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Improving energy efficiency in logistics systems:

On the road to environmental sustainability

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Abstract

Logistics are essential to efficiently managing the flow of materials and products between various nodes that operate in multiple systems. In that process, the activities of moving and storing materials and products, especially through road freight transport, consume significant energy resources and emit greenhouse gases that harm the environment. To develop logistics systems in an environmentally sustainable way, a holistic approach to logistics remains necessary. In response, this thesis seeks to expand current understandings of how environmentally sustainable development can be facilitated by improving the energy efficiency of logistics systems.

The thesis draws from a series of five studies in order to critically examine road freight transport before expanding focus to logistics at the point of consumption and, in turn, to post-consumption flow of household waste. First, as a basis for the research, logistics system levels suitable for improving energy efficiency are identified, and the flow of goods towards the point of consumption is investigated, especially in terms of underutilised capacity and means of mitigation. Second, the fulfilment of logistics in the last mile before consumption is analysed, particularly concerning the end consumer's role, by pinpointing the characteristics of energy efficiency that various fulfilment options afford. Third, the transformation of logistics service providers into environmentally sustainable actors is evaluated, along with their maturity in those roles. Fourth, focussing on the post-consumption flow of household waste, the logistics of waste collection are assessed. Therein, the household is viewed as a co-producer of the waste collection service that can increase the value of waste as a resource and boost energy efficiency during waste collection. Fifth and last, by using modularity as a concept and service blueprinting as a tool for improving energy efficiency, the design of logistics services is analysed by disassembling services for waste collection into their various components and modules.

In sum, the thesis compiles five papers based on three semi-structured interview studies and two case studies. Multiple qualitative methods were applied in conjunction with data collection via site visits, brainstorming sessions and a focus group as well as secondary data collection addressing the flow of goods to the point of consumption and in the post-consumption flow of household waste. By mapping current industrial activities performed by multiple actors in different logistics systems, the thesis proposes opportunities for improving energy efficiency in logistics systems and for contributing to environmentally sustainable development. Viewed from a systems perspective, logistics systems are examined as operating in steady interaction with their environments, and service logic is applied to understand the provider and customer ends of logistics services and their interaction.

Keywords: *Capacity utilisation, distribution structure, first mile, household waste, last mile, logistics fulfilment, point of consumption, road freight transport, service blueprint, service logic, service modularity, system levels, systems perspective, value co-creation*

List of appended papers

Paper 1

Wehner, J. (2018), "Energy efficiency in logistics: An interactive approach to capacity utilisation", *Sustainability*, Vol. 10, No. 6, 1727.

A previous version of this paper 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 28th annual Nordic Logistics Research Network Conference (NOFOMA 2016) held on 8–10 June 2016 in Turku, Finland.

Paper 2

Halldórsson, Á. & Wehner, J. (2017), "Last-mile logistics fulfilment: A framework for energy efficiency in the last mile".

This paper was published in the proceedings of the 29th annual Nordic Logistics Research Network Conference (NOFOMA 2017) held on 8–9 June 2017 in Lund, Sweden. The paper was submitted to an international journal. Both authors contributed equally to the paper's planning, data collection, analysis and writing.

Paper 3

Wehner, J., Taghavi, N., Altuntas Vural, C. & Halldórsson, Á. (2019), "Environmental sustainability transition of LSPs through energy efficiency initiatives".

A previous version of this paper was presented at the 5th International EurOMA Sustainable Operations and Supply Chains Forum held on 5–6 March 2018 in Kassel, Germany. The paper has since been submitted to an international journal. All authors contributed equally to the paper's planning, analysis and writing, whereas the first author played a leading role in data collection.

Paper 4

Halldórsson, Á., Altuntas Vural, C. & Wehner, J. (2019), "Logistics service triad for household waste: Consumers as co-producers of sustainability", *International Journal of Physical Distribution & Logistics Management,* Vol. 49, No. 4, pp. 398-415.

A previous version of this paper was published in the proceedings of the 30th annual Nordic Logistics Research Network Conference (NOFOMA 2018) held on 14–15 June 2018 in Kolding, Denmark, where it received the Best Paper NOFOMA 2018 award. All authors contributed equally to the paper's planning, data collection, analysis and writing.

Paper 5

Wehner, J, Altuntas Vural, C. & Halldórsson, Á. (2019), "Energy efficiency in logistics through service modularity: The case of household waste".

A previous version of this paper was published in the proceedings of the 31st annual Nordic Logistics Research Network Conference (NOFOMA 2019) held on 12–14 June 2019 in Oslo, Norway. The paper has since been submitted to an international journal. All authors contributed equally to the paper's planning, analysis and writing, whereas the first author played a leading role in data collection.

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Jessica Wehner

Gothenburg, January 2020

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1 Introduction

This chapter introduces the research conducted for the thesis. After describing the background of the research, it articulates the purpose and research questions, delineates the scope of the research and ends by providing an outline of the thesis.

1.1 Background

Logistics are essential to efficiently managing the flow of materials and products between various nodes that operate in multiple systems. In that process, logistics activities not only consume vast amounts of energy resources but also emit greenhouse gases (GHG) known to harm the environment. Although efforts towards sustainable development, famously advanced in a report by a politician (Brundtland, 1987), have steadily responded to those problems during the past 30 years, their evolution relative to the crisis has been far too slow. As average global temperatures continue to rise (Wen *et al.*, 2011), chiefly due to GHG emissions (Intergovernmental Panel on Climate Change, 2019), the call for immediate change and action issued to governments worldwide has been fiercely brought to the fore, perhaps most prominently by a teenager on social media (UN News, 2019).

For its part, the European Union (EU) has sought to halt climate change from exceeding 2° Celsius above pre-industrial levels (European Commission, 2011c, 2016b). Following suit, all EU member countries have committed themselves to reducing GHG emissions by 80–95% as of 2050 compared to 1990 levels (European Commission, 2011b, 2011c). In that time frame, such an undertaking will require reducing GHG emissions by at least 60% in the transport sector, even as GHG emissions in the sector continue to rise (European Commission, 2011c). Indeed, transport ranks amongst sectors that emit the most emissions; in 2016, of all GHG emissions in the EU, it was responsible for 27%, of which road transport for freight and passengers accounted for a whopping 72% (European Economic Area, 2019). Worse still, even as the great demand for products requiring transport in the forward and backward flows of logistics systems critically challenges society, the International Energy Agency expects transport volumes to nearly double by 2050 compared to 2006 figures (OECD/IEA, 2009).

Freight transport, perhaps the most basic activity of logistics as well as its most energy-intensive one (Halldórsson *et al.*, 2019b; Halldórsson and Svanberg, 2013), connects nodes in logistics systems and moves goods between them. Logistics systems focus on certain settings and segments of supply chains including urban logistics (Lagorio *et al.*, 2016) and omni-channel distribution (Hübner *et al.*, 2016a), but also after the point of consumption, as in reverse logistics (Blackburn *et al.*, 2004) and waste logistics (Jahre, 1995). In all such systems, logistics service providers (LSPs) are key actors that supply logistics to other actors—for instance, product manufacturers, retailers and end consumers—in the form of transport, warehousing and value-added services, amongst others.

At present, road freight transport is primarily powered by fossil fuels (OECD/IEA, 2015), largely as a holdover from a time when such sources of energy were inexpensive and plentiful (Rogers *et al.*, 2007). Even as recently as 2013, transport was responsible for more than 63% of the world's oil consumption (OECD/IEA, 2015), and in the future, the International Energy Agency expects energy consumption in transport to increase even further: by nearly 30% as of 2030 and by 80% as of 2050 (OECD/IEA, 2009). Likewise, the Swedish Transport Administration foresees a 50% increase in freight transport, excluding air freight, by 2030 compared to 2006 levels and projects that road freight transport will grow the most of all forms of freight transport (Trafikanalys, 2016). In response, as reflected in the United Nations' (2015) sustainable development agenda on responsible consumption and production, as well as by climate actions aimed at ensuring access

to affordable, reliable, and sustainable forms of energy for all humans by 2030, both using energy more efficiently in logistics systems and reducing their overall energy consumption can foster environmentally sustainable development.

Both in industry and academia, the number of studies concerning environmental sustainability in the logistics sector has grown in recent years (Centobelli *et al.*, 2017b; Halldórsson and Kovács, 2010; McKinnon, 2016b; McKinnon and Piecyk, 2012). In parallel, different approaches to counteracting climate change have been proposed, including ones involving new technologies, electrification and a shift to fossil-free fuels. Although such strategies gesture towards the environmentally sustainable development of logistics, they are solely not sufficient to that task but also entail trade-offs and implications that warrant sustained consideration. For example, new technologies that make vehicle designs more aerodynamic and engines more fuel-efficient can increase overall energy efficiency; however, they may prompt a rebound effect in which people begin driving farther and placing orders to be shipped more often due to the reduced cost for energy (Sorrell *et al.*, 2009). For another example, and as researchers have highlighted, relying solely on technological advancements to combat increasing energy consumption is an insufficient solution (Aronsson and Huge-Brodin, 2006; Chapman, 2007; Johansson, 2009). On the one hand, making electricity the key source of energy in the logistics sector stands to incite competition for the energy source with other sectors in which the demand for electricity is increasing as well. On the other, shifting to fossil-free fuels might trigger conflicts over, for instance, geographical dependencies, storage and the use of resources to produce biofuel instead of food (Svanberg and Halldórsson, 2013). Even without those potential setbacks, neither electricity nor fossil-free fuels come without GHG emissions depending upon the primary energy source used (Piecyk *et al.*, 2015).

An approach to both tackling the problem of high energy consumption and GHG emissions in logistics and fostering environmentally sustainable development is improving energy efficiency in logistics systems—that is, optimising the use of energy while remaining able to meet the demand for transport. Indeed, scholars have argued that accelerating the environmentally sustainable development of logistics requires applying a holistic approach (Abbasi and Nilsson, 2016; Aronsson and Huge-Brodin, 2006). In support, the European Commission (2011a) envisions that energy efficiency will not only spare resources but also afford the quickest, most cost-effective way to better secure energy supplies. Potentially against that approach, however, are national goals that can easily stifle environmentally sustainable development. The Swedish government, for example, aims to ensure all citizens' access to transport (e.g. Swedish regulation, 2010:185), which can exacerbate the use of transport resources if translated to allow unlimited deliveries and unnecessary returns. At the same time, operating principles in logistics such as flexibility, cost efficiency, speed and reliability directly conflict with the goal of energy efficiency. McKinnon (2016b) has underscored, for instance, that agile supply chains and just-in-time deliveries are difficult to reconcile with energy-efficient practices.

For an alternative, this thesis suggests approaching the problem from a systems perspective, chiefly as a means to qualitatively investigate how current logistics systems can practice energy efficiency. An indicator originating from the energy sector, energy efficiency comes with the expectation that it is measurable and mathematically verifiable. However, this thesis discusses the concept in qualitative terms with respect to environmental sustainability and refrains from measuring it. As Kalenoja *et al.* (2011) have pointed out, along with quantitative information about supply chains, qualitative information is also required in order to calculate and measure energy efficiency. Taking such a qualitative approach, the thesis follows previous qualitative research on

investigating performance indicators, such as cost efficiency and lead times (e.g. Bowersox and Daugherty, 1995; Chopra and Sodhi, 2014).

Special attention should be paid to logistics services provided close to the point of consumption, which typically means the use of road freight transport. As the most basic logistics activity and most common logistics mode of reaching individual households, road freight transport is also the most energy-consuming logistics activity and thus exhibits outstanding potential for improving energy efficiency. Road freight transport to and from the point of consumption is the most dominant mode in urban areas in particular, where most consumers live (United Nations, 2018) and where the most products are needed. In receiving so much traffic, cities generate high rates of GHG emissions (OECD/IEA, 2016), and their residents are especially exposed to those emissions as well as to noise and congestion (European Commission, 2011c). By the same token, households are often the end consumers of products, and in setting demands that affect activities upstream in supply chains, they should not be ignored when investigating the energy efficiency of logistics systems (Pagell and Shevchenko, 2014). Even after products arrive at the point of consumption and are consumed or used, they often continue onward in the product life cycle, either in being returned via reverse logistics or in being discarded as waste collected for recycling, incineration or the landfill.

Taken together, all of those trends suggest that investigating the point of consumption from both sides of supply chains—the provider side and the consumer side—can be especially fruitful. Thus, this thesis sets its sights not only on products in the forward flow to the point of consumption but also on waste in the post-consumption flow. In both flows, examples of logistics inefficiencies with implications for energy efficiency abound:

- Logistics service providers (LSPs) cannot completely fill their trucks due to their customers' diverse time constraints;
- Shippers receive returned products from customers, which they need to examine, clean and repackage, each stage of which requires additional transport;
- End consumers order products online that are delivered to their individual addresses by delivery trucks with low fill rates;
- If end consumers are not at home when their online purchases arrive, then LSPs have to return, potentially several times, before deliveries can be completed;
- Waste collection from households by different waste service providers (WSPs) requires several trucks to visit each household during weekly collection rounds; and
- Although municipalities, which are seldom considered to be actors in logistics systems, design waste collection services for entire cities as well as individual households, energy-efficient collection is not their chief goal.

According to Marchet *et al.* (2014) and Evangelista *et al.* (2018), although environmental sustainability in logistics and freight transport continues to gain interest amongst academics, investigating the topic in the logistics industry remains necessary (Centobelli *et al.*, 2017b). In a recent literature review, Centobelli *et al.* (2018) pointed out five topics not addressed in recent literature on energy efficiency: (1) drivers of and barriers to adopting energy efficiency and environmental sustainability initiatives, (2) the classification of energy efficiency and environmental sustainability initiatives, (3) the impact of energy efficiency and environmental sustainability on supply chain performance, (4) the customer's role in energy-efficient and sustainable supply chains, and (5) information and communication technology (ICT) that supports energy efficiency and environmental sustainability initiatives. Such gaps in the literature show that several aspects of energy efficiency and environmental sustainability in logistics systems remain relatively unknown so far. Furthermore, as highlighted by Pagell and Shevchenko (2014),

researchers in supply chain management (SCM) should not view sustainability as a separate domain but as an integrated part of their investigations. That logic also holds true for research on logistics, which can be viewed as a part of SCM (Larson and Halldórsson, 2004).

In response to those trends and circumstances, this thesis incorporates environmental sustainability into logistics operationalised through energy efficiency. For one, because structures determine how logistics systems are designed, including in the number of movements made, the handling of goods, transport distances, the directness of shipping routes and the utilisation of capacity (Aronsson and Huge-Brodin, 2006), the thesis has been designed to investigate the structural characteristics that shape logistics systems. In the process, by examining a logistic system's underlying structural characteristics from a systems perspective, the thesis adopts the sort of holistic approach encouraged by Abbasi and Nilsson (2012, 2016)—that is, one that can elucidate the mechanisms of environmental sustainability in logistics by viewing sustainability as an integrated part of logistics research (Pagell and Shevchenko, 2014). At the same time, because the thesis investigates logistics systems from the provider side by scrutinising energy efficiency initiatives taken by LSPs, it can identify the drivers and barriers to adopting energy efficiency and environmental sustainability initiatives as well as classify those initiatives, as encouraged by Centobelli *et al.* (2018). On that note, in response to the fourth gap identified by Centobelli *et al.* (2018), the thesis extends focus to the customer side of logistics systems by investigating logistics services at the provider–customer interface. Last, the thesis also examines the sustainable maturity of LSPs, which Fabbe-Costes *et al.* (2011) have highlighted as another gap in literature on sustainable supply chains.

Instead of being theory-driven, the thesis is phenomenon-driven (Schwarz and Stensaker, 2014), particularly by centring on the phenomenon of energy efficiency in logistics systems while contributing to the understanding of environmentally sustainable development. According to Schwarz and Stensaker (2014), phenomenon-driven research is founded in a relevant problem, a phenomenon, and theory helps to position the research. In that sense, the thesis has adopted not only a systems perspective to shed light on logistics as a system that interacts with its environment (Arbnor and Bjerke, 2009) but also service logic to emphasise the importance of value creation between providers and customers (Grönroos, 2006, 2011).

1.2 Purpose and research questions

The thesis approaches the improvement of energy efficiency in logistics systems as a means to environmentally sustainable development by adopting a holistic perspective on such systems. Herein, because environmentally sustainable development is characterised as a process geared towards a favourable state (Robèrt *et al.*, 2002), the aim is to identify different principles that enable such a process instead of exploring that process over time. Those principles, here approached with reference to certain structural characteristics, logistics initiatives taken by LSPs and logistics services offered to customers, together constitute energy efficiency in logistics systems that, in turn, contributes to environmentally sustainable development.

Romme (2003) states that research needs to produce new systems or new states of existing systems, instead of merely seeking to understand general patterns and forces that explain phenomena. In line with that thinking, the research conducted for the thesis originated in a systems perspective, which holds that a part of a system cannot be understood by focussing solely on its individual components (Arbnor and Bjerke, 2009) but instead requires taking a holistic approach and acknowledging multiple actors. Moreover, because the research was explorative, logistics systems were approached as so-called "soft" systems instead of "hard" ones (see

Chapter 2.1). With reference to those considerations, the purpose of the research was formulated as follows:

> **Purpose:** *To expand current understandings of how environmentally sustainable development can be facilitated by improving the energy efficiency of logistics systems.*

Improving energy efficiency is one way to develop logistics that facilitate environmental sustainability, complementary to approaches such as technological advancements, the electrification of logistics systems and shifts to fossil-free fuels. Because understanding the environmentally sustainable development of logistics calls for taking a systems perspective on logistics, the purpose of the research was operationalised by developing three research questions addressing relevant structural characteristics, the provider side of logistics systems and, in turn, the customer side of those systems. Such a multi-actor approach was adopted in a bid to include all actors involved in the process of rendering logistics services.

The first research question, derived from an explorative approach, sought to shed light on underlying assumptions instead of closing gaps in the literature (Alvesson and Sandberg, 2013). Building upon the systems perspective (Arbnor and Bjerke, 2009), it targeted characteristics of structures that shape energy efficiency in logistics systems—that is, *structural characteristics*—that have implications for energy.

> **RQ1 (Characteristics):** *What structural characteristics are relevant to improving energy efficiency in logistics systems?*

Structural characteristics included levels and boundaries that enable the recognition, definition and measurement of energy efficiency, as well as all actors relevant to improving energy efficiency. After all, understanding energy efficiency is a prerequisite for implementing measures of energy efficiency in logistics (Kalenoja *et al.*, 2011).

Building upon the structural characteristics addressed in the first research question, the second research question aimed to identify logistics initiatives taken by LSPs not only internally but also in relation to their customers and how such initiatives contribute to environmentally sustainable development. The question centred on logistics providers from a unilateral perspective, meaning that it focussed on initiatives to improve energy efficiency—activities, internal processes and services, for example—undertaken by LSPs only:

> **RQ2 (Initiatives):** *How do logistics initiatives taken by logistics service providers improve energy efficiency in logistics systems?*

The research also sought to detail how the numerous initiatives for environmental sustainability in logistics (Centobelli *et al.*, 2017b; Colicchia *et al.*, 2013; Evangelista *et al.*, 2018) can improve energy efficiency in logistics systems and help to transform LSPs in environmentally sustainable organisations. Energy efficiency was first approached by addressing capacity utilisation, because that concrete aspect of logistics systems allows for different levels of analysis. In a second step, other actions, internal processes and services, all regarded as initiatives offered by LSPs, were investigated, particularly concerning how LSPs need to cooperate with them in order to mature into environmentally sustainable organisations.

Also building upon the first research question, the third research question addressed logistics systems and services from the customer side—that is, as they concern the final customer or end consumer. Because the research focussed on logistics services in terms of energy efficiency at the moment of provider–customer interaction, the third research question was answered from a

multilateral perspective, namely by including all actors involved in the logistics service process, albeit with the customer as the focal actor:

> **RQ3 (Services):** *How do logistics services improve energy efficiency in logistics systems?*

To that purpose, logistics services offered by LSPs to end consumers at the point of consumption were investigated in detail by using service modularity as a perspective and service blueprinting as a tool. Modularity can help researchers and practitioners to examine the nature of logistics services and identify which service components and modules may improve energy efficiency. At the same time, taking the theoretical perspective of service logic allowed the creation of the value of energy efficiency between providers and customers to be investigated.

The three research questions were answered by conducting five studies. The first question laid the groundwork for the research by directing focus towards the overall structural characteristics of logistics systems, all of which impose conditions upon energy efficiency therein, whereas the second question approached energy efficiency from the provider side. Last, the third question targeted logistics services at the moment of provider–customer interaction with particular focus on the customer.

1.3 Research scope

By concentrating on energy efficiency, the research conducted for the thesis focussed on one of the three pillars of sustainability: environmental sustainability. Environmentally sustainable development realised by improving the energy efficiency of logistic systems can be conceived as a process of forging a new state of logistics, one that complements the long-term development of the same field, beginning with physical distribution in the 1960s, transforming into time-dependent just-in-time systems in the 1980s and, in the 2000s, shifting focus to SCM and e-logistics (Klaus, 2009). Today, dominated by e-commerce in the face of energy scarcity and the need for sustainability, logistics require new business models that can respond to current and future developments (Bask *et al.*, 2011; Bocken *et al.*, 2014).

Accordingly, the scope of the research encompassed logistics systems along supply chains. Therein, the term *logistics system* was adopted to identify a particular sort of setting involved in a supply chain that focusses on the physical flow of products from suppliers to customers (Fahimnia *et al.*, 2011). Following Stevens (1989), who established that every supply chain begins with the source of the supply and ends at the point of consumption, the thesis extended the conceptualisation of supply chains to also include the post-consumption flow of household waste from the point of consumption to the manufacturer of products from recycled material or to other facilities where waste is processed (see Figure 1.1). As another departure, although the *point of consumption*, often embodied in the household or consumer, has been defined as the point at which no further value can be added to products (Lambert and Cooper, 2000), this thesis argues that, despite being consumed, products can be given added value in the post-consumption flow, by being returned either to shippers or to the waste flow as resources to be recycled or reused. Indeed, as represented by the dotted line in Figure 1.1, the point of consumption remained the focal point of the research scope, at both the first and last mile of supply chains. Of course, the leg after the last mile and the leg before the last mile were also included in the scope, because they are exposed to the effects of adjustments made in either mile.

