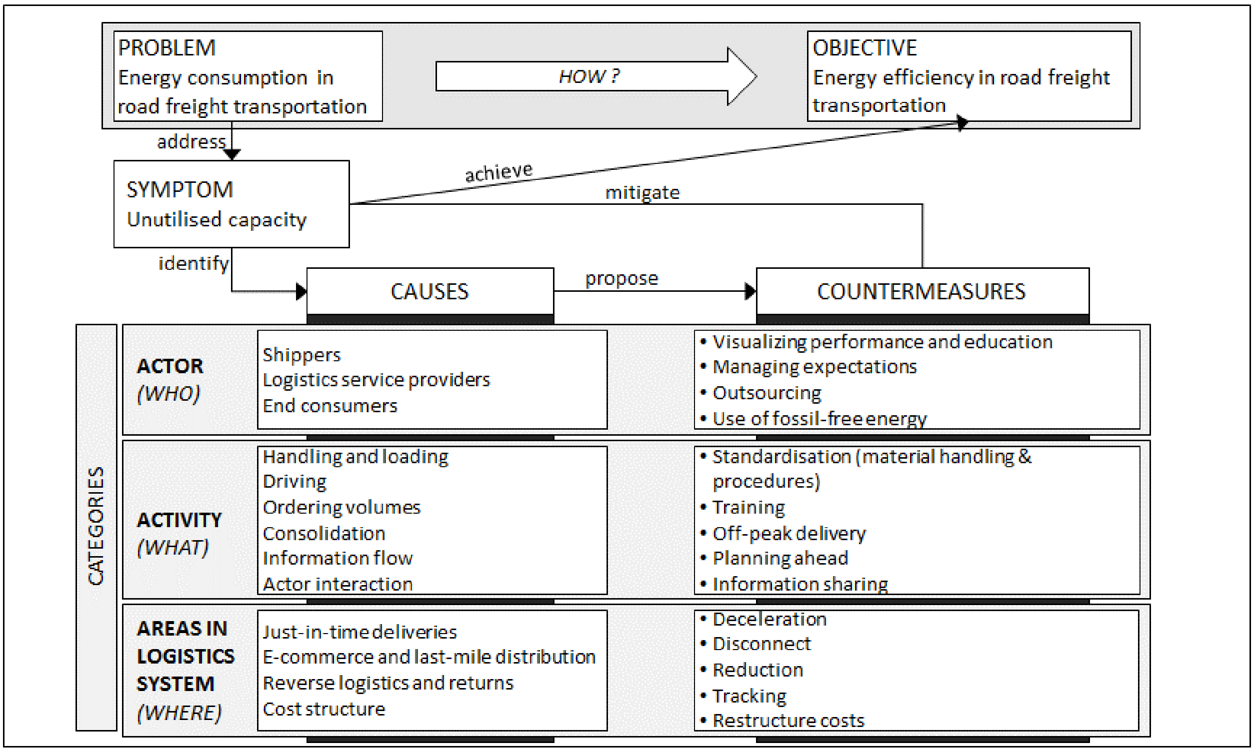


*Figure 5.4: Framework of causes and countermeasures of unutilised capacity*

## 5.3 RQ3: Explorative question

The third research question is the explorative question which is looking into emerging opportunities for energy efficiency when the traditional system boundaries of companies are extended. One opportunity lies within the involvement of actors in logistical activities (Chapter 5.3.1) and, taking this idea further, within the last-mile fulfilment (Chapter 5.3.2), which is one of the most energy-intensive parts of the supply chain.

### 5.3.1 Actors' involvement in logistical activities

Several causes of unutilised capacity could be related to the involvement of actors in logistical activities, which have been described in Papers 2 and 3. The main reasons are demands and requirements that set conditions affecting energy consumption. These demands and requirements are mostly set by one actor which in turn restricts the action of the next actor and leads to a higher energy consumption. End consumers demand short lead times and certain delivery windows. Shippers then forward those short lead times to the LSP by sending their products as late as possible during a day, while consumers want to receive their goods as early as possible. Furthermore, shippers might set certain requirements on routing and consolidation. In cases when LSPs outsource their transportation, the demands and requirements on time and routing are also forwarded to the transport provider. Many interviewees stated that end consumers have very high demands on short lead times and they are the ones triggering fast processes and high energy consumption along the supply chain.

The potential for improvement of energy efficiency lies in assigning the actors new roles. The end consumer, for example, can become a transport provider when transport capacity in the last mile is shared among end consumers (e.g. BagHitch and Piggy Baggy).

In the interviews, several notions were brought up suggesting how the actors' involvement might change in the future to increase energy efficiency in logistics. These notions can be summarised as follows:

- *LSP*. LSPs tend to alter their processes to fulfil their customers' demands (e.g. concerning delivery and pickup times and certain routes) which increases energy consumption. But by focusing less on customer service and more on energy consumption, energy efficiency could be improved – meaning that excessive offering of services to consumers should be avoided.
- *Shipper*. Customers of logistics services are very demanding but should be more willing to accept compromises (e.g. on delivery and pickup times), and should collaborate more closely with other actors which would improve energy efficiency.
- *End consumer.* In their demands and behaviour, end consumers often neglect the environmental considerations of transportation. Therefore, end consumers need higher awareness and better education. They should be open to the possibility of receiving the information they need to take decisions considering environmental sustainability. Such an attitude change could alter their behaviour and result in lower demand for express deliveries and allow more regional or national sourced products with shorter transport distances.