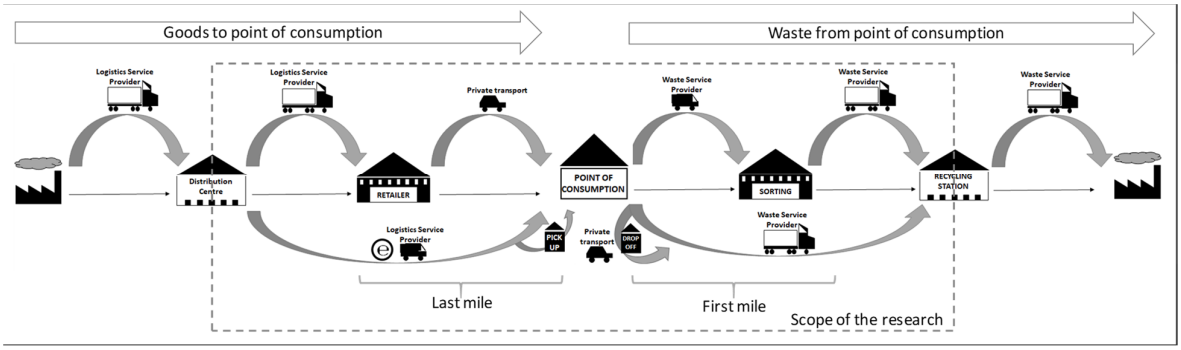


Figure 1.1: Scope of the research

Attention to logistics fulfilment in the last and first miles is paramount to improving energy efficiency, because the dominant mode of transport in each mile is road freight transport, which accounts for 72% of all GHG emissions in the transport sector (European Economic Area, 2019; European Commission, 2016a). Although different modes of transport differently affect the total energy consumption in logistics, switching to a more energy-efficient mode is not always possible, as Lindholm and Behrends (2012) have pointed out, especially not in urban areas, all of which rely heavily on road freight transport. In that light, investigating logistics fulfilment to and from the point of consumption and by improving the collaboration between actors in those legs shows outstanding promise for energy efficiency, mostly because points of reception are as numerous as households. On top of that, because most end consumers live in urban areas, improving the energy efficiency in last- and first-mile logistics fulfilment also stands to curb GHG emissions, noise exposure and congestion in urban areas (European Commission, 2011c). For those reasons, the scope of the research encompassed both legs, the principal structural characteristics of which are described in what follows.

Last mile. Last-mile logistics include logistics activities during the last leg of supply chains—that is, the transfer of goods from retailers to households at the point of consumption (Hübner *et al.*, 2016b; Hübner *et al.*, 2016c). Such transport can be provided by LSPs with commercial vehicles or by consumers themselves with private vehicles or another mode of transport. Of all legs of supply chains, the last mile commonly involves households in logistics fulfilment (Carbone *et al.*, 2018). As Allen *et al.* (2012) have pointed out, energy efficiency in urban freight transport is affected by the municipality's or settlement's size, the provision of local facilities, the accessibility to local transport infrastructure and networks, the availability of parking facilities and the type of road network.

First mile. First-mile logistics describes the transport activity from a resource's point of origin to the subsequent point of the logistics process (Halldórsson *et al.*, 2019a). From a circular perspective on supply chains, the point of origin can also represent the point of consumption. First-mile logistics can cover the collection of household waste by WSPs as well as entail reverse logistics performed by LSPs. In this thesis, the first mile is conceived to involve household waste from the point of consumption to the first sorting or recycling facility. Given the high amount of transport activities to and from each household, the last and first mile are each especially energy-intensive.

The research was conducted in a Swedish context. Although Sweden is the fifth largest nation in Europe by area, its population amounts to only 10 million people (Statistics Sweden, 2019). As a result, residents are relatively dispersed across the country, which continues to influence the structure of logistics systems there. That being said, data for the research were collected primarily from southern Sweden, where the population density is far higher than elsewhere in the country.

Amongst other contextual factors, several dangers to Sweden's road and rail transport systems are expected to rise in frequency and intensity due to global warming and climate change. According to the Swedish Transport Administration (2019), more rainfall will cause more snow during the winter in northern Sweden, while floods during the spring and warmer summers, combined with colder winters together with higher moisture, threaten to damage asphalt and the tracks of road and rail systems.

To further refine the scope of the research, two significant delimitations were made. Aside from environmental aspects of sustainable development, the research also holds improvement potential for social and economic aspects. On the one hand, reduced emissions stand to directly affect the social dimension of sustainability and to improve living conditions for societies. For example, achieving logistics systems in which fewer delivery vehicles operate could reduce congestion (European Commission, 2011c) by reducing the volume of traffic, which stands to also lower the risk of accidents involving delivery vehicles and increase safety on roads for private vehicles, pedestrians, cyclists and other users. At the same time, decreasing the environmental impact and raising awareness about sustainability can also positively influence the public mind-set and, in turn, promote behaviours such as walking, biking and other means to healthier lifestyles. On the other hand, decreasing the consumption of fossil fuels not only encourages independence from fluctuating oil prices but also competitive, resource-efficient freight transport and logistics. Energy efficiency is therefore the most cost-effective way to also promote the security of the energy supply (European Commission, 2011a; Halldórsson and Svanberg, 2013) and impact the economic dimension of sustainability. Although environmental aspects cannot be improved in isolation from those social and economic aspects, the investigation of the latter two is not focus of the thesis.

1.4 Outline

The remainder of the thesis is organised as follows. Chapter 2 presents the frame of reference for the research conducted, after which Chapter 3 presents the research methodology, its underlying epistemological stance, the research design, explanations of the five studies and methods used, the quality of the research and the research process. Next, Chapter 4 summarises all appended papers and the book chapter to which the author contributed. After Chapter 5 presents the results in terms of the three research questions, Chapter 6 provides a discussion including propositions, theoretical contributions and managerial implications. Last, Chapter 7 concludes the thesis with final remarks, limitations of the research and directions for future studies.

2 Frame of reference

This chapter discusses different concepts and theories concerning logistics that were built upon to answer the research questions. It begins by conceptualising logistics as a system from a theoretical perspective and explains which systems were studied in the research. Thereafter, the chapter borrows concepts from SCM as well as a theory from service management and integrates them into a conceptual framework.

2.1 A systems perspective on logistics

In logistics research, systems perspectives are more commonly cited than applied (Aastrup and Halldórsson, 2008; Lindskog, 2012) and are especially recommended for use in research on sustainable development (Robèrt *et al.*, 2002). Lindskog (2012) differentiates so-called "soft" from "hard" schools of systems perspectives. Whereas the hard school, rooted in technical and mathematical approaches, typically involves mathematical modelling and optimisation in problem solving and viewing social agents as deterministic, the soft school recognises purposeful human activities as part of the system and views system models not as "models of the world but instead as models useful for argumentation about the world" (Lindskog, 2012:66). Arbnor and Bjerke (2009) have applied a systems perspective to create a model of the real world while stressing the totality of a complicated world in which all parts more or less depend upon each other (Arbnor and Bjerke, 2009:112). According to Arbnor and Bjerke (2009:103), in seeking to understand what "common patterns, behaviour, and properties" systems have, "all phenomena can be regarded as a web of relationships" amongst the components of those systems. By extension, that logic can be transferred to logistics systems to pinpoint which structures, actors and their interplay may influence their energy efficiency. For many years, the systems approach has been acknowledged as a means to create efficiencies (Churchman, 1968).

Any logistics system can be viewed as an open system in constant interaction with its environment (Aastrup and Halldórsson, 2008; Arbnor and Bjerke, 2009). According to Arbnor and Bjerke (2009), the system's reactions to the environment can be summarised in three types: variation, structural change and paradigmatic shift. Temporary in character, *variation* from the normal state implies that the environment will eventually return to its point of departure. By contrast, *structural change* describes an irreversible change from a previous state, whereas a *paradigmatic shift* explains cases in which radical change engender a new state and in which only a completely new model can represent the real world (Arbnor and Bjerke, 2009; Romme, 2003). Considering those definitions, the research conducted for the thesis was open to all three types of reactions, because the complexity of the studied phenomenon means that structural changes and even paradigmatic shift could be necessary.

A systems perspective was selected as a theoretical framework for the research, not only because it was thought to allow approaching energy as being in constant interplay with the components of its surrounding environment, but also because it acknowledges the human side of systems. In that sense, the research involved applying the so-called "soft" school described by Lindskog (2012). The components of the environment include both the narrow environment of transport vehicles and warehouses and the wider structure of logistics systems and supply chains in which multiple actors interact. The systems perspective on energy efficiency in logistics systems informed the research, especially by emphasising that the problem cannot be solved by viewing components in isolation but that a holistic approach is needed in order to improve the energy efficiency of logistics systems.

2.2 Logistics systems

The second theoretical framework applied was a particular view on logistics and SCM. The research adopted the understanding of Cooper *et al.* (1997) that logistics is concerned with planning, implementing and controlling material and information flows as well as inventory, along with the definition of *SCM* articulated by Stock and Lambert (2001) that the activity revolves around the integration of different actors along supply chains (i.e. suppliers, manufacturers and customers) and the provision of products, services and information that add value for customers and other stakeholders. To that mix, the unionist perspective brought forward by Larson and Halldórsson (2004), in which logistics forms part of SCM, was added as well.

Herein, a logistics system is understood as the network of organisations, people, activities, information and resources involved in the physical flow of products from suppliers to customers (Fahimnia *et al.*, 2011). Such a conceptualisation helps in scoping out a particular setting of supply chains by highlighting logistics activities—for example, in the last mile, when goods such as clothes and groceries are transported to end consumers. By extension, that definition was also applied to the first mile, when waste is supplied by households and subsequently collected and transported to facilities to be processed. Logistics systems examined in the research were therefore conceived as being centred on the point of consumption as either the arrival or starting point.

In decades past, logistics performance was primarily assessed in terms of costs, profitability and lead times (Christopher, 2011). Applying that conceptualisation, however, researchers often overlooked environmental indicators. By contrast, using more current conceptualisations, scholars have revealed that the staggering consumption of fossil fuels during transport in the first and last miles counteracts ambitious emissions targets set for the future. As researchers have also shown, the last mile requires significant energy resources due to the small number of products carried per vehicle, empty running, redundant trips and the return of goods (Piecyk and McKinnon, 2010). In short, the fewer goods being transported per vehicle, the higher the energy consumption per transported unit (Browne *et al.*, 2006). In particular, consumers' transport of goods from stores to their homes significantly affects the total transport energy that products consume (Brown and Guiffrida, 2014; Browne *et al.*, 2005). The transport of yoghurt, for instance, from the supermarket back home has been shown to use nearly as much energy as all upstream transport activities from the farm to store combined (Browne *et al.*, 2006; Rizet *et al.*, 2012). Similarities can be drawn for the first mile as well, where waste is often collected from each household (Jahre, 1995). By some contrast, however, the first mile can also be characterised by whether the reverse supply chain is centralised or decentralised (Blackburn *et al.*, 2004), according to the distances to be travelled by the households to reach the first consolidation point (Jahre, 1995) and product differentiation (Blackburn *et al.*, 2004).

In sum, both legs adjacent to the point of consumption require intensive transport resources that do not use energy to its full potential. In that sense, they are essential to research on improving the energy efficiency of logistics systems and, as encircled within the research scope, have characteristics that impose certain conditions upon logistics systems.

2.3 Conceptual framework

To conceptualise logistics systems and explore ways in which energy efficiency can be improved therein, a conceptual framework—namely, the SCM framework developed by Cooper *et al.* (1997) and Lambert and Cooper (2000)—was borrowed from the literature and modified for the research. The following sub-chapters explain why it was chosen and why certain changes were necessary to make it applicable for research on energy efficiency in logistics systems.

2.3.1 Concepts from the literature

Shown in Figure 2.1, the SCM framework developed by Cooper *et al.* (1997) and Lambert and Cooper (2000) was deemed to be an appropriate framework for conceptualising the building blocks necessary to improve energy efficiency in logistics systems. In the following chapters of the thesis, all three research questions as well as the presentation of results are therefore structured around the framework.

A major reason why that particular SCM framework was applicable to the research about energy efficiency in logistics systems is that the framework incorporates the systems perspective and emphasises the interrelated nature of elements in SCM, both of which can also be used to characterise logistics. That theoretical dynamic is crucial, because the systems perspective facilitates viewing energy efficiency as an integrated part of any logistics system (see Chapter 2.1). At the same time, Cooper *et al.* (1997) clearly differentiate SCM from logistics in their framework and explain that SCM is an extension of pure logistics in which business operations are integrated. The aim of their research was to provide guidance for designing and managing supply chains. Likewise, the overarching aim of the research presented here was to describe how the design and management of logistics systems can be improved in terms of energy efficiency.

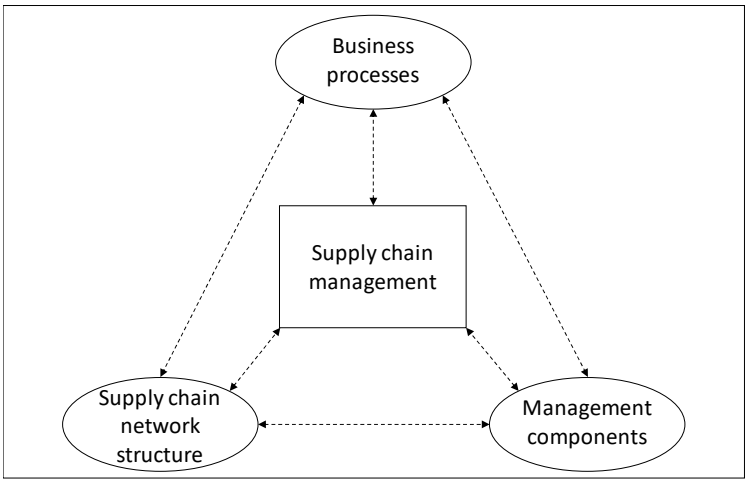


Figure 2.1: Supply chain management framework, adapted from Cooper *et al.* (1997) and Lambert and Cooper (2000)

The building blocks from the SCM framework were used to explain the research conducted for the thesis, however they needed to be modified to suit the research on energy efficiency in logistics systems. In the following, it is explained how they are applied in the thesis.

"Supply chain network structure" becomes "structural characteristics". According to Lambert and Cooper (2000), the building block of network structure consists of three structural dimensions: the network, types of links and members. As their framework demonstrates, structures cannot be viewed in isolation from members, meaning that members are essential to the building block. Cooper *et al.* (1997) have also described the building block as the configuration of companies within the system. Although the same logics were observed in the research for the thesis, the building block was renamed "structural characteristics" in order to emphasise the thesis's focus not on the structure of logistics systems but on the structural characteristics that shape them. More specifically, such structural characteristics were conceived as being vertical and horizontal ones of a logistics system and its members.

"Management components" become "logistics initiatives". The building block of management components describes how processes are structured and managed (Cooper *et al.*, 1997; Lambert

and Cooper, 2000). On that topic, the authors have described numerous components that require managerial attention in managing supply chain relationships, including planning and control, the facilitation of product and information flows, management methods, leadership, risks, rewards, culture and attitude (Lambert and Cooper, 2000). In logistics, the responsibility for managing activities rests primarily with LSPs, professional logistics actors tasked with performing logistics activities for other actors. Accordingly, in being transferred to a provider-centric logistics context, the building block was renamed "logistics initiatives". Such initiatives were conceived as the results of managerial efforts of LSPs towards enhancing the energy efficiency and environmental sustainability of LSPs. Although the building block was renamed, its function within the framework retained the original rationale.

"Business processes" become "logistics services". According to Cooper *et al.* (1997), the building block of business processes describes the integration of such processes, or activities, along supply chains that add value for customers. As described by Lambert and Cooper (2000), the building block includes all activities that produce output of value to customers. Transferred to the logistics context, the activities that generate value for customers are logistics services. Guided by service logic, that dynamic allows an inquiry at the provider–customer interface about how LSPs can produce energy-efficient services with value for customers. Therefore, the building block was renamed "logistics services".

Altogether, the three building blocks help to conceptualise the phenomenon of energy efficiency in logistics systems. Borrowing those concepts from the literature as well as adapting and integrating them helped to identify which characteristics need to be considered, which improvement initiatives need to be taken and how logistics services can be offered to enhance energy efficiency in logistics systems.

2.3.2 Structural characteristics

Because the research involved examining not one but several logistics systems, scrutinising their structural characteristics helped to describe differences in their structures. After all, structural characteristics shape logistics systems and pose implications for the systems' overall energy efficiency. The following sub-chapters discuss those characteristics, including vertical ones in the form of system levels (Chapter 2.3.2.1), horizontal ones in the form of system boundaries (Chapter 2.3.2.2) and, in both directions, the members of logistics systems (Chapter 2.3.2.3).

2.3.2.1 System levels

One way to characterise structures that shape energy efficiency in logistics systems is by vertically differentiating system levels. For example, Aronsson and Huge-Brodin (2006) have suggested delineating vertical levels for modelling overall, strategic, tactical and operational decisions regarding environmental consequences. Somewhat similarly, McKinnon and Bilski (2014) and McKinnon (2016a) have proposed eight system levels for examining scope of innovation and decarbonisation. Figure 2.2 shows those eight system levels, starting with technical dimensions as the basis for the overall structure of a supply chain.

Depicted in the figure, the first two levels—vehicle technology and alternative fuels combined and vehicle maintenance—have been central to numerous studies (Léonardi and Baumgartner, 2004; Liimatainen *et al.*, 2012; McKinnon and Ge, 2004). The next three levels—driving, vehicle loading, and vehicle routing and scheduling—are operational and comprise the core activities of LSPs (McKinnon and Bilski, 2014). At the sixth level, modes are differentiated into road, rail, sea and air transport. The logistics system design is determined by individual shippers of products, whereas the structure of a supply chain is influenced by other supply chain partners who set conditions for the logistics activities. In SCM, similar levels of analysis have been proposed for

evaluating sustainability in contexts other than logistics, namely in respect to networks (e.g. Fabbe-Costes *et al.*, 2011).

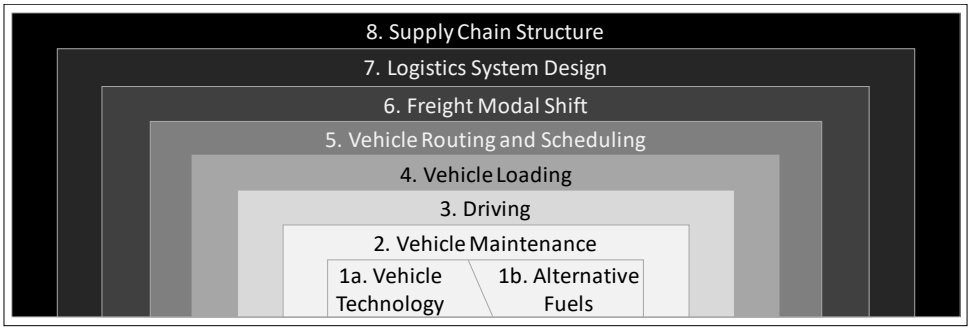


Figure 2.2: System levels of logistics activities and innovation, adapted from McKinnon and Bilski (2014) and McKinnon (2016a)

The concept of system levels was selected because it provides a structured overview of different logistics activities that characterise structures shaping energy efficiency in logistics systems. Such a vertical differentiation enables identifying the potential for improving energy efficiency at different levels of the system. Of those levels, Levels 4 to 8 formed the focus of the research presented herein.

2.3.2.2 System boundaries

An additional way of characterising logistics structures is by setting system boundaries. Emerging in connection to different supply chains actors, such boundaries are referred to as *horizontal structural characteristics*. The definition of *system boundaries* is essential when working with energy efficiency, including when measuring (Kalenoja *et al.*, 2011) and improving it. Likewise, setting such boundaries is pivotal, for it substantially influences the results of assessing energy consumption and efficiency (Reap *et al.*, 2008).

The example of system boundaries for measuring energy efficiency in logistics provided by Kalenoja *et al.* (2011) shows the scope of different system boundaries in which a company can operate, plan and manage its logistics operations. When extended horizontally, system boundaries can be used to assess energy efficiency, as depicted in Figure 2.3. Therein, System Boundary A encompasses the activities from production and outbound logistics, as well as their energy consumption and their emissions, whereas System Boundary B adds energy consumed and emissions generated by inbound logistics, including warehousing, raw material acquisition from suppliers and disposing of waste from the system. Beyond that, System Boundary C covers the whole supply chain, including logistics to retailers and end consumers, along with reverse logistics, meaning that it covers logistics fulfilment in the last and first miles. Most broadly, System Boundary D encompasses a product's entire life cycle, including its recycling.

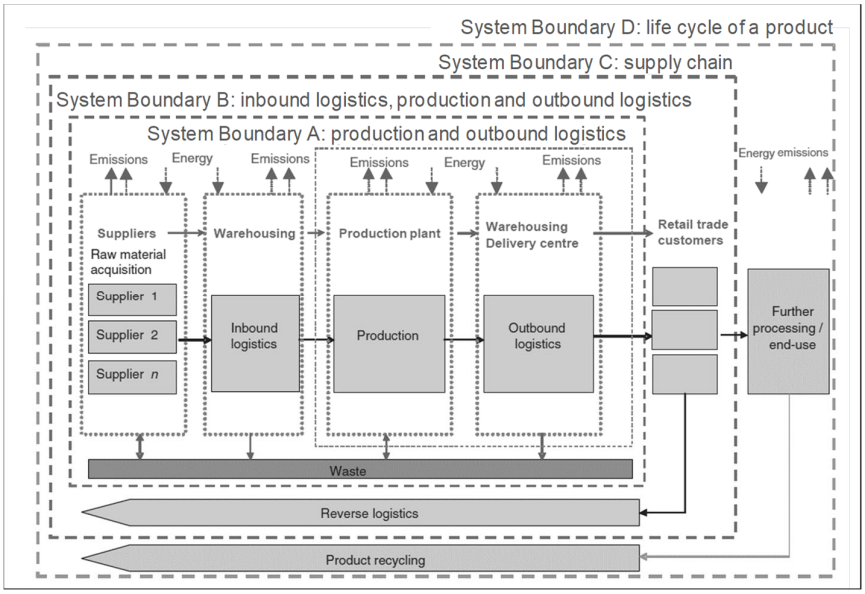


Figure 2.3: System boundaries for measuring energy efficiency in logistics (Kalenoja *et al.*, 2011)

Each system contains a finite number of activities as well as actors. By expanding the system boundaries horizontally, it is possible to identify new potential for improving energy efficiency amongst those activities and actors. By extension, adjusting the system boundaries, as suggested by several researchers (Aronsson and Huge-Brodin, 2006; Bottani *et al.*, 2014; Brown and Guiffrida, 2014; Browne *et al.*, 2005; Wolf and Seuring, 2010; Wu and Dunn, 1995) can allow including new actors, strengthening their roles and widening their scope of activity. The wider structure in which transport operates also depends upon the design of the corresponding supply chain and the location of terminals. The extended system boundaries reveal new intersections of unused potential, for example, in interaction and collaboration, the underutilisation of vehicles and high requirements. To minimise the environmental impact of logistics, every element in a supply chain has to be included in the management and planning process (Wu and Dunn, 1995).

In brief, the concept of system boundaries in logistics informed the research for the thesis by broadening the view from a single company to its bordering operations and actors, including LSPs and end consumers. That extension derives from the systems perspective, from which a company has to be viewed in terms of its interaction with its environment.

2.3.2.3 Members of logistics systems

Members of logistics systems also collectively constitute a structural characteristic that shapes energy efficiency in logistics systems. Depending upon the perspective taken, members in logistics systems can act in dyadic or triadic relationships and networks. Larson and Gammelgaard (2001) have characterised the triad as the smallest unit of analysis in logistics networks. To that, Bask (2001), who also used triads to describe relationships between logistics actors—LSPs, sellers and buyers—has stated that, by definition, LSPs (i.e. third-party logistics actors) are members of a triadic form of relationship. That perspective was also applied in the research herein, which was built upon the assumption that members of a triad are closely related to their system's structure (Lambert and Cooper, 2000). Moreover, such thinking aligns with the systems perspective, which always views actors within the environment in which they act.

In investigating *service triads*, relationships of buyer-subcontractor-end customer, van der Valk and van Iwaarden (2011) have highlighted that when a service is outsourced, the end customer becomes the direct receiver of the service, which is typically delivered by a subcontractor. That

characterisation aligns with the observation of Wynstra *et al.* (2015), who have highlighted that any exchange in a service triad occurs between a supplier and a customer, not between a supplier and a buyer, as is the case in a manufacturing context, for instance. However, in the context of logistics services, there can be more than three actors, including carriers and logistics service intermediaries (Stefansson, 2006; Sternberg, 2011). Wagner *et al.* (2018), who studied triads in the aftermarket context, have posited that triads can adapt to different forms and relationships between actors, have presented different relationship archetypes and, in turn, have extended triads to tetrads.

Figure 2.4 depicts two service triads illustrating the fundamental relationships between actors examined in the thesis: (a) a logistics service triad in the forward flow of goods and (b) a waste service triad in the post-consumption flow of household waste.

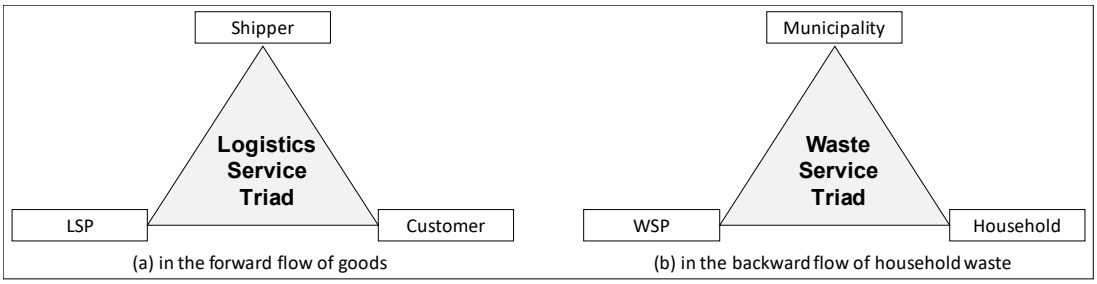


Figure 2.4: Service triads [Note. LSP = Logistics service provider, WSP = Waste service provider.]

In logistics systems, members influence the systems by transforming or reproducing them, while the systems themselves simultaneously set conditions for their members (Aastrup and Halldórsson, 2008). In the view that logistics systems cannot be detached from the actors or members therein, systems have to be understood in relation to them. That thinking originates from the systems perspective, from which actors are viewed as operating in constant interaction with their environments (Lindskog, 2012). From that, it follows that different logistics service triads characterise energy efficiency in logistics systems differently.

2.3.3 Logistics initiatives

Logistics initiatives provided by LSPs aim to provide value to their customers' operations, including in terminal activities, inventory management, warehousing, forwarding, packaging, distribution and information processing (Bask, 2001). In that sense, any initiative that focusses on improving the environmental sustainability of a logistics activity seeks to further improve the customer's operations.

The following sub-chapters present a broad range of improvement initiatives by LSPs identified in the literature as relating to environmental sustainability and energy efficiency in logistics. In the process, a way of categorising them adopted from the literature is outlined as well.

2.3.3.1 Capacity utilisation as an initiative

The management of logistics activities rests chiefly with LSPs, all of whom perform certain logistics activities for other members of logistics systems. In one such activity, transport—the most energy-intensive and basic one (Evangelista *et al.*, 2018)—an initiative for improving energy efficiency is increasing capacity utilisation.

In logistics, capacity is often associated with *loading capacity*, defined as the physical ability of a vehicle to carry freight during a certain time (Konings *et al.*, 2008) and most simply expressed as a load factor or fill rate (Browne *et al.*, 2006; McKinnon and Ge, 2004). A truck is often referred to as the key unit of capacity utilisation in road freight transport.

However, capacity often means more than a mere load factor or fill rate and is frequently difficult to measure. Somewhat ahead of their time, Wu and Dunn (1995) viewed capacity as a factor that directly influences the environmental impact of logistics systems. A decade later, Hayes *et al.* (2005), applying their background in manufacturing and operations, defined *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). By extension, Kalantari (2012:xii) applied the term *underutilised capacity*, an approximate synonym for *overcapacity*, defined as "the operational underutilisation of resources" and "an indication that efficiency improvements are possible". According to Pfohl and Zöllner (1997), increasing homogeneity between products and markets prompts the more efficient use of capacity in logistics. Indicators for underutilised capacity in logistics systems include low prices for logistics services, low fill rates, the number of insolvencies amongst LSPs and low earnings.

The literature provides different tools for managing the interplay of those components and for measuring energy efficiency, including frameworks, key performance indicators, life cycle assessments and balanced score cards (Browne *et al.*, 2005; Kalenoja *et al.*, 2011; McKinnon and Ge, 2004).

2.3.3.2 Categorisation of initiatives

Several researchers have presented various environmental sustainability initiatives and practices implemented by LSPs to add value for customers (Centobelli *et al.*, 2017a, 2017b; Colicchia *et al.*, 2013; Evangelista *et al.*, 2018; Marchet *et al.*, 2014). As a prime example, following a review and analysis of 46 works on the topic published from 2000 to 2014, Centobelli *et al.* (2017b) identified five areas of activity in the field: classifying initiatives, evaluating their performance, identifying their drivers and barriers, capturing the perspective of customers and rating how ICT has been supporting green initiatives.

In another example, Colicchia *et al.* (2013) developed a framework for identifying initiatives geared towards environmental sustainability, differentiated as either intra-organisational environmental practices (i.e. distribution strategies and transportation execution, warehousing, reverse logistics, packaging management and internal management) or inter-organisational ones (i.e. collaboration with customers and external parties). Another classification proposed for initiatives was developed by Pieters *et al.* (2012), who suggested using a sustainability activity matrix with internal and external approaches on one axis and, by contrast, activities of optimisation and innovation on the other (see Figure 2.5).

	ACTIVITIES OF OPTIMIZING	ACTIVITIES OF INNOVATING
INTERNAL APPROACH	• Green driving • Greener trucks • Improve internal planning • Energy saving programs • Increase load rates	• New software applications • Intermodal • Longer heavier vehicles • Electrical vehicles
EXTERNAL APPROACH	• Improve delivery planning • Increase efficiency • Improve cooperation with supply chain partners	• Green orders • Developing new concepts for delivery • Packaging • Cooperation with stakeholders • Cooperation with competitors

Figure 2.5: Sustainability activity matrix (Pieters *et al.*, 2012)

Highlighting the strategic importance of implementing environmentally sustainable initiatives for LSPs, Centobelli *et al.* (2017a) have proposed a framework with green aims at the top, green practices beneath that and technological tools on the bottom. Using the framework, they pinpointed several aims for environmental sustainability strategies for LSPs derived from studies on the topic. Amongst them, ones related to the research presented here are reducing the use of oil and other fossil fuels, reducing greenhouse gas emissions and reducing energy consumption. To that, with reference to their review of literature, Centobelli *et al.* (2018) added initiatives aimed at energy efficiency and identified barriers, drivers, initiatives, support technologies, impacts and customers' perspectives on energy efficiency and environmental sustainability initiatives. As a result, they highlighted the importance of extending the system boundaries in vertical and horizontal directions when investigating factors influencing such initiatives. Even though they focussed their research on SCM, their findings can be transferred to logistics. Figure 2.6 summarises literature on environmental sustainability and energy-efficient SCM reviewed by Centobelli *et al.* (2018).

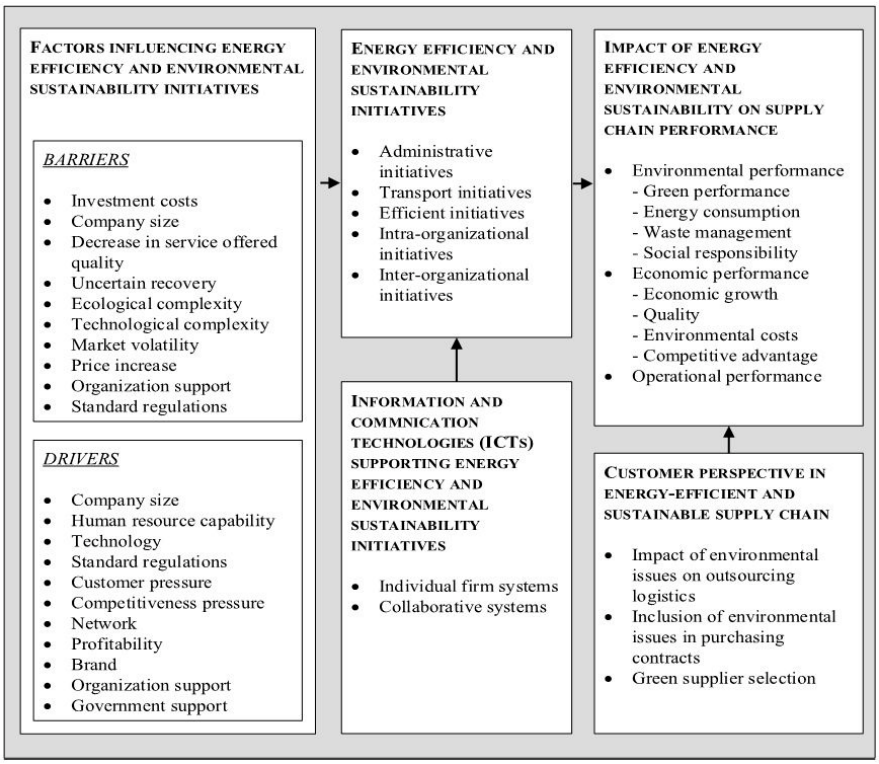


Figure 2.6: Map of literature on environmental sustainability and energy-efficient supply chain management (Centobelli *et al.*, 2018)

That same year, Evangelista *et al.* (2018) also reviewed literature on initiatives geared towards environmental sustainability taken by LSPs and highlighted five subtopics therein: factors affecting the adoption green actions, greening actions and performance, ICT for green services, energy efficiency in road freight transport and the shipper's perspective together with collaboration. Beyond that, they highlighted gaps in the current body of knowledge to reveal that analyses of interactions amongst key actors in logistics systems have been limited and that more sustained, in-depth analysis on the relationships between green actions and mitigation measures remains necessary. Evangelista *et al.* (2018) additionally emphasised the need to fill gaps in LSPs' service offerings and collaborative mechanisms between buyers and LSPs, both as topics that also need further investigation. In other work, Wagner and Sutter (2012) have highlighted

another need—namely, more robust collaboration between LSPs and customers—and emphasised that LSPs need to develop their services, in the form of internal innovations directed towards enhanced cooperation with customers. Last, in another categorisation scheme, logistics service provision was examined by Bask (2001), who classified such services in terms of their complexity (i.e. complex, medium and simple), the customer relationship involved (i.e. close, moderate and simple) and type (i.e. customised, standard and routine). Taken together, all of those classifications and trends identified in the literature can inform further examinations of the provider–customer interface in general and the concept of service in particular, as done in the following sub-chapter.

To sum up, the environmental sustainability initiatives of LSPs have been discussed and categorised, and barriers to as well as drivers of energy efficiency and environmental sustainability have been pointed out. However, the perspective most often taken in the process has been that of providers. In response, the research for the thesis approached the logistics system not only from the provider side but also from a perspective focussed on the interface of providers and consumers as well as the logistics services offered.

2.3.4 Logistics services

In every instance when a product arrives at the right place at the right time and meets the customer's requirements, a process of coordinated logistics activities has been executed in the background. Recently, logistics have been conceptualised more often as value-adding services that LSPs provide to customers than as a set of activities (Christopher, 2011), especially from a multilateral perspective—that is, a stance considering the perspectives of all actors involved in the service process, while at once emphasising the customer side of logistics systems. In the following sub-chapters, theories and concepts in connection to logistics services are explained. As revealed, a service can be viewed with the theoretical lens of service logic, as done by Grönroos (2006, 2011) and detailed in Chapter 2.3.4.1, and its design can be examined in terms of service modularity and service architecture, as detailed in Chapter 2.3.4.2.

2.3.4.1 Service logic

Service logic provides a certain perspective on how to view business models with a focus on customers (Edvardsson and Olsson, 1996). At base, a *service* is a supporting process that creates value (Grönroos, 2006). Unlike physical goods, services cannot be stored and are both produced and consumed at the same time. By extension, a *service offering* is a process in which value is created during the use of a service, in which the firm's task is to provide a supporting function (Grönroos, 2006, 2011).

To date, scholars have developed a bi-level perspective on service. On the macro-level, Stephen L. Vargo and Robert F. Lusch have conceptualised service-dominant logic, while on the micro-level, particularly in Scandinavia, Christian Grönroos has developed service logic. The principal difference between the logics rests in the idea of value co-creation. According to Vargo and Lusch (2004, 2008), value is always co-created between providers and customers, whereas Grönroos (2006, 2011) has countered that the customer creates the value while the firm supports the process and that co-creation is always optional. Both logics have roots in marketing (Edvardsson and Olsson, 1996; Grönroos, 2006) and build upon the value-in-use meaning of *value* (e.g. Grönroos, 2006, 2011; Vargo *et al.*, 2008). Considering the process-based nature of services, Grönroos (2006) has identified customers of services as both co-producers and consumers of those services—"firms and customers are co-producers of the service"—but also as "co-creators of value" when they opt to co-create value (Grönroos, 2006:324). That logic not only illuminates understandings of logistics services and their potential co-creation in the provider–customer

interface but also suggests that energy efficiency can be a value co-created by both customers and providers.

Vargo and Lusch (2004, 2008) have formulated originally nine foundational premises of service-dominant logic and revised them, after which Grönroos (2011) aligned them with service logic (see Table 2.1). As described in Premise 7a, the customer creates value while the firm facilitates value creation (Grönroos, 2011). In that light, co-creation can occur only when the firm and customer interact directly within the service process, as depicted in the lower part of Figure 2.7.

Table 2.1: Foundational premises in line with service logic, adapted from Vargo and Lusch (2004), Vargo Vargo and Lusch (2008) and Grönroos (2011)

No.	Premises	References, original and developed from
1	Reciprocal value creation is the fundamental basis of business, with service as a mediating factor.	Vargo & Lusch (2004), Grönroos (2011)
2	Indirect exchange masks the fundamental basis of exchange.	Vargo & Lusch (2004, 2008)
3	All resources and processes are distribution mechanisms for service provision, albeit without value in themselves.	Vargo & Lusch (2004), Grönroos (2011)
4	Operant resources are the fundamental source of competitive advantage.	Vargo & Lusch (2004, 2008)
5	All economies are service economies.	Vargo & Lusch (2004, 2008)
6	Fundamentally, the customer is always a value creator.	Vargo & Lusch (2004), Grönroos (2011)
7a	1) Fundamentally, the firm is a facilitator of value for the customer. 2) Provided that the firm can engage with its customers' value-creating processes during direct interactions, it has opportunities to co-create value jointly with them.	Vargo & Lusch (2004), Grönroos (2011)
7b	The firm is not restricted to offering value propositions only but has an opportunity to directly and actively influence its customers' value creation as well.	Vargo & Lusch (2004), Grönroos (2011)
8	A service-centred view is inherently customer-oriented and relational.	Vargo & Lusch (2004, 2008)
9	All social and economic actors are resource integrators.	Vargo & Lusch (2004), Grönroos (2011)
10	1) Value accumulates throughout the customer's value-creating process. 2) Value is always uniquely and both experientially and contextually perceived and determined by the customer.	Vargo & Lusch (2004), Grönroos (2011)

As demonstrated in this thesis, service logic can facilitate the study of logistics systems at the provider–customer interface, explain actors' roles relative to each other in triadic relationships and aid the description of the co-creation of value by involving multiple actors that integrate resources (Vargo and Lusch, 2004, 2008). Although service logic foremost focusses on dyadic relationships, the research for the thesis involved applying the theoretical perspective for triads. In support of that departure, Nätti *et al.* (2014) have praised the use of the triadic approach to examine value co-creation. In either type of relationship, services are better understood through the use of the concepts of service modularity and service architecture, as described in the next sub-chapter.

2.3.4.2 Service modularity and architecture

The concept of modularity originated in production and manufacturing (e.g. Baldwin and Clark, 1997; Sanchez and Mahoney, 1996). On the one hand, Baldwin and Clark (1997:84) have defined *product modularity* as the ability of "a complex product or process" to be built "from smaller subsystems that can be designed yet function together as a whole". In its evolution, the idea of product modularity has been extended to service management, in which it developed mostly from the concept of process modularity and for the purposes of product-related services (Bask *et al.*, 2010a). In a recent systematic literature review on the evolution of modularity, Frandsen (2017) identified three papers as the starting point of modularity in services: Bask *et al.* (2010a), Pekkarinen and Ulkuniemi (2008) and Voss and Hsuan (2009). Whereas Pekkarinen and Ulkuniemi (2008) focussed on a platform-based approach for developing services, Voss and Hsuan (2009), stressing that service architecture is important when designing services, concluded that modularity establishes the foundation for service customisation and customer choice, effective product development and outsourcing. The following year, referring to the case of an LSP, Bask *et al.* (2010a) described a logistics delivery process consisting of activities (e.g. order handling, procurement, production planning, testing, warehousing and transporting) that can be subdivided into several standardised, invisible procedural steps. When applied, the concept of service modularity can enable designing and developing services with the aim of improving energy efficiency as a core attribute.

On the other hand, Voss and Hsuan (2009:546) have defined *service architecture* "as the way that the functionalities of the service system are composed into individual functional elements to provide the overall service delivered by the system". They devised a framework of service architecture with four levels: the industry, the service company or supply chain, the service bundle and, at the most detailed level, the service package or component. Therein, *service interfaces* describe the intersection of components such as people, information and standards (Voss and Hsuan, 2009).

By extension, service interfaces and components can be visualised with service blueprinting, a practical technique that helps firms to illustrate a service process by focussing on customers and highlighting contact with them (Bitner *et al.*, 2008). When used for service innovations and improvement (Bitner *et al.*, 2008; Fließ and Kleinaltenkamp, 2004), service blueprints also help to design services and divide the service process into actions and components, all while maintaining "that a total service is greater than the sum of its parts" (Bitner *et al.*, 2008:88). In that light, service design focusses on the interactions of customers and the organisation, both internally and within a wider network (Avlonitis and Hsuan, 2017; Bitner *et al.*, 2008). To map the entire service design, however, it is crucial to go beyond the touchpoints of provider–customer interaction (Rawson *et al.*, 2013; Tax *et al.*, 2013). Figure 2.7 illustrates the notions of service logic developed by Grönroos (2011) together with the service process and the components of a service blueprint: physical evidence, consumer action, front office, back office and support process.

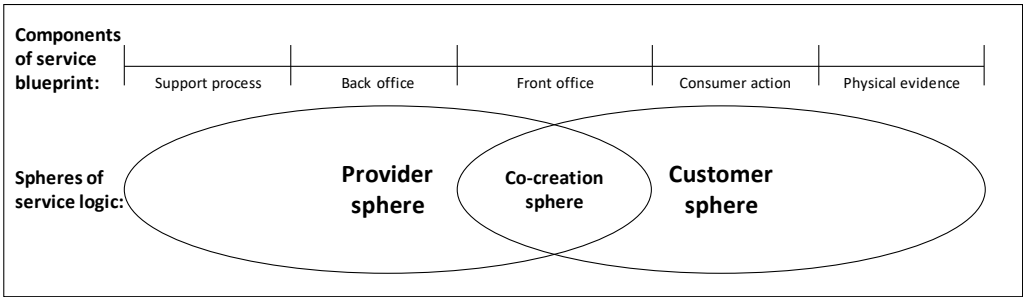


Figure 2.7: The notions of service logic and service blueprint combined

More recently, scholars have presented a typology of interfaces pertaining to service modularity (i.e. open, close, customer-oriented and information-based) (de Blok *et al.*, 2014), reviewed their use in research and provided an initial attempt to identify their common themes (Peters *et al.*, 2018). Nevertheless, they and other authors have also detected a persistent gap in literature on using modularity in the service industry and in cross-disciplinary work (e.g. Avlonitis and Hsuan, 2017; Brax *et al.*, 2017; Peters *et al.*, 2018).