### 5.3.2 Last-mile fulfilment

Since the distribution during the last mile is very energy-intensive, it also offers great potential for improvement of energy efficiency. Paper 3 analysed that potential in greater detail, and a framework with an interactive approach to energy efficiency on the last-mile logistics was advocated. The energy efficiency of the last mile of the supply chain can be understood in regard to three building blocks: (A) distribution structure, (B) transportation execution and (C) household logistics capability (see Figure 5.5).

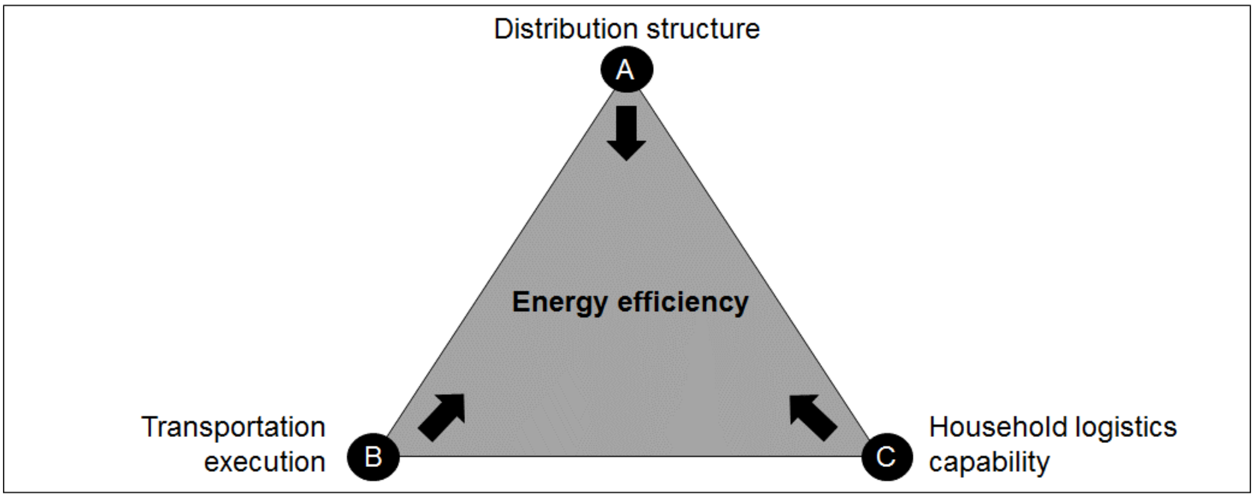


*Figure 5.5: Interactive approach to energy efficiency in the last-mile logistics fulfilment*

The downstream part of the supply chain presents an array of (A) *distribution structures* which differ as to the origin of the shipment (e.g. distribution centres, terminals and stores), the destination (e.g stores or other collection points) and the attributes of the delivery process (e.g. speed and flexibility). The (B) *transportation execution* is characterized by how the transport of goods is executed and can be divided into private and commercial transportation. Special emphasis is laid on the (C) *household logistics capabilit*y which assigns the end consumer a role in the logistics system, rather than simply being a receiver. End consumers can be engaged in last-mile fulfilment by *collecting* (active role) the goods at a pickup point or store, *receiving* (passive role) goods by home delivery or showing involvement in a hybrid form – a mix of active and passive roles. But even with the passive role, the end consumer has to fulfil the role of a co-producer of the final logistics service. The ability to collect and receive goods has implications on the energy efficiency. The term household logistics capability devotes skills, involvement and resources at the household end of the supply chain to perform logistics activities.

Whether consumers pick up their products or receive them via home delivery, transport activities in the last leg of the supply chain are very energy intensive. Therefore, it was asked in the interviews what changes could lead to more energy efficiency in logistics in that last part of the supply chain and could they suggest a change that includes all three building blocks. One example given was that home deliveries would be developed and increase noticeably, which in turn could create a tighter delivery net, higher fill rates of delivery vehicles and more efficient route planning. What is more, private vehicles would no longer be needed for shopping trips and might become unnecessary. Although this change would increase logistics activities, it could still lead to increased energy efficiency because private transportation would be reduced. Another example raised by several interviewees focussed on the distribution structure by changing the setup of pickup points. At present, pickup points belong to one LSP, but by creating LSP-independent points, the pickup net could be denser, which would enable the end consumer to walk more often and take the car less.

## 5.4 Summary of results

Table 5.2 summaries the results from the previous subchapters.

*Table 5.2: Summary of results of each research question*

| Research questions | Studies | Papers | Results |
|---|---|---|---|
| RQ 1 – 'Identification question' | Literature review, secondary evidence and *capacity* study (interviews) | Paper 1, Paper 2 | Difficult for companies to measure energy efficiency: (a) difficulty in collecting the right data, (b) multiplicity of collected indicators and (c) difficulty to define system boundaries.<br>Capacity has to be viewed as an *interactive concept* of several components that can be units and actors.<br>Viewing capacity on different levels opens up new potential within the category *activities*, *actors*, and *areas* |
| RQ 2 – 'Utilisation question' | Literature review, *capacity* study and *fulfilment* study (interviews), secondary evidence | Paper 2, Paper 3 | Unutilised capacity can be caused by shippers, LSPs and end consumers (*actors*), by handling and loading, driving, ordering volumes, consolidation, information flow and actor interaction (*activities*), and through just-in-time deliveries, e-commerce and last-mile distribution, reverse logistics and returns and the cost structure (*areas in the logistics system*).<br>Countermeasures include better visualisation of performance, education of different actors, management of expectations, outsourcing of tasks to other actors, use of fossil-free energy, standardisation of material handling and procedures, training, off-peak delivery, better planning, information sharing, deceleration, disconnection, reduction, tracking and a new cost structure of LSPs. |
| RQ 3 – 'Exploration question' | Literature review, *fulfilment* study (interviews) | Paper 3 | Actors set demands and requirements which set conditions on the energy consumption.<br>Energy efficiency in the last-mile logistics fulfilment is defined through the interplay of three building blocks *distribution structure*, *transportation execution* and *household logistics capability*.<br>Household logistics capability devotes skills, involvement and resources at the household end of the supply chain to perform logistics activities. |