Early on, scholars interested in modularity applied the systems perspective to define a service architecture as a system design that specifies how its overall functionality can be dismantled into various components and how those components interact to make a system design functional (Voss and Hsuan, 2009). However, that conceptualisation was developed in the context of processes and products, and as Bask *et al.* (2010a) has argued, service modularity has many similarities with process modularity. From another angle, Pekkarinen and Ulkuniemi (2008) have indicated that the logistics industry provides a fruitful context for studying modular service development. However, in the research for this thesis, service modularity was applied as a lens able to elucidate energy efficiency's potential to be improved in logistics systems.

In sum, the concepts of service modularity and service architecture, as well as the tool of service blueprinting, can be mobilised to analyse logistics services in depth, to provide opportunities to evaluate their components and modules, especially in relation to energy efficiency, and to link components vertically and horizontally in the context of interfaces that, taken together, can depict the whole service.

2.4 Synthesis: Environmentally sustainable development through improvements of energy efficiency in logistics systems

To contribute to environmentally sustainable development, different paths can be taken. This thesis operationalises that goal by approaching energy efficiency as a path to such development by means other than new technologies, electrification and a shift to fossil-free fuels.

In logistics, energy efficiency helps to decrease the total energy consumed and contributes to reaching the EU target to reduce total GHG emissions set for 2050. The European Union (2012) defines *energy efficiency* 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". In practice, 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). Nevertheless, the difficulty with energy efficiency is measuring it. Despite that challenge, Kalenoja *et al.* (2011) have underscores that being able to assess energy efficiency is essential to implementing and planning measures of energy efficiency in logistics. Quantitative indicators such as vehicle fill rate, empty running, fuel efficiency, vehicle time utilisation and deviations from schedule have been used in

past studies to monitor efficiency in transport (McKinnon and Ge, 2004). By contrast, this thesis approaches energy efficiency in qualitative terms and assesses energy efficiency improvements as decreases in energy consumption and increases in the output of logistics activities with constant quality, reliability and flexibility.

The previous sub-chapters have identified and described concepts and theories used in the research presented herein. Once a framework from SCM was adapted, energy efficiency in logistics systems could be conceived in terms of certain building blocks, as depicted in Figure 2.8. Structures in logistics that shape energy efficiency have been characterised as existing on vertical levels (McKinnon, 2016a), along horizontal boundaries (Kalenoja *et al.*, 2011) and with respect to the system's members (Lambert and Cooper, 2000), and all of those structural characteristics have been shown to directly influence a system's energy efficiency and measurement of it (Kalenoja *et al.*, 2011). In that dynamic, logistics initiatives bear direct influence on the energy consumption of logistics systems (Centobelli *et al.*, 2017b; Colicchia *et al.*, 2013; Evangelista *et al.*, 2018), in which logistics services, understood according to service logic (Grönroos, 2011) and service modularity (Avlonitis and Hsuan, 2017; Bask *et al.*, 2010b), visualised by service blueprinting (Bitner *et al.*, 2008) and depending on their offerings, require different amounts of energy.

In conclusion, energy efficiency is the phenomenon that motivated the research for the thesis. The necessary improvement of energy efficiency can be approached by probing its structural characteristics, initiatives and services, as articulated in the research questions and illustrated in Figure 2.8.

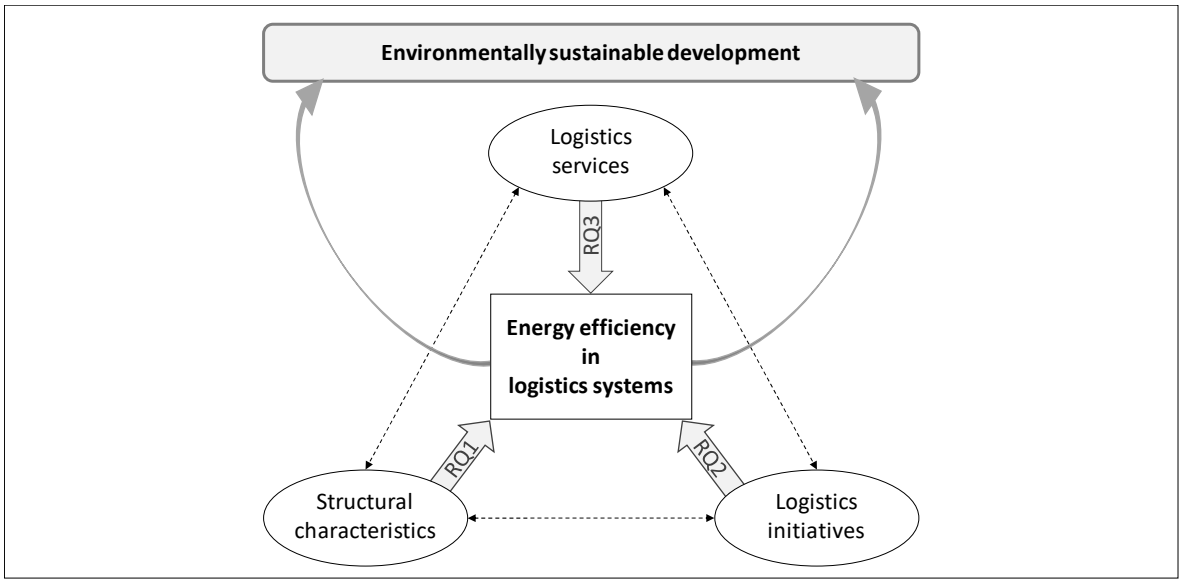


Figure 2.8: Conceptual framework of building blocks and research questions (RQ)

3 Methodology

This chapter describes the research approach, including the author's epistemological stance, the research design, the five studies performed and their methods. After that, it elaborates upon how the quality of the research was ensured and, in closing, recounts the research process.

3.1 Epistemological stance

Epistemology is concerned with theories of knowledge and perceptions in science (Flick, 2014). In the research for this thesis, the author adopted the stance of critical realism (Aastrup and Halldórsson, 2008) to view not only the problem of high energy consumption in logistics but also the underlying mechanism in logistics systems that create the conditions for the phenomenon. In other words, the high demand for transport, along with its high energy consumption and GHG emissions, was conceived to stem from an underlying mechanism rooted in the logistics system and its design, in promises for short lead times, flexibility, reliability and low costs, and in its actors who demand transport with numerous deliveries under significant time constraints.

In general, critical realists engage in two intertwined activities. First, they describe observed trends, or *practices*, and subsequently, they analyse the mechanisms of those trends in order to generate theses, or *theory* (O'Mahoney and Vincent, 2014). Likewise, the research presented herein followed an abductive approach characterised by alternating between theory and practice (Kovács and Spens, 2005; Spens and Kovács, 2006), as depicted in Figure 3.1. During the research, every study began with a review of literature and thereafter shifted between the collection of empirical evidence and the re-examination of theory. The abductive approach also guided the alternation between developing an interview guide from the literature, a dialogue with feedback from the industry on preliminary findings and a comparison of the results with past findings.

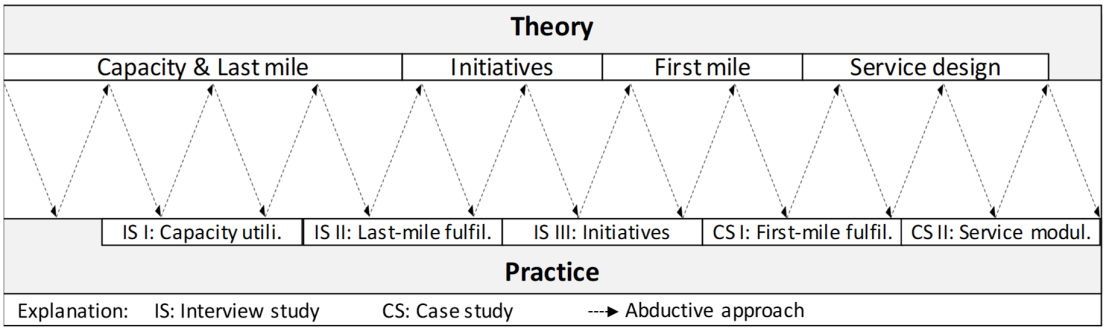


Figure 3.1: Abductive reasoning as applied in the research

Both adopting the systems perspective and viewing logistics systems as being open and in constant interaction with their environments align with critical realism (Aastrup and Halldórsson, 2008; O'Mahoney and Vincent, 2014:6). The assumptions of critical realism are also reflected in the conceptual framework, particularly in the building block of structural characteristics (e.g. structural dimensions and members) that set conditions for actors who, in turn, influence the structure by transforming or reproducing it (Aastrup and Halldórsson, 2008). As Aastrup and Halldórsson (2008) have highlighted, agents in the system, including individual actors and organisations, are influenced by the logistics systems in which they act and, at the same time, influence those same systems. Moreover, because logistics research has been influenced by several disciplines—engineering, operational research, management and economics—the author's engineering background facilitated approaching logistics as an objective world, albeit one open to subjective interpretations.

From the critical realist perspective, reality can be viewed in three domains: the real, the actual and the empirical (Mingers and Standing, 2017; O'Mahoney and Vincent, 2014). The *real* refers to the external world of mechanisms and structures that, given their properties and causal powers, behave in certain ways. By contrast, the *actual* describes the interaction of those mechanisms at different levels that generate events that occur or, despite expectations, do not occur. Last, the *empirical* encompasses a small part of actual events that are observed and recorded as empirical evidence for research. To collect in-depth information and expand understandings of complex logistics systems, qualitative studies were conducted that involved interviews and case studies, both of which were conceived as being adequate to the task. Used together with supplementary material and additional research methods (e.g. a focus group and brainstorming sessions; see Table 3.1), such approaches facilitated the collection of rich data describing the situations examined and their underlying conditions. At the same time, bearing the underlying assumption of critical realism in mind, the author has remained aware that interviewing a limited number of actors in the industry cannot afford a full, real picture but only a fraction of the actual, as presented in this thesis.

3.2 Research design

The research design comprised research questions, the planned methods and studies (e.g. literature reviews, interviews and secondary data collection) and means to ensure a certain level of research quality (Bryman and Bell, 2011). Guided by the research design, the research involved following a qualitative approach based on semi-structured interviews and case studies. Concerning qualitative research, Flick (2014) has stated that the qualitative research process requires a sequence of decisions to be made about research questions, goals, theoretical frameworks and the selection of empirical material in light of available resources. More particularly, Maxwell (2013) has characterised research questions not as a starting point but as the core of research that connects all components of the research design. In his interactive model of research design, Maxwell (2013) places research questions at the centre, where they are surrounded and thus influenced by the conceptual framework, goals, methods and means of ensuring validity, all of which also influence the questions. In the research conducted for the thesis, the research questions were developed over time and in constant interaction with the methods, the purpose and the theoretical frame of reference. In part, the research design was founded upon the conceptual framework of the research developed with reference to the framework by Cooper *et al.* (1997) and Lambert and Cooper (2000). Figure 3.2 visualises the relationships between the research questions, studies and papers, although only key relationships between research questions and studies are depicted. A more detailed overview appears in Table 3.1.

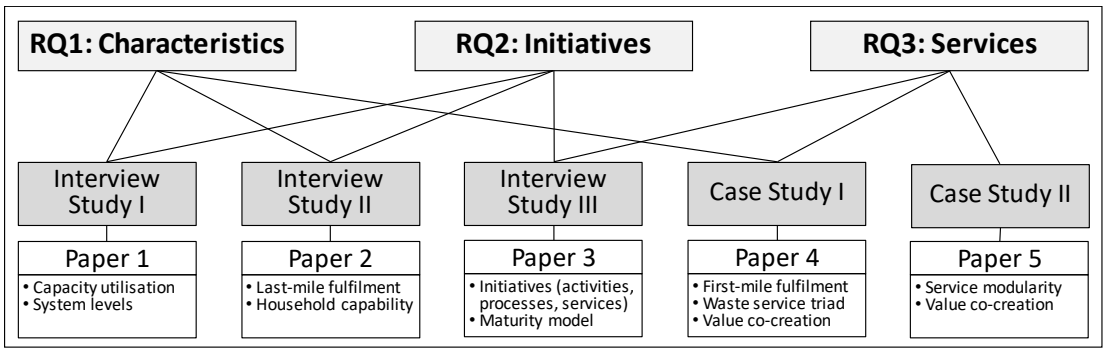


Figure 3.2: Relationships between the research questions (RQ), studies and papers

During three interview studies and two case studies, empirical data were collected that served to answer the research questions. A literature review conducted in connection with each study not only served as a foundation for the respective interview or case study but was also continuously updated during the research process. All of the methods are explained in the following sub-chapters. In addition to the five papers produced as a result of the studies, a book chapter was written, which afforded an opportunity to combine several studies with additional material and offered another outlet of academic work. Because of copyright concerns, the book chapter is not appended to this thesis, although a summary is presented in Chapter 4.6.

3.3 Research studies and methods

Each of the five studies resulted in one paper and helped to answer at least one research question. Table 3.1 provides an overview of the studies and research questions, which are elaborated upon in the following sub-chapters.

Table 3.1: Interplay of studies, papers and research questions

No.	Study	Paper (P)	Data sources	Unit of analysis	Research question (RQ)
1	Interview Study I: Capacity utilisation	P1	- Literature on capacity utilisation - Semi-structured interviews - Site visits - Publicly available data (e.g. impact cases of companies, company websites and sustainability reports)	Capacity	RQ1 (Characteristics) RQ2 (Initiatives)
2	Interview Study II: Last-mile fulfilment	P2	- Literature on last-mile logistics - Semi-structured interviews - Site visits - Benchmarks for e-commerce delivery services - Publicly available data (e.g. company websites)	Last-mile fulfilment options	RQ1 (Characteristics) RQ2 (Initiatives)
3	Interview Study III: Initiatives	P3	- Literature on the green initiatives of LSPs - Semi-structured interviews - Publicly available data (e.g. company websites and sustainability reports)	Processes, services and activities	RQ2 (Initiatives) RQ3 (Services)
4	Case Study I: First-mile fulfilment	P4	- Literature on first-mile logistics and service marketing - Semi-structured interviews - Brainstorming sessions - Site visits - Focus group - Secondary evidence (e.g. reports from the municipality, internal guidelines and company websites)	Waste service triad	RQ1 (Characteristics) RQ3 (Services)
5	Case Study II: Service modularity	P5	- Literature on service design and service modularity - Semi-structured interviews - Brainstorming sessions - Use of service blueprints - Secondary evidence (e.g. reports from the municipality) - Publicly available data (e.g. company websites)	Waste logistics service	RQ3 (Services)

Each conducted in the forward supply chain to the point of consumption, the interview studies entailed multiple interviews with representatives from several companies. By contrast, both case studies were conducted in the post-consumption flow—that is, the flow of household waste from the point of consumption—and focussed on the first mile. All of the case studies involved multiple methods, and aside from interviews with several representatives from a limited number of companies, additional evidence was gathered to investigate a single setting in a certain context (da Mota Pedrosa *et al.*, 2012). The setting was particularly interesting; because waste collection is organised in highly regulated contexts, the setting granted the opportunity to depict the system with a small sample. Of course, a similar opportunity is difficult to find in the forward flow of goods due to the large number of dispersed logistics actors in the market.

The descriptions of Interview Studies I and II share a sub-chapter because of their overlapping features, although their similarities and differences regarding case sampling, data collection and analysis are highlighted. Meanwhile, separate sub-chapters are dedicated to Interview Study III and each of the two case studies.

3.3.1 Interview Studies I and II: Capacity utilisation and last-mile fulfilment

The strength of any interview study rests in the possibility of obtaining the complex stock of knowledge of an expert or group of experts (Flick, 2014:217), along with expert perspectives on the topic being studied. In the research for the thesis, that affordance furnished an insider view on the logistics industry as well as feedback from interviewees concerning the findings.

3.3.1.1 Sampling and data collection

The sampling process for Interview Studies I and II began with convenience sampling (Flick, 2014:175) by interviewing companies in a reference group connected to the research project. Later, additional individuals from different companies were interviewed to represent different actor groups in the logistics industry. By interviewing a range of professionals who work with logistics (e.g. retail managers and managers of LSPs), along with an expert on implementing lean energy in the manufacturing industry (i.e. an approach for reducing waste and improving services), a broad picture of the current situation could be painted. Following such a multi-actor approach, each interview study was performed with a diverse sample.

The multi-actor approach was chosen to broaden the research's perspective by collecting data from different actors in supply chains, primarily as a means to map efforts made in the logistics industry towards energy efficiency and environmental sustainability. By following that approach, different logistics activities occurring on different system levels could be pinpointed and analysed. Following the premise of theoretical sampling (Flick, 2014:172), the sample size was not initially defined, and the sampling process was finished when theoretical saturation was reached and enough data had been collected to fulfil the study's purpose. On the whole, several interviews with participants from one company were conducted.

Table 3.2 briefly describes all companies sampled and their size. Both interview studies focussed on the flow of goods downstream in supply chains into and within urban areas supported by road freight transport and adjacent logistics operations.

Table 3.2: Companies sampled for Interview Studies I and II

No.	Brief description of company sampled	Size of company[1]	Interviews conducted	Operation in supply chain segments[2]	Included in	
					Interview Study I	Interview Study II
1	Manufacturer of machine elements and logistics service provider	Large	1	(0, 1,) 2, 3	x	
2	Manufacturer of packaging, processing and distribution solutions	Large	1	(0,) 2	x	
3	Manufacturer of paper and tissue products	Large	1	(0, 1,) 2, 3	x	
4	Garment retailer with physical stores and e-commerce presence	Medium	3 + site visit (same interviewee)	(0,) 2, 4, 6	x	x
5	E-grocery retailer and deliverer	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 + site visit	(1,) 2, 3, 5, 6		x
8	Nordic logistics service provider	Large	3 (different interviewees)	(1,) 2, 3, 5, 6	x (2/3)	x (1/3)
9	Nordic logistics service provider	Medium	1	(1,) 2, 3, 5	x	x
10	LEAN energy consultancy	Small	3 (same interviewee)	n/a	x	

[1]*Small: <1.000 employees, medium: 1.000-9.999, large: >10.000 employees.*
[2]*In combination with Figure 3.3.*

Figure 3.3 visualises a supply chain and, together with Table 3.2, illustrates in which segment each examined company operates. Production logistics (Segment 0) and upstream logistics activities (Segment 1) were beyond the scope of the research. Instead, the focus was logistics within distribution centres (Segment 2), transport to retailers (Segment 3), the in- and outbound logistics of retailers (Segment 4), transport to customers (Segment 5) and, in the case of online ordering, home delivery from distribution centres (Segment 6).

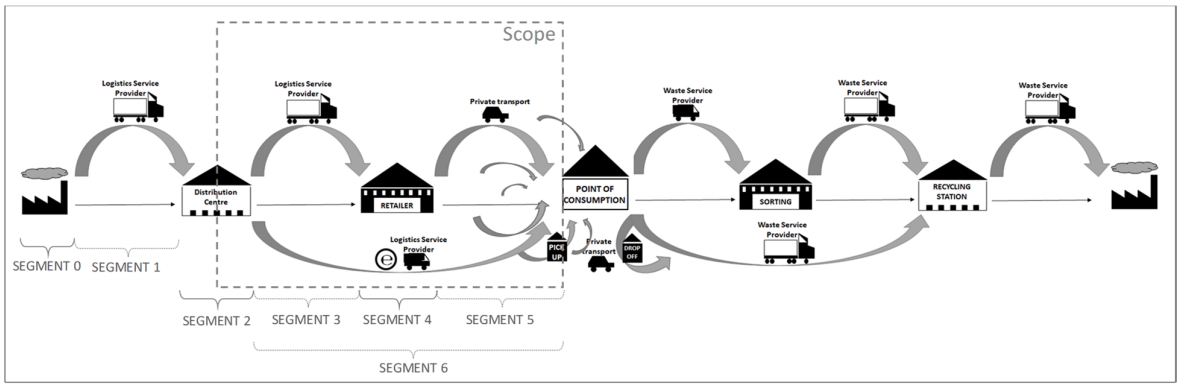


Figure 3.3: Scope of Interview Studies I and II showing the segment in which sampled companies operate

Interview Study I: Capacity utilisation

Addressing capacity utilisation, Interview Study I entailed 17 interviews with participants from 10 companies. Companies were selected according to criteria such as industry, size and logistics

strategy. To paint a broad picture, different companies were chosen from Segments 2, 3, 4, 5 and 6 of the supply chain (see Figure 3.3) that focussed on road freight transport between distribution centres and retailers (i.e. Segment 3).

The literature identified from a literature review on capacity utilisation, in combination with the aim of the study, revealed several six themes that guided the formulation of the interview questions. Emerging from literature on energy logistics and capacity as well as last-mile fulfilment, the themes were (1) measuring energy efficiency and goal-setting, (2) measuring energy consumption, (3) collaboration between actors, (4) end consumers, (5) logistics systems and (6) the last mile. Interview questions for each theme were developed, and their relationships with the literature are listed in Table 3.3.

Table 3.3: Review of literature, themes and building blocks for the interview guide, adapted from Wehner (2018)

Relevant literature	Dimension of energy efficiency	Relationship to capacity utilisation	Theme(s)
Centobelli *et al.* (2018), Kalenoja *et al.* (2011), Liimatainen and Pöllänen (2010), Liimatainen *et al.* (2015), McKinnon and Ge (2004), Wu and Dunn (1995)	Measuring energy efficiency Setting goals	Defining system boundaries Taking a broad approach to energy efficiency	Measurement of energy efficiency and goal setting
Browne *et al.* (2006), Browne *et al.* (2005), Piecyk and McKinnon (2010)	Measuring energy consumption Reducing fuel and energy consumption Positioning energy as an essential cost driver	Recognising that vehicle load factor, empty running, transport distance and weight of goods influence capacity utilisation Acknowledging the interplay of components	Measurement of energy consumption
Björklund (2011), Bottani *et al.* (2014), He and Zhang (2018), Plambeck (2012), Wolf and Seuring (2010), Yuan *et al.* (2018)	Discussing collaboration and information sharing Connecting collaboration and energy efficiency	Collaborating to enable the use of underutilised capacity	Collaboration between actors
Brown and Guiffrida (2014), Browne *et al.* (2006)	Identifying the end consumer's role Raising end consumers' awareness of their impacts on energy consumption	Recognising that end consumers' behaviour creates underutilised capacity Considering consumers' transport when viewing supply chain	Role of end consumer
Aronsson and Huge-Brodin (2006), Kalenoja *et al.* (2011), McKinnon (2016b), Pfohl and Zöllner (1997)	Establishing responsibilities for the environment and transported products Discussing just-in-time deliveries Discussing returns	Taking a systems perspective on supply chains Decelerating supply chains	Logistics in form of a system
Brown and Guiffrida (2014), Kin *et al.* (2018), Rizet *et al.* (2012)	Discussing e-commerce Handling last-mile delivery	Recognising that last-mile transport is not used to its full capacity	Last-mile fulfilment

Based on those themes, an interview guide was developed for semi-structured interviews, meaning that interviews followed the guide but also allowed interviewees to address other topics and concepts important to them. Lasting from 60 to 90 minutes, each interview initially focussed on capacity as a means to identify causes for underutilised capacity in the corresponding logistics system and possible ways of using such capacity (i.e. means of mitigation). When several rounds of interviews were conducted with one company, the same persons were usually interviewed in each round.