# 6 Discussion

Returning to the purpose, this thesis seeks to identify the potential for improvement of energy efficiency in logistics through the utilisation of capacity in road freight transportation in order to enhance environmental sustainability. From the results from Chapter 5 and the appended papers, five propositions were derived. These propositions are justified by discussing their significance in relation to each other (Chapter 6.1) and in relation to the literature (Chapter 6.2). The propositions are:

1. The problem of measuring energy efficiency and working with it relates to
    a) lack of conceptualisation of energy efficiency in logistics
    b) the problem of methodology
    c) diversity in practice
2. Energy efficiency improvements in logistics can be achieved directly by approaching ‘energy’ (type and amount) and indirectly through utilising overcapacity from road freight transportation and adjacent logistical activities
3. Approaching capacity utilisation on different system levels opens up new potential for improvement of energy efficiency
4. The complex logistics system needs to be simplified and broken down so the problem of high energy consumption becomes manageable
    a) LSPs can improve energy efficiency by utilising capacity in the transport vehicles and on a higher system level through coordination of logistical activities
    b) Shippers can see their business processes in relation to the logistics system and understand where their requirements cause unutilised capacity
5. End consumers can take on both active and passive roles in the logistics fulfilment in order to improve energy efficiency

The first proposition highlights a serious problem in industry and calls for more exact tools and comparable methods to overcome the difficulties of measuring and working with energy efficiency. This measurement problem relates to how energy efficiency is conceptualised in logistics, since there is no distinct or common definition that can guide researchers or professionals. Further, it is a methodological problem, because the view on energy efficiency and the level of achievement, depends upon the actor that has been interviewed and is therefore heavily founded in subjectivity. And finally, it is a practical problem because the data are not reliable and cannot be compared.

The second proposition emphasizes that while energy efficiency in logistics can be improved directly by approaching ‘energy’ in terms of fuel type and amount, to exploit the full potential for improvement of energy efficiency, capacity in road freight transportation and adjacent logistical activities needs to be utilised. The third proposition relates capacity on different levels to the potential for improvement of energy efficiency. Fourth, by applying a structured approach and dealing with the causes of unutilised capacity one by one by addressing corresponding countermeasures, the problem can be reduced to a simpler, more manageable problem. This however, does not mean, that the systems view can be neglected; instead, different approaches for LSPs and shippers can be derived. Finally, assigning the end consumer an active or passive role, devotes skills, involvement and resources to the last mile of the supply chain and applies an energy-centric perspective to logistics fulfilment. This highlights the importance of a behavioural change from the actors.

## 6.1 Discussion of results in relation to each other

In the following discussion, the propositions are justified by discussing their significance in relation to each other.

Proposition1 stands alone by highlighting a problem and not an opportunity, as the other propositions do. However, this proposition is essential because differences in practice make it difficult to measure and compare the energy efficiency of different transport activities. This is a problem for LSPs as well as shippers.

Propositions 2, 3 and 4 all acknowledge the interactive nature of capacity and are relevant to both actors, LSPs and shippers. Proposition 2 recognises the contribution of overcapacity from road freight transportation to energy efficiency but also points out that further potential for improvement lies within a wider system. Proposition 3 concentrates on the existence of capacity on different system levels. Proposition 4 agrees with both previous propositions. However, it goes a step further and addresses the necessity to break down the complex logistics system to make the problem of high energy consumption manageable for LSPs and shippers. LSPs can improve energy efficiency by utilising capacity in the transport vehicles and on a higher system level through coordination of logistical activities. Shippers can see their business processes in relation to the logistics system and understand where their requirements cause unutilised capacity.

Like all the other propositions, Proposition 5 addresses the actors, LSP and shipper, but beyond that it also involves the end consumer. First, it assigns the end consumer with the attribute of the household logistics capability a distinct role in the last-mile fulfilment, which can describe active or passive involvement. Second, it acknowledges the importance of the logistics fulfilment structure by applying an energy-centric perspective to the logistics fulfilment. This proposition is especially strong and novel, and highlights not only the need for behavioural change from the customers of logistics services (i.e. shippers) and LSPs, but also from the end consumers. This proposition goes beyond capacity utilisation and focuses more on the underlying structure.

Although the propositions address different dimensions of where the potential for improvement of energy efficiency in logistics can be identified, they are not exclusive to each other but rather strengthen one another.

## 6.2 Discussion of results in relation to the literature

This discussion is structured around four papers. The first two papers, by Liimatainen *et al.* (2015) and Browne *et al.* (2006), served as core literature for this thesis and the appended papers. They have been chosen because of their relevance to the research by focusing on the energy-logistics domain and environmental sustainability. The other two papers, by Marchet *et al.* (2014) and Centobelli *et al.* (2017), are novel literature reviews that reflect therefore a large share of the current body of knowledge. By comparing the results with these papers, the research can be discussed in terms of its significance in relation to the current body of knowledge. A summary of this discussion is presented in Table 6.1.

Liimatainen *et al.* (2015) discuss trends and identify four driving forces impacting the development of road freight $CO_2$ emissions:

- the structural change of the economy,
- changes in logistics practices and technology,
- changes of consumer habits and
- energy and environmental concerns

A structural change of the economy as well as changes in logistics practices and technology make a transition to different system levels necessary; therefore, Proposition 3 confirms this part of the literature. By broadening the scope and shifting to a higher system level, new business models can be developed and new logistics services offered with a focus on energy efficiency. The changes of consumer habits include the expectation that more and more small shipments are demanded by the end consumer which emphasizes the importance of involving the end consumer actively to shape an energy efficient last-mile fulfilment solution (confirmed through Proposition 5). Concerns of energy and the environment accompanied with a growing awareness of environmental issues underline the need to change the current situation, reorganise the freight transport sector to utilise overcapacity and assess adjacent logistical activities for further potential for the improvement of energy efficiency (Proposition 2).

Browne *et al.* (2006) conclude that in order to increase energy efficiency in transport activities, the following steps are necessary:

- A reduction of commercial freight transport energy consumption is needed through less globalised supply chains and through distribution of goods to stores in large vehicles with high load factors.
- A reduction of consumer transport energy consumption is needed by having centrally located retail outlets in cities, thus causing less use of cars, and shopping trips to big outlet retailers outside the city centre are only executed under the premise of buying full shopping baskets.
- The design of the supply chain should be reconsidered, including the number of stockholding points in the chain, transport modes, vehicle load factors and transport distances in regard to their impact on energy consumption.

The need for reducing commercial freight transport energy consumption by reducing distances and increasing vehicle utilisation shows simple steps toward higher energy efficiency in logistics. The steps address the overall problem. It shows that manageable steps are necessary to solve the complex problem and confirms Proposition 4. Further, the need for reducing consumer transport energy consumption is reflected in Proposition 5. A new design of the supply chain and fulfilment options to reach higher energy efficiency is supported through the need to shift perspectives and system levels, and is confirmed through Proposition 3.

The literature review by Marchet *et al.* (2014) categorises research on environmental sustainability in logistics and transportation presented according to five themes. These were chosen to challenge key issues of sustainability initiatives and compare the literature on environmental sustainability in logistics and transportation in a literature review. The themes are:

- initiatives towards environmental sustainability,
- benefits achieved after adoption,
- motivations for adoption,
- critical issues and barriers to adoption and
- evaluation and measurement of environmental initiatives

The propositions are reflected in the themes by Marchet *et al.* (2014). Initiatives towards sustainability can be approached through simple and manageable steps by identifying the causes of unutilised capacity and following up with corresponding countermeasures (Proposition 4). The benefits are summarized by Marchet *et al.* (2014) as better air quality, fewer trips, less congestion and reduced transportation costs, which shows the significance of utilising capacity and exploiting other potential to contribute to energy efficiency and is reflected in Proposition 2. Motivations to adopt these initiatives are manifold, such as external factors like the involvement of other actors to actively shape an energy-efficient logistics fulfilment solution (Proposition 5) or the possibility for companies to find new potential when shifting system levels (Proposition 4) which might enable business advantages. The difficulty of measuring energy efficiency, which is reflected in Proposition 1, is not only a barrier to adoption of sustainability initiatives but calls for a more common approach to evaluate and measure environmental sustainability to be able to compare results among different companies and activities.

Centobelli *et al.* (2017) identify six gaps in the literature on the subject of environmental sustainability of the service industry of LSPs. The gaps concern:

- the classification of green initiatives,
- the impact of green initiatives on LSP performance,
- the evaluation of sustainability performance,
- the factors influencing the adoption of environmental sustainability initiatives,
- the customer perspective in the sustainable supply chain and
- the information and communication technologies supporting green initiatives

Classification of green initiatives involves the concern that such initiatives neglect involving the management. However, by approaching the potential for improvement of energy efficiency on different system levels, the focus is also set on the management level (Proposition 3). The impact of green initiatives on LSP performance and the need for a common method and approach to evaluate sustainability is confirmed through Proposition 1 which suggests that comparable and consistent methods are needed. The factors influencing the adoption of environmental sustainability initiatives are reflected in the significance of the step-by-step approach in Proposition 4. The customer perspective in the sustainable supply chain is confirmed through Proposition 5 which highlights the necessity to involve the end consumer actively in logistics fulfilment. Support of green initiatives through information and communication technologies can be tied closely to the need to shift between system levels (confirmed through Proposition 3) which opens up new potential for improvement on different system levels.

The key propositions in relation to the literature are presented in Table 6.1. They are related in regard to themes which are known from the literature and new themes.

*Table 6.1: Key propositions related to the literature*

| No. | Propositions | Themes from the literature | New themes |
|---|---|---|---|
| 1. | The problem of measuring energy efficiency and working with it relates to (a) lack of conceptualisation of energy efficiency in logistics; (b) the problem of methodology and (c) diversity in practice | Evaluation and measurement of environmental sustainability (Marchet *et al.*, 2014)<br>Need of evaluation of sustainability performance (Centobelli *et al.*, 2017) | Criticalities and barriers to adoption of initiatives towards sustainability (Marchet *et al.*, 2014) → new approach needed<br>Impact of green initiatives on LSP performance (Centobelli *et al.*, 2017) → mitigating the symptom of overcapacity by proposing countermeasures |
| 2. | Energy efficiency improvements in logistics can be achieved directly by approaching ‘energy’ (type and amount) and indirectly through utilising overcapacity from road freight transportation and adjacent logistical activities | Reduction of commercial freight transport energy consumption (Browne *et al.*, 2006)<br>Benefits achieved after adoption of initiatives towards sustainability (Marchet *et al.*, 2014) | Concerns of energy and environment (Liimatainen *et al.*, 2015) → reorganising the freight transportation sector and utilising overcapacity |
| 3. | Approaching capacity utilisation on different system levels opens up new potential for improvement of energy efficiency | Motivations to adoption (Marchet *et al.*, 2014) such as business advantages<br>Information and communication technologies supporting green initiatives (Centobelli *et al.*, 2017) | Structural change of the economy and changes in logistics practices and technology (Liimatainen *et al.*, 2015) → shifting to higher system level and developing new business models and services<br>New design of the supply chain (Browne *et al.*, 2006) → taking perspective of higher system level |