Interview Study II: Last-mile fulfilment

For Interview Study II, questions about last-mile fulfilment and e-commerce were added to the interview guide, and several interviewees from Interview Study I were interviewed again, albeit about transport in the last mile (Figure 3.3, Segments 5 and 6). To that purpose, a selection criterion was that the case companies had contact with the end consumer (B2C), such as via e-commerce, in which goods purchased online are shipped either to the retailer's store for pickup by the end consumer or directly to the point of reception—that is, the end consumer's home or nearby pickup point (Hübner *et al.*, 2016b).

Interviewees were asked about fulfilment in the last mile and in the second-to-last leg (i.e. the transport leg from a distribution centre to a retail store). That leg was included in data collection, because, depending on the last-mile fulfilment option, goods might need to be repackaged and reloaded in the previous leg, which affects the energy efficiency of the overall transport.

The focus of the interviews was e-commerce, possible fulfilment options and their energy consumption, the involvement of end consumers in last-mile distribution and challenges for LSPs. Each interview lasted from 60 to 120 minutes.

3.3.1.2 Data analysis

During the interviews, comprehensive notes were taken, and in three cases, the interviews were recorded and afterwards transcribed. The data analysis was conducted for both studies as follows.

Interview Study I: Capacity utilisation

Data analysis first referred to the themes revealed by the literature review, which originally helped to construct the interview guide and were used as the initial nodes in coding. Other nodes were added as needed while the data were repeatedly analysed and sorted under the nodes. Next, the nodes were reduced to overall categories in order to obtain a sufficient overview of the key areas (Ellram and Tate, 2015). From Interview Study I, three categories were derived that guided the sorting of causes of underutilised capacity into the categories of actors, activities and areas within the corresponding logistics system. Those three categories were chosen because they explained who (i.e. which actor) and what (i.e. which activity) were responsible for the underutilised capacity as well as where (i.e. which area in the logistics system) it had emerged. Causes of underutilised capacity were extracted from the interview data and grouped under one of the three categories, the latter of which supported the process of identifying means of mitigation. Along with the causes, examples from the interviews were identified that clearly illustrated the underuse of capacity. Subsequently, the causes were linked with corresponding means of mitigation also derived from the empirical data. Last, a framework of the causes of underutilised capacity and means of mitigation was developed.

Interview Study II: Last-mile fulfilment

The collected data, including the content of interviews and field notes taken during site visits, were processed with NVivo, a software for qualitative data analysis, for the key terms "e-commerce", "consumer", "speed", "energy consumption", "energy efficiency", "collaboration", "capacity", "home delivery" and "pickup". Last-mile fulfilment options and their characteristics were mapped and validated by the interviewees in several rounds of interviews. The data were structured around the framework previously generated with reference to the data and three building blocks: distribution structure, transport execution and household logistics capability. Next, implications for energy efficiency for an array of last-mile fulfilment options were derived, and the interviewees helped to map and rank the energy consumption of those options.

3.3.2 Interview Study III: Initiatives

3.3.2.1 Sampling and data collection

Companies sampled for Interview Study III, all providers focussing on energy efficiency in their approach to sustainable development, were purposefully selected (Bryman and Bell, 2011). Sampling began with companies obliged to conduct energy mapping by Swedish law (2014:266) who were believed to have implemented a systematic approach to the continuous improvement of energy efficiency. The sample was supplemented with other companies also believed to have done so but whose size rendered the law inapplicable. Such sampling was done via snowballing based on convenience sampling. Interviewees with extensive knowledge about improving energy efficiency were contacted (Flick, 2014:217), which resulted in 10 interviews conducted at 9 companies (see Table 3.4). The interview guide was developed with reference to the integrative energy management framework created by Schulze *et al.* (2016), which provides a systematic approach to energy efficiency by establishing commonalties and boundaries around energy efficiency initiatives.

Table 3.4: Companies sampled for Interview Study III

No.	Brief description of company	Size of company[1]	Interview date and duration	Position of interviewee(s)
1	Freight forwarder by road and rail	Large	Nov 2017, 100 min	Process and environment manager
2	Freight forwarder for express deliveries by road and air	Large	Dec 2017, 55 min	Sustainability manager
3	Freight forwarder	Large	Dec 2017, 40 min	Environmental manager
4	Third party logistics provider	Large	Dec 2017, 60 min	Environment, energy and quality manager
5	Waste logistics provider by road	Medium	Nov 2017, 65 min	Logistics development manager, environmental manager
6	Freight forwarder by sea	Large	Jan 2018, 95 min	Performance manager
7	Fourth party logistics provider	Medium	March 2018, 75 min	Site and general manager
8	Freight forwarder by road and rail	Large	March 2018, 60 min	Distribution manager
9	Third party logistics provider	Large	April 2018, 50 min	Transport manager
10	Third party logistics provider	Large	May 2018, 55 min	Sustainability manager

[1]Small: <1000 employees, medium: 1000–9999 employees, large: >10,000 employees.

Figure 3.4 illustrates the scope of Interview Study III.

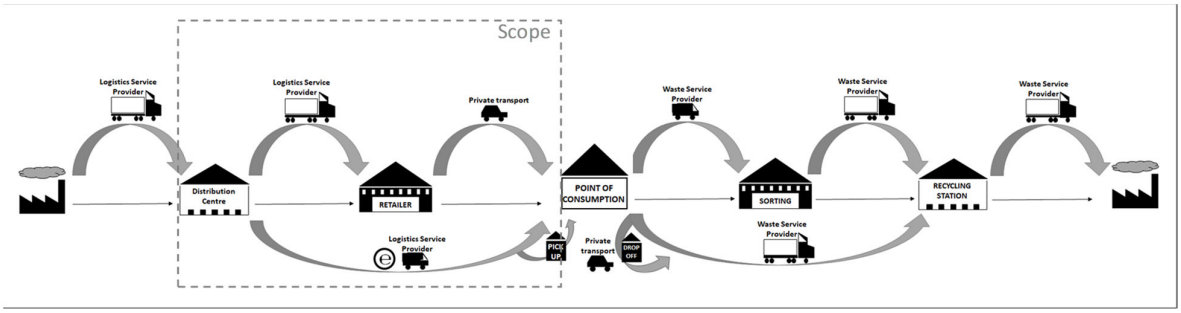


Figure 3.4: Scope of Interview Study III

3.3.2.2 Data analysis

Once all 10 interviews were recorded and transcribed, analysis proceeded in two steps. First, the raw interview data were inductively coded, in which codes (i.e. high-order categories and dimensions) were derived from the literature. Second, axial coding (Ellram and Tate, 2015) was used to unite the codes in new and different ways in order to reveal relationships amongst them. After the number of codes was reduced in an iterative process, the results were summarised according to the dimensions of actions, services and processes, as developed following an abductive approach alternating between the literature and the empirical data. Last, quotations from the interviews were selected to illustrate the findings. Table 3.5 summarises the dimensions and axial codes as well as presents which company interviewed had implemented which initiative. The literature was continuously examined during the coding process, and ultimately, a maturity model for LSPs was formulated.

Table 3.5: Data analysis for Interview Study III

Dimensions	Axial codes	Respondent in company No.	Number of companies meeting the code
Action	Building design	2, 3, 4, 8, 9	5
	Vehicle design	1, 2, 3, 5, 6, 8, 9, 10	8
	Information communication technology	5, 7, 8	3
	Managerial actions	1, 2, 3, 4, 5, 6, 7	7
	Monitoring and reporting	1, 4, 5, 6, 7, 8, 9, 10	8
Service	Demand for sustainable services	1, 2, 3, 4, 5, 7, 9	8
	Sustainable transport solutions	1, 4, 7, 8, 9, 10	6
	Sustainable delivery	1, 2, 8, 9	4
	Other sustainable services	1, 6, 7, 8, 9, 10	6
Process	Energy mapping process	1, 2, 3, 4, 5, 10	6
	Environmental performance measurement process	1, 2, 3, 4, 5, 6, 7, 8, 10	All
	Management process	1, 2, 3, 4, 5, 6, 7, 8, 10	All
	Operation management process	1, 9	2
	Environmental training process	1, 2, 3, 4, 6, 10	6
	Internal communication process	2, 3, 4, 5, 7	5
	Investment process	1, 3, 4, 8, 9, 10	6

3.3.3 Case Study I: First-mile fulfilment

3.3.3.1 Sampling and data collection

The case studies were conducted in the last mile of logistics fulfilment—that is, after the point of consumption—and focussed on the collection of household waste. Figure 3.5 depicts the scope of Case Study I.

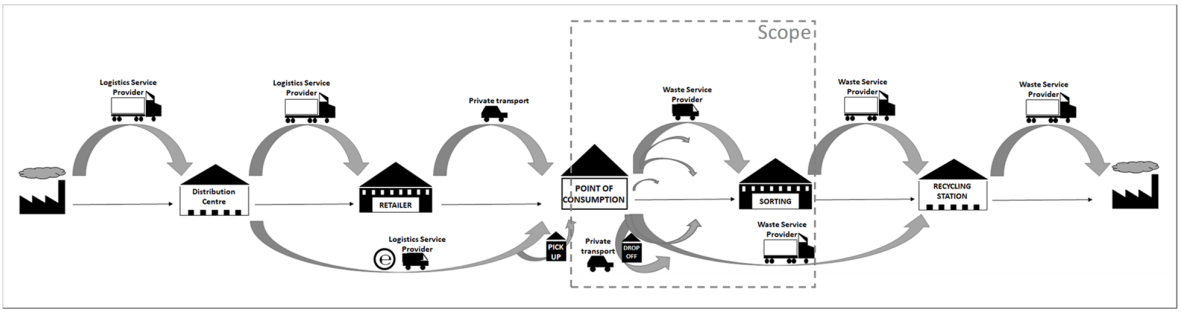


Figure 3.5: Scope of Case Study I

To ensure a thick description, data were collected from all actors in the waste service triad (Halldórsson *et al.*, 2019a) shown in Figure 2.4. Those actors were:

(1) The municipality, which is responsible for the collection of household waste and for organising and regulating waste collection services not covered by the waster producers (European Union, 2008);
(2) The households, which reside in houses or apartment buildings and interact in different ways with the other members of the triad depending upon the services that they have bought; and
(3) The WSP, which oversees the collecting, moving, sorting, handling and sometimes trading of household waste.

A reverse LSP, the WSP is managed by the municipality and ranks amongst the largest in Sweden. Used by 10 municipalities, it operates between those municipalities and households in the first mile, and other than collecting food and residual waste, it also collects packaging waste for manufacturing companies.

To collect rich, in-depth data (Flick, 2014) about the case, multiple methods of data collection were applied, which supported the exploratory and multi-actor nature of the study. Data were collected on 14 occasions from March 2017 to May 2018 with methods such as brainstorming sessions (Osborn, 1953), semi-structured interviews with employees from different units of the municipality and WSP, a focus group with representatives of private households, site visits and a meeting with the WSP's shareholders (see Table 3.6).

Table 3.6: Data collection for Case Study I, adapted from Halldórsson *et al.* (2019a)

No.	Representatives (reps.)	Form of data collection	Date	Duration	Additional evidence gathered
1	2 reps. from WSP	Conversation or semi-structured interview	Mar 2017	90 min	- Guide for energy mapping of Sweden's transport industry (used by WSP) - End report on previous research addressing waste management of apartment complexes in Sweden (given by MUN and WSP in 2016)
2	1 reps. from WSP 1 reps. from MUN	Brainstorming session	April 2017	70 min	
3	1 reps. from WSP 3 reps. from MUN	Brainstorming session	May 2017	180 min	
4	3 reps. from MUN	Brainstorming session	Sept 2017	130 min	

5	2 reps. from MUN	Brainstorming session	Sept 2017	170 min	- MUN internal document ("Waste management strategy")
6	1 reps. from MUN 1 reps. from WSP	Site visits	Oct 2017	180 min	- MUN internal document ("Guide for choosing waste collection systems in multi-apartment buildings")
7	2 reps. from WSP	Semi-structured interview	Nov 2017	70 min	- MUN-commissioned report on attitudes and behaviours of owners of apartment complexes from 2017
8	2 reps. from MUN	Validation of results	Jan 2018	60 min	
9	6 reps. from HH	Focus group	Feb 2018	60 min	
10	WSP's shareholders	Dissemination of results	Mar 2018	20 min	
11	2 reps. from MUN	Validation of results	April 2018	90 min	- MUN-commissioned report on attitudes and behaviours of owners of one-family houses from 2017
12	1 reps. from WSP	Validation of results	April 2018	60 min	
13	3 reps. from MUN	Data collection on HHs	May 2018	120 min	- Service descriptions on websites

Note. HH = Household, MUN = Municipality, WSP = Waste service provider.

Data collection began with a conversation with the WSP, in which the set-up of the study was discussed, and the case developed several rounds of brainstorming sessions, semi-structured interviews and processes of validation with the municipality and the WSP. Several researchers were involved in data collection whose notes were compared. On top of that, six waste collection and recycling sites were visited for tours guided by a representative of the municipality: an indoor waste collection station at an apartment building, an outdoor and underground waste collection station in a residential area, a recycling centre for households, a waste sorting facility, a facility for biological waste and an incineration plant. To document observations, notes and photographs were taken during the site visits (Flick, 2014). For clarify the empirical understanding, additional evidence in form of internal documents and reports, most of them provided by the municipality or WSP or else publicly available on the websites of the facilities, was gathered and read.

Data were also collected from a focus group of household representatives. Individuals in single-family and apartment-dwelling households were invited to participate in the focus group, which was moderated by a researcher who also facilitated the discussion (Greenbaum, 1998). In the group, each representative could freely participate and contribute ideas (Greenbaum, 1998), and two forms with questions provided to allow participants to take notes. The forms were collected after the session for analysis, and the session was recorded and transcribed following the recommendations of Kitzinger (1995).

3.3.3.2 Data analysis

Starting with the data collected during brainstorming sessions, analysis was performed to construct three different first-mile options used for structure the analysis of all other data. The data collected from notes, transcripts, the forms from the focus group session and photographs from the site visits were analysed qualitatively to glean the actors' roles and their implications on not only energy efficiency during transport but also the quality of waste according to the predefined last-mile structures. Although following an abductive approach, analysis referred to theoretical codes from the literature and inductive codes added during analysis (Miles *et al.*, 2014). The codes and their categorisation, revisited during several iterations of data collection (Pratt, 2008), were used to understand activities performed by members of the service triad and to relate those activities to the co-production of value by triad members as operand resources (i.e. operated upon) or operant ones (i.e. able to operate upon other resources), as detailed in Table 3.7. The analysis resulted in two distinct perspectives—use value and exchange value—for members of waste logistics service triad to adopt in the first mile.

Table 3.7: Data analysis for Case Study I (Halldórsson *et al.*, 2019a)

Actor	Theoretical code	Activity
Household (HH)	**Outcome sought** • Use value • *Exchange value* **Social roles** • Consumer (operand resource) • *Supplier (operant resource)* **Interaction** • In traditional logistics services for disposing of waste • *In value-added logistics services for higher quality* **Resources to be exchanged** • Lower-quality waste • *Higher-quality waste*	**Sorting** • At home • Different numbers of fractions • Different ways of sorting • Different capacities for sorting **Moving** • 3–5 locations • Different frequencies • Different transportation modes
Municipality (MUN)	**Outcome sought** • Use value • *Exchange value* **Social role** • Public service provider (operand resource) • *Customer (operant resource)* **Interaction** • In designing and managing waste collection service • *In designing and organising further flows of recycled waste to markets for raw materials* **Resources to be exchanged** • Equipment, relationships, space and processes for waste collection • *Equipment, relationships, space and processes for producing and distributing of higher-quality waste*	**Organising** • Duty distribution • Category specification • Location selection and specification **Informing** • HHs: How to recycle • WSPs: Where to collect residual and food waste • Producing companies: Where to put packaging waste • Other MUNs: How to exchange best practices **Investing and servitising** • Invest in and servitise via WSPs • Provide waste collection services to both WSPs and HHs **Managing** • Relationships between actors in waste service triad
Waste service provider (WSP)	**Outcome sought** • Use value • *Exchange value* **Social roles** • Waste logistics service provider (operand resource) • *Second-tier supplier (operant resource)* **Interaction** • In providing waste collection and incineration services • *In treating and trading higher-quality waste with markets for raw materials* **Resources to be exchanged** • Equipment, relationships, space and processes for waste collection • *Equipment, relationships, space and processes for production and distribution of higher-quality waste*	**Sorting and handling** • Automated sorting at facilities • Hand sorting at facilities • Short-distance movements in different categories **Moving** • Small trucks to reloading centres • Large trucks to sorting stations or treatment plants • New, energy-efficient technology for trucks **Storing** • Segregated storage for different types of waste **Trading and treating** • Trade high-quality waste • Treat waste for energy recovery • Compete in the market

Note. Normal text describes "use value", italic text describes "exchange value".

3.3.4 Case Study II: Service modularity

3.3.4.1 Sampling and data collection

For Case Study II, sampling was purposive, and data were collected by interviewing representatives of two actors in the waste service triad. Although the study was a continuation of Case Study I in some ways—for instance, knowledge gained from Case Study I informed the study—entirely new data were collected during several rounds of semi-structured interviews in order to fulfil the study's purpose. The scope of the case study is depicted in Figure 3.6.

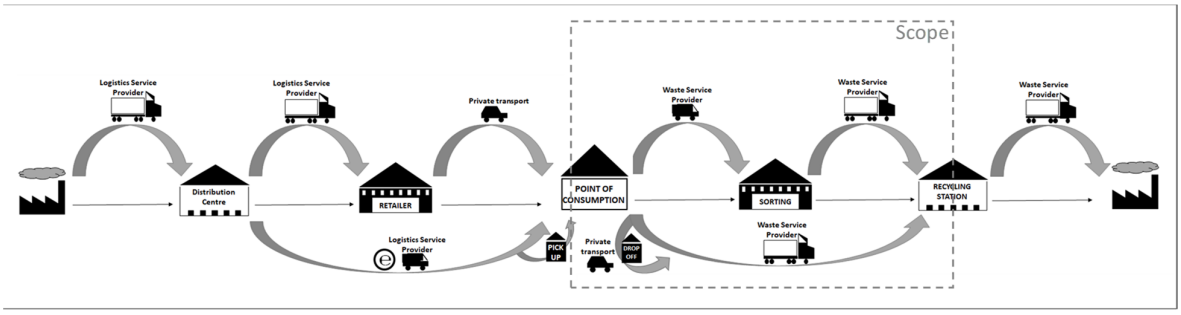


Figure 3.6: Scope of Case Study II

Interviewees were purposively sampled from two municipalities and from a WSP. Although the WSP is employed by both municipalities and both hold shares in it, the WSP can be regarded as an independent organisation. Collected on 12 occasions (see Table 3.8), data were validated with a consultant in waste service management.

Table 3.8: Data collection for Case Study II (Wehner *et al.*, 2019a)

No.	Interviewee	Form of data collection	Date	Duration
1	Development manager for logistics from WSP	Brainstorming session	Mar 2017	90 min
2	Development manager for logistics from WSP	Brainstorming session	April 2017	70 min
3	Development manager for logistics and environment and quality manager from WSP	Semi-structured interview	Nov 2017	90 min
4	Strategic advisor and manager of unit from MUN1	Brainstorming session	Nov 2018	80 min
5	Process leader waste collection from MUN1	Semi-structured interview, round I	Jan 2019	75 min
6	Service developer waste collection from MUN1	Semi-structured interview, round I	Jan 2019	85 min
7	Sanitation manager from MUN2	Semi-structured interview, round I	Jan 2019	90 min
8	Strategic advisor from MUN1	Brainstorming session	Jan 2019	60 min
9	Strategic advisor from MUN1	Brainstorming session	Feb 2019	60 min
10	Process leader waste collection from MUN1	Semi-structured interview, round II	Feb 2019	75 min
11	Service developer waste collection from MUN1	Semi-structured interview, round II	Feb 2019	85 min
12	Waste service consultant	Validation	Mar 2019	40 min

Note. MUN = Municipality, WSP = Waste service provider.

Two rounds of semi-structured interviews were conducted. In the first, interviewees were asked to describe different services so that services to be investigated could be identified. In the second, interviewees referred to service blueprints so that the services could be mapped in detail.

In total, data were collected about five services, categorised as either traditional or new. On the one hand, *traditional services*, involving the collection of residual and food waste, enabled rich descriptions by virtue of being offered to households for many years. Collection at apartment buildings was differentiated from that at single-family houses due to differences in service offerings. On the other, the *new service*—namely, the collection of gardening waste—has been offered for only 1 to 4 years in response to demand from households. In the latter case, interviewees could describe in detail how the service came into existence, for they had been involved in its development. The five logistics services for waste collection are listed in Figure 3.7.