| | | | |
|---|---|---|---|
| | | | Concerning the classification of green initiatives (Centobelli *et al.*, 2017) → focus on management level |
| 4. | The complex logistics system needs to be simplified and broken down so the problem of high energy consumption becomes manageable for LSPs and shippers | Reduction of commercial freight transport energy consumption (Browne *et al.*, 2006) | Initiatives towards environmental sustainability (Marchet *et al.*, 2014) → identify causes and counteractions (structured approach)<br>Factors influencing the adoption of environmental sustainability initiatives (Centobelli *et al.*, 2017) → step-by-step approach necessary |
| 5. | End consumers can take on both active and passive roles in the logistics fulfilment in order to improve energy efficiency | Reduction of consumer transport energy consumption (Browne *et al.*, 2006)<br>Motivations to adoption of initiatives towards sustainability (Marchet *et al.*, 2014)<br>Customer perspective in the sustainable supply chain (Centobelli *et al.*, 2017) | Changes of consumer habits: increasing demand of small shipments (Liimatainen *et al.*, 2015) → involvement of end consumer necessary<br>Motivations to adoption of initiatives towards sustainability (Marchet *et al.*, 2014) → active shaping of logistics fulfilment through end consumer |

## 6.3 Reflection on the theoretical perspective

As stated in Chapter 2.4.1, the systems view serves as a theoretical perspective for this research. The systems view helps to understand the real world in its totality of interconnected parts simplified in a model (Arbnor and Bjerke, 2009) and underlines the complexity of this research field. However, there are other interesting theories, which can be connected to logistics and supply chain management on a cross-section to environmental sustainability. For example, Sarkis *et al.* (2011) review several theories which have been used in green supply chain management, such as complexity theory, ecological modernization, information theory, institutional theory, resource-based view, resource dependency theory, social network theory, stakeholder theory and transaction cost economics.

Considering the core of this research on energy efficiency improvements in logistics as a means to environmental sustainability, it seems suitable to connect further theories to the theoretical foundation of the systems view to emphasise environmental sustainability, scarcity of resources and dependency among different actors in the supply chain. Against this background, the *resource-based view* (RBV) is suggested for future research. RBV proposes that competitive advantage can be achieved and held by having superior resources which are protected by an isolating mechanism that prevents their diffusion throughout industry (Barney, 1991). RBV is often applied in connection to greening supply chains (Sarkis *et al.*, 2011) and a suitable stream within RBV for future research could be the dynamic capabilities view which focusses more on competitive advantage of a company in response to a fast changing environment.

Furthermore, the *resource dependency theory* (RDT) could be used for future research. It centres on the scarcity of resources and dependency among different actors. The strength of RDT is that it points out the importance of building up long-term relationships, instead of aiming for short-term benefits at the cost of others (Sarkis *et al.*, 2011). RDT describes companies as being dependent on each other and not fully self-sufficient. However, to acquire scarce and valuable resources, companies need to build up relationships and collaborations (Carter and Rogers, 2008).

Additionally, *information theory*, also called information asymmetry and signalling theory, delivers insights into the lack of knowledge of certain actors, which is referred to as information asymmetry (Sarkis *et al.*, 2011). Information in general, and in detail on environmental sustainability, from the upstream part of the supply chain often does not reach the end consumer. These information asymmetries can occur purposefully when companies seek to hold power within the supply chain, but can also be the result of bad communication and education. With a focus on logistics fulfilment, this theory advises the understanding of the end-consumer's position and behaviour and how the lack of knowledge can be approached.

## 6.4 Summary of discussion

Figure 6.1 summarises the conducted research, including the frame of reference, research questions, papers and the particularities of the results in a conceptual model. The conceptual model has been developed from Figure 2.4 and Figure 5.1.