Logistics service for waste collection	
Traditional service	*New service*
Food and residual waste	**Gardening waste**
1. Collection at apartment houses of (a) food waste (b) residual waste 2. Collection at one-family houses of (a) food waste (b) residual waste	3. Collection at one-family houses of gardening waste

Figure 3.7: Typology of logistics services for waste collection in Case Study II, adapted from Wehner *et al.* (2019a)

In the second round of interviews, data were collected with reference to service blueprints so that components constituting the service modules could be mapped in detail (see Figure 3.8). Bitner *et al.* (2008) have provided instructions on how to collect data with the same service blueprint template in six steps: (1) clearly articulating the service process or sub-process to be blueprinted and specifying the customer segment on which it focusses, (2) delineating the actions of customers, (3) establishing the actions of contact employees at both the front and the back end, (4) adding links that connect customers to contact employees, (5) adding physical evidence as the last component and, (6) if desired, adding more data to the blueprint for greater detail. Ultimately, the service blueprint for each main service, drawn in collaboration with the interviewees, guided data analysis.

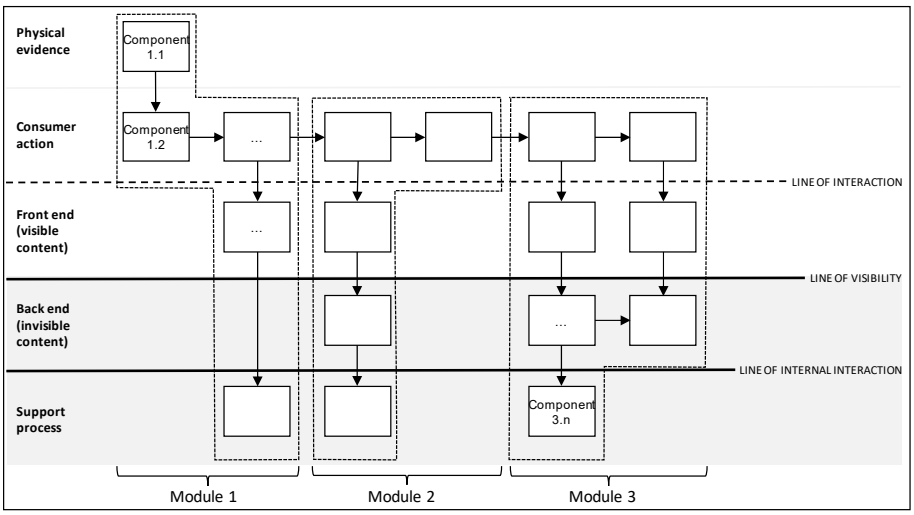


Figure 3.8: A service blueprint used for data collection in Case Study II

3.3.4.2 Data analysis

The interview data were used as a basis for the service blueprints as well as to understand the design of each service. Each blueprint also helped to illustrate the point in the service at which customers interact with the organisation, actions taken and forms of contact beyond those touchpoints (Avlonitis and Hsuan, 2017; Rawson *et al.*, 2013; Tax *et al.*, 2013). Since the waste service was co-created in a triad, the designation "organisation" could refer to either the WSP or the municipality. Each blueprint created in collaboration with the interviewees was merged to create a detailed service blueprint for each service (see Appendix A for the service blueprints).

The service blueprints were analysed with reference to the four levels of service architecture developed by Voss and Hsuan (2009), as well as used to identify service process modules and interfaces guided by the service logic by Grönroos (2006, 2008, 2011). Mapping the service offerings helped to compare the modules across the services, to identify customised as well as standardised components and to pinpoint modules with the greatest impact on energy efficiency.

3.4 Research quality

Research quality was ensured by carefully constructing the research design to represent a logical set of statements (Yin, 2014). Beginning by reviewing the literature afforded not only an overview of current knowledge in energy, logistics and environmental sustainability but also informed all of the studies, all of the papers and the book chapter. It also helped the author to form a theoretical and conceptual perspective on the topics being studied. Furthermore, from the literature, themes for the interview guides emerged, which ensured that the interview questions were relevant to the topics.

Yin (2014) has suggested judging the quality of the research design of a case study in terms of construct validity, internal validity, external validity and reliability. For assessing the quality of qualitative research data, Bryman and Bell (2011) have highlighted the importance to evaluate the criteria of reliability and validity. Referring primarily to research on logistics, Halldórsson and Aastrup (2003) have suggested trustworthiness, particularly in the dimensions of credibility, transferability, dependability and confirmability, as an alternative criterion for assessing the quality of qualitative research. The criterion of trustworthiness and its four dimensions was chosen to assess the quality of the research reported here, because it reflects the development of logistics into a multi-paradigmatic field and considers its so-called "soft" side (Halldórsson and Aastrup, 2003).

The first of the four dimensions, *credibility* refers to the degree to which research demonstrates that no single objective reality exists and that reality exists only in the minds of participants (Erlandson *et al.*, 1993). According to that criterion, research findings should be validated with participants to ensure a correct understanding of the world as they understand it. The second dimension, *transferability*, describes the applicability of findings beyond the specific context examined in research (da Mota Pedrosa *et al.*, 2012; Halldórsson and Aastrup, 2003). To ensure transferability, richness of detail is essential. For that reason, interviews performed for the thesis were repeated with several interviewees or conducted with multiple respondents. The third dimension is *dependability*, meaning the possibility of replicating the study and its findings (Guba and Lincoln, 1989) or at least their trackability (Erlandson *et al.*, 1993). Transferability can be ensured by keeping records of all phases of the research process and documentation of all methodological decisions (Halldórsson and Aastrup, 2003). To that end, the results of the research were presented at international conferences, and peers reviewed and discussed them with the author. Fourth and last, *confirmability* refers to the degree to which conclusions represent results and are free of bias on the part of the researcher (Halldórsson and Aastrup, 2003). For

the research presented here, confirmability was ensured by cross-checking the data and comparing the data with the current body of knowledge. Table 3.9 summarises the criteria for research quality and their application in the research.

Table 3.9: Research quality

Criteria	Meaning	Application
Credibility (internal validity)	Reality as a subjective construct	- Interview guides emerged from literature - Repeating semi-structured interviewees with several respondents; often with respondents from different organisations - Findings were validated by discussing them with study participants - Review of findings by participants - Validating interview data with observations from site visits - Triangulation of case-study data by analysing data from interviews, brainstorming, focus group and site visits - Validation of findings to theory
Transferability (external validity)	General application of findings	- Interviews with multiple respondents - Collected data presented in relation to context of collection - Multiple rounds of interviews - Case studies context emphasised to ensure transferability of findings - Richness of detail
Dependability (reliability)	Possible replication of study or trackability of methodological decisions	- Recording of all phases of the research process - Discussing methodological decisions with peers - Documentation of research process in terms of problem description, participant selection, notes keeping, interview transcripts, documentation and analysis decisions - Documentation of all methodological decisions - Using nodes for data analysis based on literature - Review of findings by peers
Confirmability (confirmability)	Findings represent the results	- Division of work and collaboration amongst co-authors - Discussion of findings with peers - Comparison of data within itself (triangulation with different data sources) - Comparison of data with literature - Discussing results with academia and industry representatives

3.5 Research process

The author's course of doctoral study commenced in late January 2015 and ended 5 years later in January 2020. During that time, the author was a member of two successive research projects funded by the Swedish Energy Agency. The first, "LESS: The Fifth Fuel – Energy Efficiency through Effective Freight Transport in Sustainable Urban Areas", focussed on energy efficiency in freight transport, foremost by utilising unused capacity. The second, "ELIN: Energy Efficiency of Logistics Services – Inside-Out", focussed on innovative, energy-efficient logistics services offered by LSPs to their customers. The research of this thesis was influenced by both projects.

All research that formed part of the author's licentiate thesis was also part of the LESS project, in which the author became involved in late January 2015 with the start of her doctoral study. The project and its corresponding research focussed on determining areas of unutilised capacity in logistics systems, how the potential of unutilised capacity can be released and other opportunities for increasing energy efficiency when system boundaries are extended. To build a foundation of knowledge, the first paper in the LESS project was a literature review. Dubbed "Paper 0", the paper was a conceptual one presented at a conference but not appended to this thesis. The paper served as way for the author to become familiar with logistics and road freight transport. Although the research began by focussing on capacity utilisation as a narrow concept in road freight

transport (i.e. simplified as fill rates), that perspective was extended to view capacity in the wider context of logistics, supported by a systems perspective. As a result, the idea of an interactive approach to capacity utilisation emerged.

The collection of empirical evidence commenced with Paper 1, which was developed in close connection with the LESS project. Therein, the author for the first time came into contact with representatives from the logistics industry, tested ideas, received feedback and collected data from interviews and site visits. Results from the paper indicate that great potential for energy improvement can especially be found in the last mile, which Paper 2 investigated in greater depth. The last mile was not only the scope for Paper 2 but also inspired the argument that structural characteristics are relevant to improving energy efficiency in logistics systems. The first three papers (Papers 0, 1 and 2) formed part of the licentiate thesis, which was presented in August 2017. Around that time, a book chapter was written, bringing together several of the previous results from Paper 0, 1 and 2 and work from other researchers. By contributing to a book chapter subjected to a peer review process, the author demonstrated an ability to publish in different outlets.

Overlapping the LESS project for a few months, the ELIN project started in summer 2017 and the author worked on collecting data for Paper 3 and, in turn, for Paper 4. Paper 3 closely relates to the research project's core on logistics services provided by LSPs that contribute to environmentally sustainable development. In Paper 3, the argument for the importance of logistics initiatives by LSPs was tested. Paper 4 picked up directly where Paper 2 ended, namely by transferring the problem of energy efficiency from the last mile to the first mile in order to explore how consumers and LSPs can together create a sustainable logistics service. The argument that implications for energy efficiency are generated at the provider–customer interface was established by studying the customer's role in the logistics service. For that purpose, contact with a municipality and WSP was established, and the author conducted several site visits as well as visits of the incineration plant in an effort to acquire more in-depth knowledge on waste collection and the involvement of all actors of the waste service triad. Last, Paper 5 was a continuation of that research, one that underscores the significance of investigating the concept of service in connection to energy efficiency in logistics systems. The investigation was made possible by applying the idea of service modularity in blueprinting the logistics service of household waste collection.

At all turns, the research process was grounded in practice and driven by the phenomenon being studied, first by viewing the system's overall characteristics and later focussing on the provider side and, in turn, the customer side of logistics services. The research process is depicted in Figure 3.9.

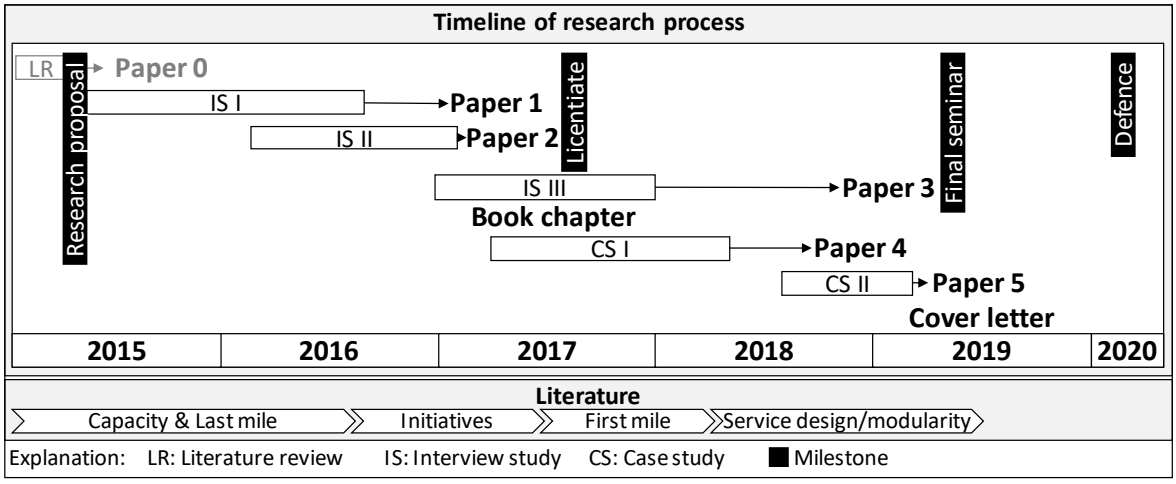


Figure 3.9: Research process

4 Summary of appended papers

This chapter summarises the five appended papers, discusses their contributions to the literature and presents the book chapter.

4.1 Paper 1: Energy efficiency in logistics: An interactive approach to capacity utilisation

4.1.1 Summary

Improving energy efficiency in road freight transport and adjacent logistics operations is crucial to environmental sustainability. The purpose of Paper 1 is to take an interactive approach to capacity utilisation, chiefly by identifying the causes of unutilised capacity and means of mitigating it, in order to contribute to sustainable freight transport and logistics.

As a result of conducting and analysing 17 semi-structured interviews with representatives of nine companies (i.e. five shippers, three LSPs and one expert in lean energy), the causes of underutilised capacity in road freight transport are mapped and structured in a framework. In turn, the paper suggests ways of overcoming the problem of high energy consumption and achieving energy efficiency. It does so by addressing underutilised capacity in terms of causes and countermeasures in three categories and pinpointing what (i.e. which activities) and who (i.e. which actors) cause underutilised capacity and where (i.e. which areas in logistics system). Means of mitigation derived from the data include, for example, visualising performance more clearly, educating different actors, managing expectations, standardising material handling and procedures, implementing off-peak delivery, planning, sharing information better and decelerating logistics operations.

4.1.2 Contributions

The paper contributes to the understanding of how energy efficiency in freight transport can be achieved in a broad, interactive system by identifying causes of underutilised capacity and means of mitigating it at different system levels. The theoretical contributions are threefold. First, it clarifies the importance of each component in an interlinked system by approaching capacity as an interactive system. Second, it presents a framework of system levels in which components can be vertically or horizontally aligned. Third, drawing from interviews with LSPs and shippers, the paper has been able to view the problem of energy inefficiency from multiple perspectives and, in that way, described a structure for logistics systems that is more conducive to energy efficiency.

The managerial contributions include an overview of the problem of low energy efficiency in logistics systems for logistics managers, one that elucidates how responsibilities cannot simply be shifted to other actors but that a holistic approach is needed. Furthermore, the paper conceptualises capacity utilisation and highlights the levels of logistics systems in terms of energy (in)efficiency that can help managers to assess energy efficiency in their logistics operation.

4.2 Paper 2: Last-mile logistics fulfilment: A framework for energy efficiency in the last mile

4.2.1 Summary

The transport of goods in the last mile—that is, before the goods arrive at the point of consumption—is the most energy-consuming logistics operation of supply chains. Paper 2 presents an array of last-mile fulfilment options and relates them to energy efficiency in terms of distribution structure, transport execution and household logistics capability. The paper's purpose

is to explore last-mile fulfilment options as they pertain to energy efficiency and in order to develop propositions for guiding energy-efficient last-mile fulfilment options. The last-mile fulfilment options analysed are conventional shopping, click and collect, pickup points, locker stations, home delivery and in-car delivery.

Empirical data were collected in 12 explorative, semi-structured interviews with Swedish retailers and their LSPs. The data were used to explore characteristics of the options' energy efficiency and map last-mile fulfilment options with their respective indicators of energy efficiency.

4.2.2 Contributions

The paper's contributions are fourfold. First, the paper complements the current body of knowledge on new and emerging last-mile fulfilment solutions that focus on energy efficiency. Second, the framework extends the system boundaries of energy efficiency from transport execution and distribution structure to include the logistics capability of households. Third, the paper considers an array of last-mile fulfilment options and stresses that improving energy efficiency has to focus on the interplay of the distribution structure, transport execution and the logistics capability of households. Fourth and last, the paper suggests approaching energy efficiency in light of different indicators, including the average distance a commercial vehicle has to travel to deliver a parcel, the vehicle's average fill rate, the average time needed to deliver a parcel and the average distance travelled by a private vehicle to fetch a parcel. In consideration of those indicators, the paper advises choosing between two strategies: speculation and postponement.

The findings suggest that integrating commercial and private transport in the last mile, namely by transporting goods with commercial vehicles in large quantities to a collection point, and completing the last mile by private transport other than cars are the most energy-efficient fulfilment options. The paper concludes by suggesting six propositions for energy efficiency in last-mile logistics fulfilment.

4.3 Paper 3: Environmental sustainability transition of LSPs through energy efficiency initiatives

4.3.1 Summary

The paper's purpose is to explore the transition of LSPs towards environmental sustainability by way of implementing energy efficiency initiatives based on a framework of sustainable development consisting of actions, internal processes (i.e. operations interface) and services (i.e. customer interface). To that end, the paper presents the initiatives of LSPs with a focus on energy efficiency understood as a means to achieve environmental sustainability.

Ten semi-structured interviews with managers from nine LSPs were conducted. The LSPs were purposefully selected according to their strong record in improving energy efficiency in their approaches to sustainable development. Results are illustrated with direct quotations from the interviewees about their organisations' actions, internal processes and services, and the transition of the LSPs towards environmental sustainability is presented with reference to a maturity model with five stages, at an early one of which LSPs are conceived to operate.

4.3.2 Contributions

The paper's contributions are twofold. First, the study seeks to capture formal as well as informal initiatives related to both internal operations (i.e. actions and internal processes) and the external market (i.e. services) by analysing the transition of LSPs towards environmental sustainability via energy efficiency in three dimensions: actions, processes and services. Second, by proposing a

maturity-oriented perspective on the transition of LSPs, the paper provides an approach to assessing LSPs and their transitions towards sustainability. Such transitions are conceived as occurring in stages through which LSPs evolve into higher states of maturity as they align their actions, internal processes and services with suppliers and customers.

From those contributions, managerial implications emerged that can help LSPs to evaluate their sustainability initiatives in a structured way and assess their maturation towards sustainability with reference to the maturity model.

4.4 Paper 4: Logistics service triad for household waste: Consumers as co-producers of sustainability

4.4.1 Summary

The paper's purpose is to explore the sustainability of waste supply chains in terms of the energy efficiency of first-mile waste collection systems and the quality of waste processed. The roles of actors in the waste service triad—that is, WSPs, municipalities and households—are investigated with a particular focus on households. By using a variety of techniques, data were collected from municipality officers, WSPs and households on 13 occasions, including brainstorming sessions, semi-structured interviews, site visits and a focus group, and supplemented with secondary data.

The findings reveal tension between the energy efficiency of waste collection logistics and the quality of waste. Households are co-producers of logistics services that provide important inputs in the form of sorting and moving waste as well as supplying raw materials into new cycles of goods circulating in logistics systems. The other members of the logistics service triad are municipalities, which act as regulators, and WSPs, which act as reverse LSPs.

4.4.2 Contributions

The theoretical contributions pertain to extending the waste service triad of household waste and viewing consumers as co-producers of logistics services. By considering waste as a resource and consumers as its suppliers, a new way to conceive logistics services for waste collection is provided. On top of that, the paper extends literature on first-mile logistics.

The practical implications include principles for policymakers and practitioners in evaluating the energy efficiency of waste management options in light of the quality of waste. Furthermore, the concepts of logistics services and quality of waste demonstrate the potential to provoke innovative thinking about how to involve consumers in resource recovery.

4.5 Paper 5: Energy efficiency in logistics through service modularity: The case of household waste

4.5.1 Summary

Service modularity promotes efficiency at the provider end of supply chains and customisation at the customer end. The purpose of Paper 5 is to investigate how logistics service modularity contributes to sustainable development by means of energy efficiency, as analysed in the case of logistics services for household waste collection.

Data were collected on 12 occasions, including brainstorming sessions and semi-structured interviews with representatives of a WSP and municipalities in Sweden, all of which focussed on several types of waste collection services. Five services investigated were mapped by using the service blueprint as a tool that differentiated the collection of food and residual waste at apartments and single-family houses as well as collection of gardening waste at one-family houses. With reference to service logic, the interviews focussed on how those services are

planned, developed, related to energy efficiency and offered to customers (i.e. private households), and the service modules and components were identified by blueprinting the services. The findings present different service modules, whether standardised or customised, and their contributions to sustainable development operationalised as energy efficiency.

4.5.2 Contributions

The theoretical contributions are threefold: First, linking service logic with service blueprints expands understandings of modular compositions of logistics services. Second, service blueprinting can be used as a hands-on tool to illustrate modular logistics services and to capture the intersections of modules. Third, service modularity can help to improve service provision in terms of energy efficiency and, with that, can contribute to environmental sustainability.

For managers, the findings offer insights into the applicability of blueprints to identify hotspots for improving energy efficiency in various modules of their organisations' service offerings. Furthermore, five principles for an energy-centric service design are proposed that can be useful for WSPs and municipalities when developing logistics services for waste collection.

4.6 Additional publication: Book chapter

Along with the five appended papers, a book chapter titled "Sustainable Supply Chains and Energy: Where 'Planet' Meets 'Profit'", was co-written with two authors (Halldórsson *et al.*, 2019b). The chapter is part of a peer-reviewed book titled *Handbook on the Sustainable Supply Chain* edited by J. Sarkis and published in May 2019. Due to copyright restrictions, the chapter is not appended to this thesis; however, the following paragraphs provide a summary of the chapter.

4.6.1 Summary

The book chapter conceptualises energy in supply chains as an economic driver and as an environmental performance, because energy in supply chains lies at the intersection of environmental sustainability and economic performance. In that light, energy can be directly related to two dimensions of the triple bottom line: profit and planet. Supply chains' underlying structures and strategic priorities are formative in how much and what type of energy is used in them. Actions towards energy efficiency can be taken on different system levels; however, developments in technology are not enough to improve energy efficiency in supply chains. Instead, changes are needed in supply chain activities such as transport and warehousing, actors' behaviours and supply chain design, all of which sets conditions for energy consumption.

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

4.6.2 Contributions

Because energy consumption in supply chains is directly influenced by the logistics situation, the causal relationship between their design and both the amount and type of energy has to be acknowledged. The chapter explains how to unleash the potential of energy efficiency by applying a systems perspective in consideration of four areas of improvement: freight capacity utilisation, sourcing and reverse logistics, mode of last-mile logistics fulfilment and closed-loop supply chains. In closing, the chapter also highlights the importance for logistics managers to move across system levels in order improve the energy efficiency in their supply chains.

5 Results

This chapter provides answers to the three research questions presented in Chapter 1.2, with reference to results based on the findings from the five appended papers.

5.1 RQ1: Characteristics

The first research question was designed to reveal structural characteristics relevant to improving energy efficiency in logistics systems. In this thesis, the three major structural characteristics analysed are system levels, the design of fulfilment options and actors involved in both of those structural features. Herein, Chapter 5.1.1 presents system levels at which improvements in energy efficiency, operationalised as capacity utilisation, are possible. Next, Chapter 5.1.2 examines the structural characteristics in greater depth as well as the consumer's role in contributing energy efficiency in logistics. Chapter 5.1.3 focusses on the consumer's role in the first-mile of logistics fulfilment in particular, after which the sub-chapter ends by synthesising all of the findings to answer RQ1.