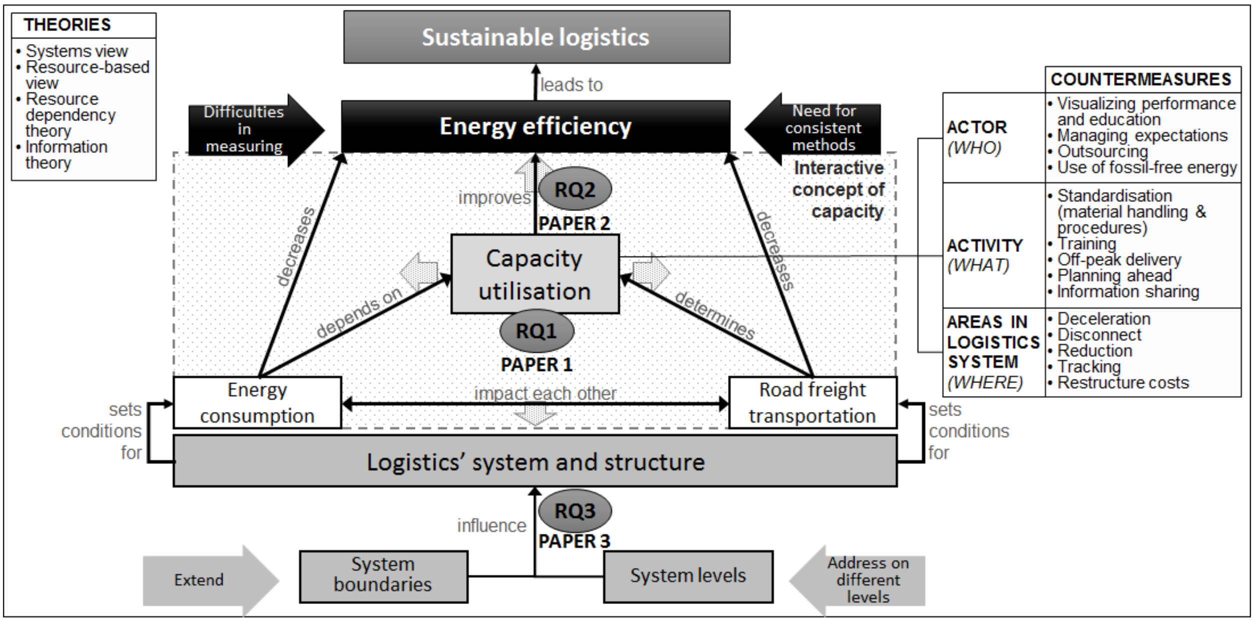


*Figure 6.1: Summary of discussion (conceptual model 3)*

The research suggests addressing capacity utilisation on different system levels and extending the system boundaries to open up new potential for improvement of energy efficiency. The interactive nature of capacity needs to be regarded. Difficulties with the measurement of energy efficiency could be highlighted, and the need for consistent methods is apparent. Systems view, resource-based view in connection with dynamic capabilities view, resource dependency theory and information theory are suggested as theoretical perspectives for further research.

# 7 Conclusion and future research

This chapter presents the conclusion of the thesis and gives suggestions for future research.

## 7.1 Conclusion

The research addressed the identification of potential for improvement of energy efficiency in logistics through the utilisation of capacity in road freight transportation to enhance environmental sustainability. By conducting four studies, which resulted in three papers and answered the three research questions, two key points could be derived:

- *Interactivity.* Capacity needs to be viewed as an interactive concept
- *Extension.* The scope on capacity needs to be extended through revision of the system boundaries

Capacity is traditionally referred to as a narrow concept but in this research it is addressed as a complex interaction of several components embedded in a wider system. As the research shows, capacity interacts with components, which can be defined in terms of units or actors. By answering the first research question, the ‘identification question’, it could be identified *where* in the logistics system unutilised capacity is available. When the components (e.g. equipment, human resources, process characteristics and products) are not in a balanced interplay, overcapacity in road freight transportation and adjacent logistical activities arises on and between different system levels. These system levels can be summarised in three categories – activities, actors and areas.

The ‘utilisation question’ addresses *how* this overcapacity can be utilised and proposes several countermeasures. The measures taken on the system level of ‘activities’ include the standardisation of material handling and procedures, training, off-peak delivery, better planning and information sharing. The countermeasures in the category ‘actors’ are better visualisation of performance, education of different actors, management of expectations, outsourcing of tasks to other actors, and the use of fossil-free energy. In the category ‘areas’, the countermeasures can be summarized by deceleration, disconnection, reduction, tracking and a new cost structure of LSPs.

The third research question, the ‘exploration question’, addresses *what other opportunities* emerge when the traditional system boundaries of logistics are extended. To broaden the scope on capacity, either the system boundaries can be extended horizontally or the view on capacity can be shifted vertically onto another system level. By reconsidering the structure, capacity can be viewed in a wider context. The extension of the system boundaries, for example, shifts the view from focussing solely on the company’s core business so that it includes inbound and outbound logistics, raw material acquisition by suppliers, transportation to retail outlets and the point of consumption, as well as returns and recycling.

This research highlights the importance of including all actors in the fulfilment of logistics – LSPs, shippers and end consumers – and assigning especially the end consumer a role and task in the logistics fulfilment at the point of consumption. Demands and requirements by one actor sets limitations on the other actors and their behaviour has a great impact on the energy consumption. Only by viewing capacity as an interactive concept can those connections as well as limitations be considered.

Reconsidering the view on capacity by shifting the system levels, makes it possible to view capacity not just as a narrow concept but instead in all its facets. The concept of capacity carries throughout all levels, starting with a product, its package fit, the pallet fit, the capacity utilisation of the warehouse and the truck, influenced by the ability of actors to adapt to time slots and other demands. Capacity on the level of the logistics systems design is impacted by location of warehouses and terminals, consolidation and the use of automation. The highest level of the supply chain structure is decisive for capacity utilisation through supplier choices and the design of the supply chain.

But capacity utilisation also has to be approached with caution. High utilisation rates do not at all times lead to energy efficiency. High fill rates in trucks can, for example, be the result of detours to collect goods or result in overordering of products and in the outcome of this, high return rates. These effects could increase energy consumption, instead of decreasing it. In addition, highly energy-efficient road freight transportation could lead to lower prices for customers and therefore additional usage of transportation – an effect called the rebound effect. Further, energy-efficient road freight transportation could make transportation by road more attractive leading to displacement of freight from other transport modes to road freight transportation. In this case, modes, like rail, which are more energy efficient, could then lose goods. This displacement of freight to road transportation mode would not enhance environmental sustainability. Therefore, it is important to view capacity in an extended structure and with its interactivity with other components. Sustainable logistics can be described as a paradox; problems solved by introducing new solutions can then become part of a later problem.

The thesis contributes to the fields of road freight transportation and logistics at a cross-section with environmental sustainability. Its managerial contribution includes the framework on causes of unutilised capacity and counteractions, identifying where the potential for improvement of energy efficiency is and how it can be exploited. Furthermore, the thesis suggests that improving energy efficiency in the last-mile fulfilment must focus on the interplay between distribution structure, transportation execution and household logistics capability and consequently highlights the importance for LSPs and shippers to involve end consumers more and assign them a distinct role.