5.1.1 System levels

The potential for improving energy efficiency can be found on different levels of logistics systems. A model of those levels emerged while developing Paper 1 and is introduced in the book chapter, which lays out a similar model.

During the collection of empirical evidence, interviewees were asked how capacity utilisation can be achieved in light of the difficulty of measuring energy efficiency (see Chapter 5.1.4). Thinking in terms of capacity utilisation served to simplify energy efficiency for the interviewees, who otherwise primarily discussed technological advancements in their fleets. Clearly, viewing capacity on different system levels and coordinating efforts across them can facilitate the improvement of energy efficiency. The development of the mentioned model was inspired by the work of McKinnon and Bilski (2014) and McKinnon (2016a), and the levels therein were validated with empirical evidence, namely interviewees' indications of the levels on which they operate and how they approach possible ways of improving energy efficiency there. Figure 5.1 illustrates the different levels at which capacity may be better utilised and categorises them into activities, actors and areas identified in this thesis. However, the list of levels is not exhaustive, and other levels could be added.

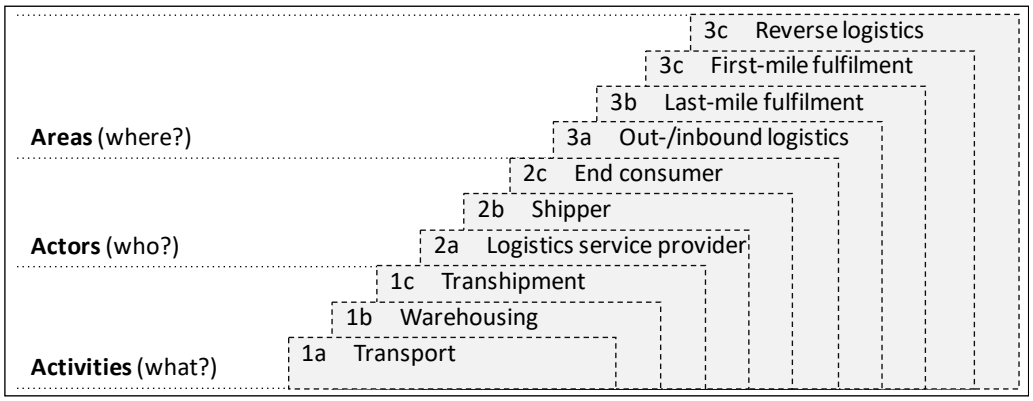


Figure 5.1: System levels in logistics, adapted from Wehner (2018)

Activities. In the category of activities, capacity in transport (i.e. Level 1a) depends upon 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 packaging, because reduced packaging requires fewer

vehicles (Kalenoja *et al.*, 2011; Wu and Dunn, 1995). Capacity in warehousing (i.e. Level 1b), by contrast, is affected by the filling of boxes and their arrangement on pallets, whereas in transhipment (i.e. Level 1c), it depend upon the ability for goods to be loaded and received as well as the adaptability of time slots. Capacity (under)utilisation on those two levels became apparent during the visit to a retailer's terminal in the relationship between the components of the warehouse, boxes and trucks, particularly in the way in which products were stacked on pallets, which affects all subsequent logistics activities. In that context, the retailer stated that when the boxes stacked on pallets were not filled completely, every 1 cm of unused capacity meant an additional cost of 1 million Swedish krona in transport activities per year.

Actors. In the category of actors, capacity is influenced by the intensity of the collaboration not only of LSPs (i.e. Level 2a) but also with other actors in supply chains with whom know-how and expertise may be shared (Plambeck, 2012). At the same time, shippers (i.e. Level 2b) who purchase logistics services set demands (e.g. delivery windows and lead times) for LSPs. Additional demands are set by end consumers (i.e. Level 2c), who may require express deliveries, a steady supply of goods and low prices, as stressed several times during interviews. However, interviewees also emphasised that reduced energy consumption in transport does not always lead to reduced total costs, because other drivers of cost are far more crucial, including human resources, products and equipment. The multiplicity of actors—in many cases, even more than three—calls for taking a multi-actor approach, an approach that was followed when conducting the research leading up to the thesis.

Areas. The system levels in the category of areas indicate potential for improving capacity utilisation along the entire supply chain, including in out- and inbound logistics (i.e. Level 3a), when a holistic view is applied (Bottani *et al.*, 2014; Kalenoja *et al.*, 2011). One potential means of improvement is decelerating logistics operations (McKinnon, 2016b), even if it stands in direct contrast with just-in-time principles often applied today. Last-mile fulfilment (i.e. Level 3b) and first-mile fulfilment (i.e. Level 3c), which cover certain segments of supply chains, are also highlighted given their reliance on highly energy-intensive transport, often by private vehicles, and low fill rates. Several interviewees pointed out that although e-commerce and the home delivery of goods remain very energy-intensive fulfilment solutions, the increased use of electric vehicles, denser delivery nets and the high fill rates of delivery trucks make that leg more energy-efficient than having consumers transport the products. Amongst other levels, reverse logistics (i.e. Level 3d) also showcases significant potential for improving energy efficiency.

To locate where improvement is possible in logistics systems, it is first necessary to discuss energy efficiency at and across the various systems levels in relation to activities, actors and areas. However, during the collection of empirical evidence, the difficulty to measuring energy efficiency was often elaborated upon, as well as how it had prompted the exploration of capacity utilisation.

5.1.2 Characteristics of last-mile fulfilment options and the consumer's role

Since distribution in the last mile is exceptionally energy-intensive due to low fill rates, the use of private vehicles and the vast number of stops, that leg of supply chains shows exceptional potential for improving energy efficiency. Paper 2 analyses that potential in detail and advocates a framework for energy efficiency in last-mile logistics, understood in terms of three building blocks: (A) distribution structure, (B) transport execution and (C) household logistics capability (see Figure 5.2).

For one, the downstream part of supply chains presents an array of distribution structures that differ regarding a shipment's origin (e.g. distribution centre, terminal or store), destination (e.g.

store or other collection point) and the attributes of the delivery process (e.g. speed and flexibility). By comparison, transport execution is characterised by how the transport of goods is executed and can be divided into private and commercial transport. As mentioned, the framework especially emphasises the logistics capability of households, which assigns the end consumer a particular role in the logistics system other than that of a mere receiver of goods. The paper also takes into account different strategies that can be followed when goods are distributed, all based on the postponement and speculation strategies devised by Pagh and Cooper (1998). By including that third building block in strategies for assessing the energy efficiency of last-mile logistics fulfilment, the system boundaries can be extended from the distribution structure and transport execution to also include the logistics capabilities of households. Along with the distribution structure, such capabilities impose conditions for energy consumption in logistics, even if the transportation execution continues to represent the immediate energy-consuming activity.

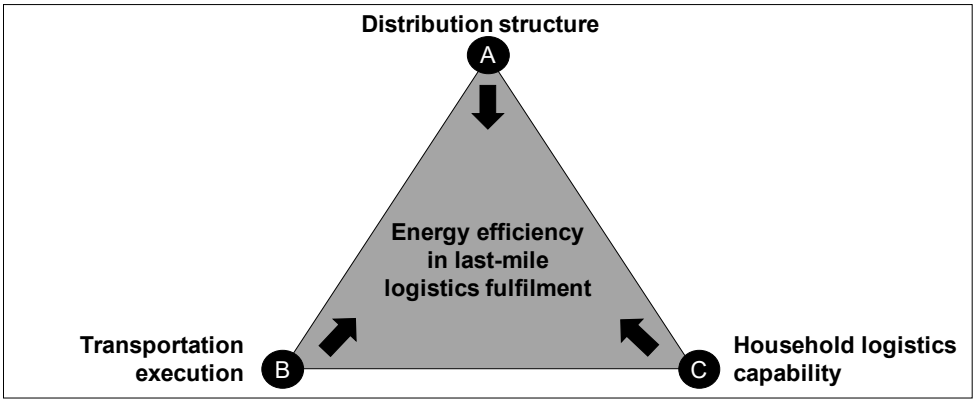


Figure 5.2: Approach to energy efficiency in last-mile logistics fulfilment (Halldórsson and Wehner, 2017)

Distribution structure. The distribution structure is characterised by the physical points of the logistics system, the distances that need to be driven or overcome and time. The physical points of a distribution structure (e.g. distribution centres, retail shops and pickup points) set the layout of the system and directly determine distances that need to be driven by commercial and private vehicles. Depending of where those points are placed, they can promote the use of private cars or modes such as walking or biking to provide last-mile transport. Time, typically in terms of hours of operation and delivery windows, also affects energy efficiency. For example, delivery windows that are missed can require additional delivery attempts that unnecessarily expend energy.

Transport execution. Transport execution describes the logistics activity performed to move goods within a logistics system. Involving either commercial or private means of transport, it means that energy efficiency is directly affected by, for example, vehicle fill rates, routing and congestion.

Household logistics capability. The logistics capability of households is described as the end consumer's engagement and ability in last-mile fulfilment by actively collecting goods at a pickup point or store, passively receiving goods via home delivery or engaging in a hybrid form of those active and passive roles. Even in the passive role, however, the end consumer necessarily acts as a co-producer of the final logistics service. The ability to collect and receive goods poses implications for energy efficiency. Altogether, the term *household logistics capability* means the allocation of skills, involvement and resources at the household end of supply chains in order to perform logistics activities.

To investigate energy efficiency in the last mile, different last-mile fulfilment options were mapped and compared, and interviewees were asked to rank the options in relation to energy efficiency. Whether consumers pick up their products or receive them via home delivery, transport activities in the last leg of the supply chain are extremely energy-intensive. Therefore, the interviewees were asked what changes could improve the energy efficiency of last-mile logistics. One example given was that home deliveries could be developed or expanded, which would in turn create a tighter delivery net, higher fill rates in delivery vehicles and more efficient route planning. Beyond that, private vehicles would no longer be needed for shopping trips and might even become redundant. Although such changes would require more commercial freight transport, it could boost energy efficiency by reducing private transport. Another example raised by several interviewees in reference to the distribution structure was changing the set-up of pickup points. At present, such points belong to one LSP; however, by creating points independent of LSPs, the pickup net could be denser, which would enable end consumers to walk more often and, in turn, curb their use of private cars. Depending on the outcome sought, an LSP can choose a strategy that allows configuring where in the logistics system the customer order is received, the delivery time and the location of distribution centres and customer interaction points.

Briefly put, and as presented in the book chapter, energy efficiency in the last mile can be enhanced by affording distribution fulfilment options that improve the use of freight transport capacity, using transport modes powered by renewable energies, reducing or avoiding failed deliveries and actively engaging customers in the fulfilment of goods distribution by introducing a tight net of pickup points. At the same time, end consumers, who often overlook the environmental impacts of transport when ordering products, need to greater awareness of and better education about those impacts. Increased sensitivity to the topic could alter their behaviour and, in turn, reduce their demand for express deliveries and allow more regional or national sourced products with shorter transport distances. In the next chapter, the consumer's role is investigated further, albeit in the context of first-mile logistics fulfilment.

5.1.3 Consumer's role in the first mile

The consumer's role in the first mile bears many similarities to the end consumer's role in the last mile. However, as explained in Paper 4, consumers and households are viewed as co-producers of value in the first mile of household waste collection, in which they contribute to the overall sustainability of the system depending upon their sorting and moving activities. By flipping the traditional role of the end consumer, the consumer becomes a supplier of a new raw material: household waste. In addition, the results from Paper 4 indicate that the sorting and moving activities executed by households in the first mile exert great influence upon the sustainability of the waste supply chain.

Viewing the consumer's role in a triadic relationship contributes to the understanding of the relationships amongst actors within logistics systems. As a reminder, the actors in any network cannot be viewed in isolation, and the triad is the smallest unit of analysis (Larson and Gammelgaard, 2001). In that relationship, *co-production* refers to practices such as developing or designing offerings together (Grönroos, 2011; Payne *et al.*, 2008). Considering that value creation can be facilitated by the user only, co-production can only be a sub-process of value co-creation (Kohtamäki and Rajala, 2016) wherein different actors collaborate and participate in creating value in a business network system (Grönroos, 2008, 2011; Vargo and Lusch, 2011). Taken together, co-production is thus the collaboration of actors within a system to develop potential value (Grönroos, 2011).

In the context of waste collection, households are viewed as suppliers of waste and, together with WSPs and municipalities, integrate their resources to co-produce the potential value of recycled

materials for different users. By co-producing logistics services for the effective sorting and moving of waste, consumers provide inputs for improved energy efficiency in logistics as well as for the improved quality of waste. The real value of those materials is defined by the industrial producers, who operate as the final customers of recycled raw materials.

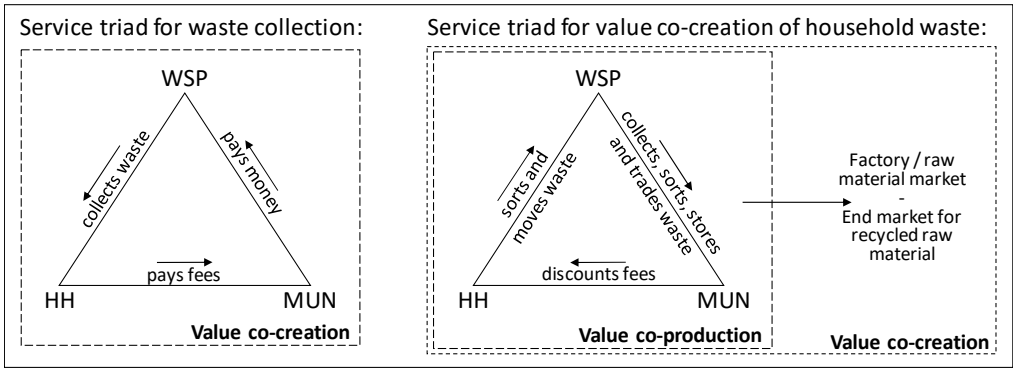


Figure 5.3: Household's role in value co-production and co-creation (Halldórsson *et al.*, 2019a)
[Note. HH = Household, MUN = Municipality, WSP = Waste service provider.]

Households are depicted as traditional consumers of waste collection services. In the traditional service triad, in which waste collection is provided by municipalities (Figure *5.3*, left triad), households generate value for themselves by disposing the waste in predefined areas. Perhaps needless to say, the sought outcome of that process is the disposal of waste. By contrast, the extended logistics service triad for household waste (Figure 5.2, right triad) depicts the co-creation of value, specifically use value for other actors. Those same actors operate within the triad, albeit in different roles. The household becomes the supplier of a raw material to the industry (Blackburn *et al.*, 2004), the WSP becomes the buyer's agent and collects the waste for further processing, and the municipality becomes the buyer of goods.

In the supplier role, households no longer create value alone. On the contrary, in a reversed supply chain, households are suppliers that can enable the co-production of value. Such findings add to what A-Jalil *et al.* (2016) found: that between forward and reverse logistics exists a pivot point at which households become first-tier suppliers and local authorities such as municipalities become first-tier customers. In that sense, the study conducted for the thesis answers the call to explore how the relationship between households and local authorities evolves, namely by analysing the interaction in the first mile of waste logistics systems from a triadic perspective.

5.1.4 Synthesis

To answer RQ1 (i.e. What structural characteristics are relevant to improving energy efficiency in logistics systems?), several characteristics of logistics systems have been highlighted.

From a systems perspective, the system levels developed in Paper 1 can help to depict such systems. Originally, the system levels proved useful in categorising the potential for improving energy efficiency, operationalised as capacity utilisation. By virtue of the research for the thesis, they also contribute to the understanding how such efficiency can be improved. Hence, the system levels help to clarify what and who can improve energy efficiency as well as where doing so is possible within logistics systems.

Referring to Romme (2003), who suggested creating knowledge by producing new systems or new states of existing systems, developing current logistics systems with an eye for energy efficiency by re-evaluating the (end-)consumer's role suggests one such new system. The new role is characterised by the structure of the logistics system, in which the consumer interacts with

the network in logistics fulfilment, and the complexity of the household's engagement in that process.

For one, the structure in which consumers interact with a logistics network can be diverse. In this investigation into last- and first-mile logistics fulfilment, it became clear that, depending upon the distribution structure, the transported product changed, for example, from an ordered product to household waste. The framework developed for Paper 2 helped to highlight the structure of logistics systems in terms of three buildings blocks (i.e. distribution structure, transport execution and household logistics capability). The complexity of a household's engagement in that fulfilment process can be visualised as occurring within the service triad. In Paper 4, the household's role in connection with other actors in the logistics fulfilment while co-creating value was also highlighted.

However, a few major difficulties emerge when working with energy efficiency in logistics systems, especially in relation to measuring it, as occurred while empirical data for Interview Study I were collected. They included difficulties with collecting suitable data, with the multiplicity of indicators collected and with defining system boundaries.

Collection of suitable data. First, many interviewees reported experiencing difficulties in their companies with collecting or receiving suitable data, if not both. Numbers had been rounded or based on assumptions, including certain fuel consumption for a given distance, and standard values had been applied. Therefore, calculations of consumed energy are far from exact.

Multiplicity of indicators. Second, when energy efficiency is assessed according to the consumption of fossil fuels, difficulties arise owing to the variety of types of fuel. In response, a unit of energy needs to be calculated. In addition, companies prefer measuring the output of CO_2 emissions instead the input of energy. As one interviewee pointed out, however, CO_2 emissions are not comparable between different LSPs. Furthermore, another indicator used by companies to track energy efficiency is costs for transport, which is done in the belief that lower costs for freight transport coincide with lower emissions (Aronsson and Huge-Brodin, 2006) and lower energy use. However, in many cases, the cost driver for logistics services is not the energy consumed but employees' salaries, product costs and the costs of equipment used.

Definition of system boundaries. Third, companies have difficulty defining the boundaries of the systems in which they operate and in mapping all of the transport activities connected to their business. Supply chains are complex, and all up- and downstream transport activities are rarely considered. The sheer number of sub-contractors makes it difficult to keep track of the energy consumed, and even if companies adapt partly to the Greenhouse Gas Protocol and attempt to follow up on their emissions from Scope 1, 2 and 3, they are not always able to.

All three difficulties with measuring energy efficiency imply that, even if companies have an agenda for improving energy efficiency, they are often unable to assess possible improvements because they cannot measure it. As a solution, a standardised approach with more exact data is needed so that results can be compared between companies. If a standard rating system for energy consumption or GHG emissions in transport were established, then shippers could use the results when choosing a LSP, which could increase competition to lower energy consumption and to boost energy efficiency.

In short, the answer to the first research question is that the structural characteristics relevant to improving energy efficiency in logistics systems with focus on and around the point of consumption are system levels, the design of fulfilment structures, as in the case for last-mile fulfilment options, and actors involved in those different structural features. On the various system levels, energy efficiency has to be improved in relation to actors, activities and areas. To that end,

a systems perspective needs to be taken when evaluating improvement potential, and a standardised approach to measure energy efficiency improvement is necessary for practitioners to follow up on their improvement. Moreover, because the design of fulfilment structures around the point of consumption is characterised in terms of distribution structure, transport execution and household logistics capability, the end consumer's role needs to be re-evaluated.

5.2 RQ2: Initiatives

Once the structural characteristics relevant to improving the energy efficiency of logistics systems were mapped, the second research question could be addressed, which focussed on how improvement initiatives by providers can enable energy efficiency in such systems. Chapter 5.2.1 summarises the causes of underutilised capacity and proposes mitigation strategies in response, after which Chapter 5.2.2 discusses the initiatives of LSPs towards environmentally sustainable development. Next, the different stages of an LSP's maturation into achieving environmentally sustainable operations are illustrated in Chapter 5.2.3, after which the chapter ends by presenting a synthesis of findings used to answer RQ2.

5.2.1 Causes of underutilised capacity and means of mitigation

One of the most basic logistics activities provided by LSPs is transport. One way of improving the energy efficiency of transport is by improving capacity utilisation, which thus served as the topic of Interview Study I. The empirical data collected from LSPs and shippers revealed that underutilised capacity can be found in three categories. The causes were sorted according to the categories of system levels, because they explain who (i.e. which actor) and what (i.e. which activity) create underutilised capacity and where (i.e. which area in logistics systems) it is created and their subcategories. Derived from the findings of Paper 1, the causes of underutilised capacity and means of mitigation are summarised in Table 5.1. Empirical evidence also factored into answering the first research question by validating the system levels with examples.