## 7.2 Future research

In order to improve energy efficiency in logistics substantially and reduce energy consumption dramatically, further research is needed. Based on this work, three different paths are suggested for future research.

First, future research could investigate the logistics fulfilment further regarding its potential for different distribution options. In Paper 3, six fulfilment options were investigated in regard to their energy-efficiency characteristics. But this array of options is not entire; instead other options and hybrid forms could be analysed in regard to their energy efficiency. Furthermore, this was a qualitative study, a quantitative validation of the results could also be of interest.

Second, the research mainly focused on the flow of goods downstream in the supply chain and towards the end consumer. But because of the steady growth of e-commerce, the number of returns is growing. Future research could investigate this return flow and analyse it in regard to energy efficiency. Questions to be answered could be: Where in the supply chain are the goods returning to? How are the goods put into the return flow by the end consumer? In other words, what is the ‘first-mile’ logistics capability?

Third, many services offered today tempt the end consumer to order and return goods, thus triggering energy-consuming activities along the supply chain. Future research could therefore investigate the driving forces influencing the emergence of the order and return service and how logistics services can steer the end consumer into a higher awareness of environmental sustainability.

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# Appendix

## Appendix A: Application of the term ‘capacity’ in the core literature

| **Paper**<br>[Author (Year): Title] | **Research design** | **Application of ‘capacity’**<br>[referring to (i) capacity as an interactive concept, (ii) ability to manage interplay of components and (iii) adjustment of system boundaries] |
|---|---|---|
| Wu and Dunn (1995): Environmentally responsible logistics systems | Conceptual | (i) Impact on environment can be reduced by different activities like reduced number of trips, good information system, collaboration and use of alternative fuels; (ii) to minimize environmental impact all activities have to be evaluated; (iii) adds level of reverse logistics (i.e. reduce, substitute, reuse and recycle) |
| Pfohl and Zöllner (1997): Organization for logistics: the contingency approach | Qualitative | (i) Efficiency in logistics is influenced by several factors (e.g. environmental relations, product line, production, technology and size of organisation); (ii) the relation of ‘flow of products’ and ‘flow of information’ determines logistical capacities; (iii) suggests different ways to integrate logistics into organizations |
| McKinnon and Ge (2004): Use of a synchronised vehicle audit to determine opportunities for improving transport efficiency in a supply chain | Quantitative survey | (i) Energy efficiency is influenced by key performance indicators (KPI) like vehicle loading, empty running, fuel efficiency, vehicle time utilisation and deviations from schedule; (ii) KPIs make it possible to measure efficiency |
| Browne *et al.* (2005): Life Cycle Assessment in the Supply Chain: A Review and Case Study | Quantitative survey | (i) Life cycle assessment (LCA) evaluates different activities (e.g. acquisition of raw material, processing, storage, transportation, use, recycling); (ii) LCA is a tool to measure the environmental impact and to identify potential; (iii) views the whole supply chain and includes the last mile (i.e. consumer transport) |
| Browne *et al.* (2006): Assessing transport energy consumption in two product supply chains | Quantitative case study | (i) Energy efficiency is influenced by sourcing, distribution centre locations, transport modes, road freight vehicle types and weights, vehicle load factor, empty running and transport distance; (iii) emphasising the importance of the last mile (i.e. consumer transport), views entire supply chain |
| Aronsson and Huge-Brodin (2006): The environmental impact of changing logistics structures | Literature review and case study | (i) Environmental impacts are influenced by i.a. consolidation, flexible warehouses, visibility, planning and modal shift; (ii) higher resource efficiency can be reached through better utilisation (e.g. higher load factor and tracing of vehicles); (iii) suggest macro perspective to view the supply chain |
| Chapman (2007): Transport and climate change: a review | Literature review | (i) Capacity is influenced by i.a. technology, transport mode, vehicle load and taxes; (ii) just-in-time deliveries transport only small loads in rapid times which creates overcapacity |
| Johansson (2009): Will restrictions on CO2 emissions require reductions in transport demand? | Quantitative case study | (i) Technology developments are not sufficient to reach the environmental targets, behavioural changes and policies are needed; (ii) fossil fuels can be replaced with alternative fuels |
| Piecyk and McKinnon (2010): Forecasting the carbon footprint of road freight transport in 2020 | Qualitative | (i) Energy efficiency is influenced by i.a. weight of goods, empty running and average vehicle energy consumption; (ii) presents a model of the interplay of different aggregates and determinants on energy efficiency; (iii) in future companies and government have to intensify their efforts to reduce their carbon footprint |
| Wolf and Seuring (2010): Environmental impacts as buying criteria for third party logistical services | Qualitative case study | (i) The relationship with a third party logistics provider (3PL) builds up on integration, cooperation and information sharing; (iii) 3PLs are often part of a global network, i.e. broad system boundaries |
| Liimatainen and Pöllänen (2010): Trends of energy efficiency in Finnish road freight transport 1995–2009 and forecast to 2016 | Quantitative | (i) Energy efficiency is influenced by i.a. average load on laden trips, empty running and average vehicle energy consumption; (ii) presents a model of the interplay of different aggregates and determinants on energy efficiency; (iii) suggests to include all levels of the logistics management when promoting energy efficiency |

| | | |
|---|---|---|
| Kalenoja *et al.* (2011): Indicators of energy efficiency of supply chains | Qualitative case study | (i) Energy efficiency is influenced by i.a. energy consumption, delivery times, transport speed, flexibility, reliability and vehicle load; (ii) life cycle assessment or a balanced score card are tools to measure energy efficiency; (iii) about the importance of defining system boundaries |
| Björklund (2011): Influence from the business environment on environmental purchasing — Drivers and hinders of purchasing green transportation services | Quantitative survey | (i) Green transportation is influenced by several factors (e.g. management, resources, image, customers, product suppliers); (ii) interplay of factors influence the concept of environmental purchasing; (iii) including the top management is one of the greatest enablers for environmental purchasing of transportation services |
| Plambeck (2012): Reducing greenhouse gas emissions through operations and supply chain management | Conceptual | (ii) Efficiency can be increased by harmonisation and coordination of different operations/actors in the supply chain; (iii) collaboration between all actors of the supply chain is important (e.g. know-how transfer to suppliers and long term commitment) |
| Allen *et al.* (2012): Investigating relation-ships between road freight transport, facility location, logistics management and urban form | Quantitative case study | (i) Energy-efficient urban freight transport depends i.a. settlement size, provision of local facilities, accessibility to local transport infrastructure and networks, availability of parking facilities and road network type; (ii) presents a model of the interplay of different key variables on energy efficiency |
| Abbasi and Nilsson (2012): Themes and challenges in making supply chains environmentally sustainable | Content analysis | (i) Energy efficiency is influenced by time taken for activities, costs, service levels and policies; (iii) emphasises the importance of the last mile (i.e. consumer transport) |
| Rizet *et al.* (2012a): Assessing carbon footprint and energy efficiency in competing supply chains: Review – Case studies and benchmarking | Quantitative case studies | (i) Energy efficiency is influenced by time taken for activities, costs, service levels and policies; (iii) emphasises the importance of the last mile (i.e. consumer transport) |
| Halldórsson and Svanberg (2013): Energy resources: trajectories for supply chain management | Conceptual | (i) Suppliers have to work together to ensure the functioning of the supply chain of inter-connected companies; (ii) managing supply chain and its entities; (iii) includes the down-stream of the supply chain (i.e. the point of consumption) |
| Brown and Guiffrida (2014): Carbon emissions comparison of last mile delivery versus customer pickup | Quantitative | (i) Consumer transport is not used to capacity and therefore generates overcapacity; (ii) a well-planned delivery route is much more efficient than an end consumer driving the last mile; (iii) emphasises the importance of the last mile and compares consumer transport with delivery |
| Liimatainen *et al.* (2014): Decarbonizing road freight in the future - Detailed scenarios of the carbon emissions of Finnish road freight transport in 2030 using a Delphi method approach | Quantitative | (i) The average fuel consumption is influenced by fuel costs, vehicle technology, environmental pressure, emission regulations, average load, empty running and the development of hybrid electric technology |
| Bottani *et al.* (2014): Improving logistics efficiency of industrial districts: a framework and case study in the food sector | Quantitative case studies | (i) Integrated approach to achieve efficiency by pooled management of packaging, procurement, warehousing and transportation activities; (ii) managing logistics in a coordinated way has potential to solve inefficiencies; (iii) applies holistic view – from producer (i.e. farmer) to market of end consumer |
| Liimatainen *et al.* (2015): Driving forces of road freight CO2 in 2030 | Quantitative | (i) Energy efficiency is influenced by i.a. average length and load of laden trips on road, empty running and average vehicle energy consumption; (ii) presents a model of the interplay of different aggregates and key indicators on energy efficiency |
| McKinnon (2016b): Freight transport deceleration: Its possible contribution to the decarbonisation of logistics | Conceptual | (i) Additional road capacity could lead to less congestions, a constant truck speed and higher fuel efficiency; (iii) acceleration of freight move enables companies to concentrate production capacity and inventory in fewer locations |

## Appendix B: Additional papers by the author

Halldórsson, Á., Sundgren, C. & Wehner, J. (forthcoming), 'Sustainable Supply Chains and Energy: Where "Planet" meets "Profit"'. Sarkis, Joe (eds.): 'Handbook on Sustainable Supply Chains'.

*This book chapter is planned to be published in 2018. A summary is included in Chapter 4.4. The planning and coordination of the book chapter was done by the first author. The writing was shared equally among all authors.*

Wehner, J. & Halldórsson, À. (2016), 'Improving Energy Efficiency in Supply Chains: Causes of Overcapacity in Road Freight Transportation'.

*Developed for the course 'Writing up for publication: concentrated academic-writing retreat' (GFOK085), 25-27 May 2016 in Gothenburg, Sweden. Based on interviews, secondary data and literature review. Contribution: Development of the system levels and explanation.*

Wehner, J., Halldórsson, À. & Lumsden, K. (2015), 'Energy-Efficient Logistics System: Improving Energy Consumption, Capacity Utilization and Flow of Goods'.

*Developed for the PhD student Workshop at the Department Technology, Management and Economics, 17-18 March 2016 in Västerlanda, Sweden. Work-in-progress of a book chapter which was later on not submitted. Contribution: Developing a framework on the interplay of 'energy, 'capacity' and 'flow' and presenting the idea of system levels.*

Wehner, J. (2015), 'A Capacity Perspective on Energy Efficiency in Freight Transport'.

*Developed for the PhD student Workshop at the Department Technology, Management and Economics, 19-20 March 2015 in Tollered, Sweden. Contribution: Conceptualising capacity and formulating the first set of research questions.*

Wehner, J., Halldórsson, À. & Lumsden, K. (2015): 'Energy Efficiency by Utilising Overcapacity in the Logistics System?'.

*Developed for the course 'Publishing in logistics and supply chain management', 12-14 August 2015 in Helsinki, Finland. Based on literature review and secondary data. Contribution: Highlighting the importance of the interplay of 'energy, 'capacity' and 'flow'. Predecessor of the LRN 2015 conference paper.*