Table 5.1: Causes of underutilised capacity and means of mitigation, adapted from Wehner (2018)

Category	Sub-category	Causes	Means of mitigation	Empirical evidence
Activity	Transport	Product characteristics and fit in vehicle Labour regulations Redundant air transport and shipping of hanging garments that lower fill rates Delivery peaks during mornings and afternoons (i.e. rush hours) Last-minute changes in routing due to express deliveries High volumes of parcels needed to fill the system that are taken from more energy-efficient systems Imbalances in volume flow and empty running	Avoid peak deliveries (e.g. incentivise delivery during off-peak times) Ensure efficient routing Track real-time need for transport Consolidate and combine heavy, low-volume products with lightweight, high-volume ones Receive fewer but fuller trucks Utilise the full height of trucks (e.g. double-stack pallets)	Capacity utilisation of a single box is influenced by the size and type of products and operations in the terminal. The boxes in which goods are carried need to be designed in cooperation with several actors in the supply chain so that the goods fit well in the boxes, the boxes fit well on pallets, and a certain number of pallets fill one truck entirely. Capacity utilisation of a truck depends upon the volume and weight of products and where the delivery stops are located (i.e. density and distance). Capacity utilisation in stores depends upon how often new products are delivered and whether the boxes are foldable so that they are smaller when emptied and returned.
	Warehousing	Human error during order picking Automation and standardisation that cause inflexibility Dysfunctional information technology	Standardise foldable and stackable boxes Label and pack products arriving at distribution centres in advance Devise alternatives to hanging garments	

			Reduce picking errors Change product designs and sizes to better fit pallets	Route planning for home deliveries provides exact delivery times. In terminals, when employees pack goods for customers, a program calculates how many products (i.e. by weight and volume) need to fit in one transport unit. Allocation of products and replenishments to stores is performed.
	Transhipment	Difficulty with sharing distribution capacity amongst shippers Limited internal and external information sharing Rules set by stronger actors and divergent interests Prohibited collaboration (i.e. anti-competition law) of larger logistics service providers (LSPs)	Order necessary volumes only Use platform and information technology to support internal and external information flows Concentrate all logistics-related knowledge in one division instead of spreading it across several divisions Use an online marketplace to sell or buy free capacity Encourage collaboration (e.g. petition the political system)	
Actor	**Logistics service provider**	Over-delivery of services Incorrect price setting and pricing model unaligned with real costs (e.g. rounded prices and "free" home deliveries) Priorities to fulfil customer demands that prompt compromises and the adaption of logistics processes A broad range of services that is uncompetitive with niche actors Responsibilities for fill rates delegated to transport providers Inflexibility with mixing certain shipments	Outsource transport from retailers to LSPs Use the same transport operator for several shippers (i.e. economies of scale) Handle bookings electronically Use electric cars for distribution in urban areas	Products from different shippers are consolidated on one truck. Dedicated roles for end consumers in last-mile logistics fulfilment can be applied. Responsibility for tracking deliveries of products and being at home to receive them can be delegated to end consumers, because mobile phone apps allow the tracking of goods.
	Shipper	Narrow delivery and pickup time frames for LSPs Requirements, inflexibility and lack of compromise Demand to receive goods early and post late Over-ordering capacity	Report all emissions and follow-up Expand flexibility in delivery time frames Set clear requirements early on (i.e. in the tendering process)	
	End consumer	Lack of awareness of consequences of own behaviour Lack of information on transport's GHG footprint Sales campaigns with free shipping and sending along retour papers Increased demand for express deliveries and returns of goods High expectations for narrow time frames for home deliveries	Educate end consumers on the consequences of their behaviour Communicate CO_2 footprint of transport to end consumers Make transport costs visible to end consumers	
Area	**Out-/inbound logistics**	Increased demand for short lead times (i.e. just-in-time) High energy consumption due to many small shipments (i.e. no economies of scale)	Decrease demand for short lead times and high speeds Only deliver just-in-time when truly necessary	Capacity utilisation in terminals depends upon the type of product and the process characteristics (e.g. automation, technology, standardisation, time constraints and return policies).

	Last mile	Increased number of small shipments instead of full pallets Standardised boxes often larger than necessary High failure rate of home deliveries	Use better-fitting packaging to avoid air transport Disconnect deliverers and end consumers Use tracking systems for end consumers Extend time frames depending upon proximity to distribution centres Avoid one hub in the supply chain	The trunk of a car can be used for delivery and as a pickup point. Capacity utilisation during the return flow is influenced by whether and, if so, how boxes can be folded and stacked and upon the number of returned products.
	Reverse logistics	Reverse logistics poorly integrated in flow to end consumers Unprofitable returns	Price products to better reflect costs Re-shelve returned products from e-commerce instead of returning them to manufacturers	

To explain how the causes of underutilised capacity can be mitigated on different system levels, a framework (see Figure 5.4) was developed for Paper 1 that tied system levels, causes and mitigation together. Their relationships can be illustrated with an example from the empirical data, in which products are revealed to have been designed so that they fill transport boxes completely. In turn, the boxes are designed so that they fit perfectly on a pallet that, when double-stacked, fills the height of a truck and, with three other pallets next to it, the width as well. The truck arrives during predefined time slots at the warehouse, where a certain number of workers are prepared to further handle the load. In short, the example highlights the interactive nature of capacity utilisation.

A limitation of the framework, however, lies within the non-illustration of the interconnectedness of different causes and countermeasures. By countering one cause, another cause or even several other causes will likely be affected, either positively or negatively, because all of the causes and countermeasures are connected within a system.

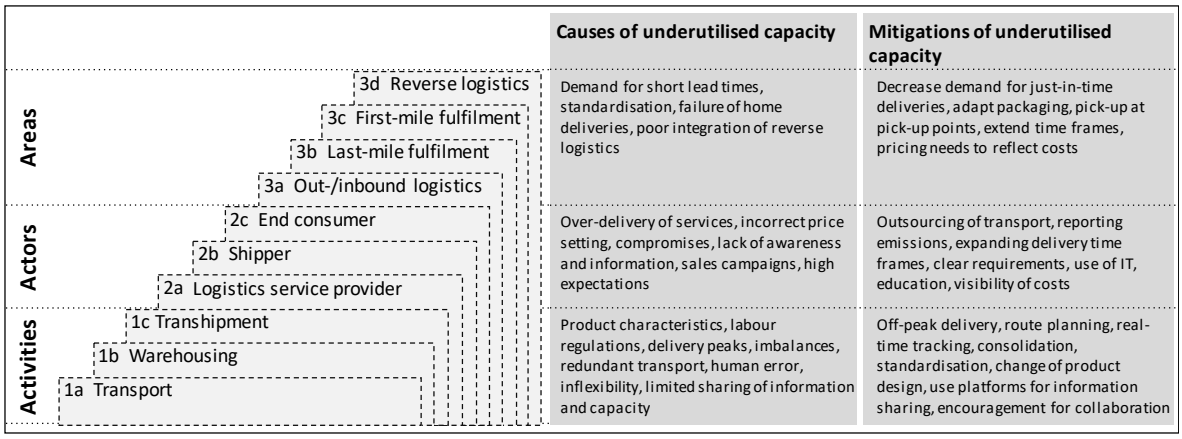


Figure 5.4: Framework of causes of underutilised capacity and means of mitigation (Wehner, 2018)

In brief, utilising capacity in freight transport is one initiative taken by LSPs, particularly in one of the most energy-intensive logistics activities, to improve energy efficiency in logistics systems.

5.2.2 Initiatives of LSPs towards environmentally sustainable development

Findings from Paper 3 shed light on the sustainable development process of LSPs from the standpoint of energy efficiency. To investigate initiatives taken by LSPs to that end, efforts towards energy efficiency in the form of actions, processes and services were scrutinised (see

Figure 5.5). In that sense, actions are general efforts taken by LSPs, processes describe a series of internal efforts, and services are rendered at the provider–customer interface.

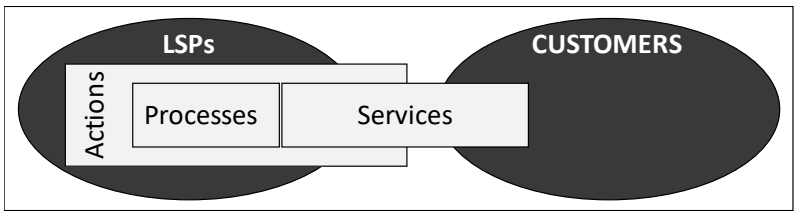


Figure 5.5: Actions, processes and services engaged in by logistics service providers (LSPs)

Actions. Representing simple, individual efforts made by a company, actions are aimed at improving the energy efficiency of LSPs' sustainable development processes. Because actions support and even enable processes, services or both, they can initiate sustainable development processes. For instance, actions related to investments in ICT facilitate both environmental performance measurement processes and carbon calculation services. However, a grey zone also exists between the conceptualisation of actions and processes for LSPs. Some actions are ad hoc and undertaken independently from processes, whereas others are embedded in existing processes.

Processes. Formal processes for energy efficiency represent a series of internal efforts and are defined by LSPs by establishing routines, designating owners of the processes and utilising certain resources to produce outputs of energy efficiency. Although the logistics industry has recently begun following regulations on energy mapping in transport introduced by Swedish law in 2014, findings show that most energy-mapping processes have been implemented only for buildings and facilities, not for transport. The logistics industry thus lags behind in implementing processes geared towards energy efficiency, as is especially apparent compared to the manufacturing industry, for example. In response, customer demand for improvement in the energy efficiency of logistics could drive the implementation of processes, although they are not sufficiently advocated at present.

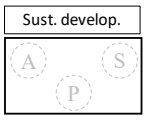
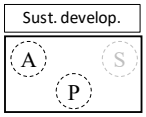
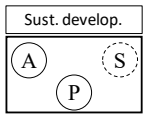
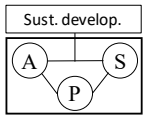
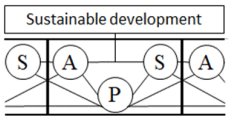
Services. Energy-efficient logistics services for sustainable development are rendered at the provider–customer interface. Services can be initiated in response to customer demand, although services such as the provision of emission reports are hardly in great demand by customers. The provision of reverse logistics services to recover energy from both reverse flows and material being transported could therefore be one service towards achieving sustainable development.

To help LSPs to mature into environmentally sustainable organisations through processes, services and actions directed at improving their energy efficiency, a sustainability maturity model is proposed in the next sub-chapter.

5.2.3 Maturity of LSPs

A sustainability maturity model for LSPs that adopts a gradual approach towards sustainable development in five stages has been proposed in Paper 3: (0) initial, (1) ad hoc, (2) managed in isolation, (3) internal institutionalisation and (4) external institutionalisation. Table 5.2 depicts how those stages of maturity affect the dimensions of actions, processes and services.

Table 5.2: Maturity model for developing the sustainability of LSPs, adapted from Wehner *et al.* (2019b)

Stage of maturity	Actions	Processes	Services	Illustration
(0) Initial	No formally defined actions	No formally defined internal processes for sustainability	Not emphasised in the market offerings	
(1) Ad hoc	Basic, infrequent actions by top management	A few compliance-oriented processes driven by regulations	Not emphasised in the market offerings	
(2) Managed in isolation	Individual projects at various units No coordination	Fragmented processes at unit level No integration	Incremental service line other than conventional logistics services	
(3) Internal institutionali-sation	Regular sustainability projects across the organisation	Scaling up to the organisational level	Customer benefits from LSP operations that incorporate sustainability	
(4) External institutionali-sation	Collaboration with industry, suppliers and subcontractors for sustainability-related actions	Scaling up to the business model Alignment of processes with suppliers and customers	Sustainability as an offering extended to customers' processes via collaborative service innovation and customisation	

Note. A = Actions, P = Processes, S = Services.

At the initial stage (i.e. Stage 0), no actions, processes or services for sustainability are observed, companies are uninterested in tracking their energy consumption, and energy performance is not measured. At the ad hoc stage (i.e. Stage 1), some compliance and conformity with regulations occur, and initial processes are set in motion. Although minor sustainability-oriented initiatives are taken by the companies, data collection is not continuous, and key performance indicators are vaguely defined. An attempt for certification by the management system may be made, but a supporting process remains missing. In the next stage, management in isolation (i.e. Stage 2), some actions, processes and services are taken, albeit mostly in isolation, and no integration is apparent. Initiatives are mostly driven by the management unit. By contrast, in the internal institutionalisation stage (i.e. Stage 3), initiatives are scaled up to the organisational level, and collaboration between different units is achieved. Energy mapping is conducted according to an integrative approach that highlights the energy efficiency of internal operations. In the final stage of external institutionalisation (i.e. Stage 4), the organisation works within its network of stakeholders to produce, deliver and receive environmental sustainability value. At that stage, LSPs undertake new sustainability actions and work together with suppliers, customers and subcontractors to align sustainable processes and develop new sustainable services. As revealed by the empirical evidence, the companies sampled were predominately operating at Stages 1 and 2.

5.2.4 Synthesis

To answer RQ2 (i.e. "How do logistics initiatives taken by logistics service providers improve energy efficiency in logistics systems?"), initiatives were examined and stages of maturity stages of LSPs proposed. As a result, the maturity model for the sustainable development of LSPs in five stages, explaining how LSPs work with actions, processes and services in isolation, should be followed until those initiatives align with the processes of suppliers and customers.

Viewed from a systems perspective, a list of initiatives towards improving capacity utilisation (see Chapter 5.2.1), together with findings from Paper 1 about system levels (see Chapter 5.1.1) and findings from Paper 2 about the characteristics of logistics fulfilment (see Chapter 5.1.2), the results show that all initiatives need to be taken across all system levels and between different actors to enable energy efficiency in logistics systems. To the same end, LSPs should work towards achieving maturity at Stage 3 (i.e. internal institutionalisation) or Stage 4 (i.e. external institutionalisation). Otherwise, improvement-oriented initiatives taken in isolation can even decrease energy efficiency. For example, high fill rates and high capacity utilisation can precipitate higher returns if goods are shipped only to utilise capacity or to maintain a high level of service but not needed by customers and ultimately returned. Thus, it is pivotal to view initiatives in logistics systems as interacting with their environments.

5.3 RQ3: Services

The third research question sought an answer to how logistics services can enable energy efficiency in logistics systems. In what follows, Chapter 5.3.1 discusses the nature of services, after which Chapter 5.3.2 presents findings about the co-creation of logistics services. Last, Chapter 5.3.3 synthesises the findings in order to answer RQ3.

5.3.1 Nature of logistics services

To answer RQ3, the nature of logistics services needed to be understood first. Using waste collection as case, such services were broken down into their components and modules by way of service blueprinting (see Appendix A for the service blueprints for all five services). As a result, the findings for Paper 5 were threefold.

First, by illustrating different services with the help of service blueprinting, the research revealed service modules and components showing which parts of the service most affect energy efficiency and how a change in one module can influence the energy efficiency of other modules due to their interface. In the illustration of a service, it is possible to identify how modules relate to each other and at which points in the system energy efficiency can be achieved. The breakdown of components via service blueprinting allowed a clearer understanding of the energy-consuming parts of logistics services and how improving energy efficiency as a means of sustainable development can be achieved by modifying individual components while continuing to observe a holistic perspective of the potential implications for other components of the service. All told, service blueprinting provided in-depth information about the nature of the services examined.

Second, comparing the five service offerings revealed how logistics services can be designed to be more energy-efficient. The investigated services in Paper 5 were all logistics services for collecting food, residual waste and gardening waste in the first mile in apartment buildings and one-family houses. A comparison of those service offerings helps to highlight standardised and customised service modules that allow for similarity and variety in the service. For example, standardised components are exchanged depending upon the customer group, and standardisation can be achieved between customer groups and offerings. A comparison of service offerings within the customer group showed changes regarding different waste fractions. As shown, most components and modules remained unchanged or else copied one to one, whereas others had been adapted.

Third, connecting the provider side of logistics system with the customer side provided evidence of the dual role of the customer–consumer in service production. Individual households influence the service by taking co-production and consumption actions (e.g. sorting) and their consumption frequency.

In short, a service is provided at the provider–customer interface, and the tool of service blueprinting and the concept of service modularity can help to understand the nature of the service. The dual role of the customer–consumer is further investigated in the following sub-chapter, which sheds light on the co-creation sphere of providers and customers.

5.3.2 Co-creation of logistics services

In Papers 4 and 5, value co-production is investigated in the context of logistics services for waste collection. The fundamental premises of service logic (see Table 2.1) hold that all parties in service interactions are resource integrators and that value is always defined by the beneficiary (Grönroos, 2011; Vargo and Lusch, 2004). Consequently, it is impossible for other market actors to define or create value unless the final customer uses the value proposition and defines the value from his or her experience with using the service.

Allocated with a new role for the household, as developed in Paper 4, the consumer becomes a *prosumer*, a term that describes households' participation in consumption and production of services co-created with companies (Halassi *et al.*, 2018), here applied in the reversed supply chain. Last, changes in social roles with respect to the generation of use value versus exchange value proposes an alternative approach to the first mile of waste supply chains.

Although the service is co-created between customers and providers, the blueprint delineates which components operate within the co-creation sphere and which operate within the customer or provider sphere. That distinction aligns the value-creation spheres composed by the provider versus the customer and the one shared—that is, service logic (Grönroos and Voima, 2013). The provider sphere spans the support processes as well as invisible employee actions and contributes to potential value formation and the facilitation of value creation by customers. The joint sphere includes components at the point of visible contact between customers and providers. Last, the customer sphere includes the consumer action and physical evidence. It bears mentioning, however, that the spheres are dynamic and can extend both ways, depending upon the extent of the interaction involve the service process. That circumstance highlights the importance of behavioural change amongst the actors.

Paper 5 proposes five principles for an energy-centric design of logistics services, all of which are presented in Figure 5.6. Those principles can help to guide the design of a logistics service that enables energy efficiency in logistics services at the provider–customer interface.

Principles for an energy-centric design of logistics services	
Energy as a resource	In modular logistics service design, modules, where energy use could be combined, are used to provide customised services in a more energy-efficient manner.
Energy efficiency at provider-customer interface	Energy-centric service design should include both the provider and customer.
Energy efficiency through service blueprinting	It is vital to visualise the whole service process, including invisible actions and back office activities, to see where improvement potential of energy efficiency is available.
Energy efficiency through convenience	Visualisation of the customer–provider interface helps to illustrate both energy-efficient and convenient actions of customers that can be duplicated in another service offering.
Energy efficiency in line with customisation	Providing a modular logistics service where customers can combine different components to form their customised environmentally friendly service package, yet constituted of standardised components, can improve the overall energy efficiency of logistics services and customer satisfaction.

Figure 5.6: Principles for an energy-centric design of logistics services (Wehner et al., 2019a)

5.3.3 Synthesis

To answer RQ3 (i.e. How do logistics services improve energy efficiency in logistics systems?), the nature of a logistics service and the co-creation of logistics services that acknowledge customers were investigated.

Paper 5 contributed by connecting service modularity and service logic in order to understand the nature of the service better, primarily by using the service blueprint to visualise the logistics service and linking service modularity with environmental sustainability operationalised as energy efficiency. Actions occurring at the stages of visible contact or household action represent the joint sphere, wherein most interactions between providers and customers occur and in which the logistics service is co-created, as explained in Chapter 5.3.2. At that point, customers interact with resources supplied by providers and, at the same time, provide a resource, such as household waste that can be used as resource further down in the supply chain, as shown in Chapter 5.1.3. It is that point at which the customer creates value-in-use.

Using the hands-on tool of service blueprinting from literature on services marketing to illustrate service modularity from literature on operations management in logistics not only combines three fields and extends theory on logistics services but also helps to clarify the customer side of logistics systems. Moreover, the combination affords in-depth understanding of the involvement of households in the service process.

In addition, as presented in Paper 3 and Chapter 5.2.3, LSPs need to mature to become environmentally sustainable providers. To operate at the maturity stage of external institutionalisation, LSPs need to cooperate with their customers and suppliers in the process of rendering services. By extension, service offerings need to connect the provider side with the customer side in order to become environmentally sustainable.

5.4 Summary of results

Table 5.3 summarises the results presented in the previous sub-chapters.

Table 5.3: Summary of results responding to each research question

Research question	Results	Discussed in sub-chapter
RQ1 (Characteristics) Answered in Papers 1, 2 and 4	The potential to improve various levels of logistics systems includes possibilities for enhancing aspects within the categories of activities, actors and areas and stresses the need to mobilise actions across levels to fully realise such potential. Difficulties for companies in measuring energy efficiency affect collecting suitable data, accommodating the multiplicity of collected indicators and defining system boundaries. Characteristics of last-mile fulfilment options have been identified, and propositions for energy efficiency in last-mile fulfilment have been formulated. The choice of strategy in last-mile fulfilment (i.e. speculation vs postponement) poses different implications for indicators of energy efficiency. Logistics systems at the point of consumption have been extended from the last mile to first mile.	6.1.1
	Energy efficiency in last-mile logistics fulfilment has been conceptualised according to the interplay of three building blocks: distribution structure, transport execution and household logistics capability. Household logistics capability devotes skills, involvement and resources at the household's end of the supply chain to perform logistics activities. The traditional waste service triad views the household as a consumer, whereas the household becomes a co-producer in an extended view on the triad.	6.1.2

	The household plays the role of co-producer in the first mile, when waste is returned to the cycle as a new resource for end users of recycled material—that is, when value is co-created.	6.1.5
RQ2 (Initiatives) Answered in Papers 1, 2 and 3	Capacity has been addressed as a complex interaction of several components embedded in a wider system. Underutilised 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 logistics systems). Means of mitigating underutilised capacity include better visualisation of performance, education of different actors, management of expectations, outsourcing of tasks to other actors, collaboration, standardisation of material handling and procedures, off-peak delivery, better planning, information sharing, deceleration, disconnection and extension of delivery time frames.	6.1.3
	Logistics initiatives of LSPs for improving energy efficiency in logistics systems are constituted through the interplay of actors, processes and services. The maturity model for the sustainability development of LSPs explains how LSPs work with initiatives in isolation or in alignment with suppliers and customers at various stages: (0) initial, (1) ad hoc, (2) managed in isolation, (3) internal institutionalisation and (4) external institutionalisation.	6.1.4
RQ3 (Services) Answered in Papers 3, 4 and 5	The service blueprint is a practical tool for visualising services and identifying their components and modules. Standardised and customised service modules allow for similarity and variety in services; energy-efficient components can be replicated in other services or components adapted to enable energy efficiency. Relationships between components and modules can be made visible, and changes in one module can change the energy efficiency in another if they share an interface. Services are co-created between customers and providers, and the blueprint visualises which components operate within the co-creation sphere and which operate within the customer or provider sphere. Principles for an energy-centric design of logistics services have been proposed.	6.1.5

6 Discussion

This chapter discusses the significance of the results in relation to the literature and, with reference to that discussion, articulates five propositions about improving energy efficiency in logistics systems (Chapter 6.1). The chapter concludes with an overview of the managerial implications of the findings (Chapter 6.2).

6.1 Discussion of results

The purpose of this thesis is to expand current understandings of how environmentally sustainable development can be facilitated by improving the energy efficiency in logistics systems. In what follows, the significance of the results, presented in Chapter 5 and summarised in Table 5.3, is discussed in relation to the literature reviewed in Chapter 2. Deriving from that discussion, five propositions targeting an academic audience are presented and explained (Chapter 6.1.1 to 6.1.5). After the propositions are synthesised in a conceptual framework (Chapter 6.1.6), the discussion concludes with a summary of the theoretical contributions of the thesis to logistics research and practice (Chapter 6.1.7).

6.1.1 Structural characteristics as conditions for energy efficiency in logistics

Beginning with the structural characteristics highlighted in the conceptual framework, this thesis emphasises the importance of applying a systems perspective (Arbnor and Bjerke, 2009) as a theoretical lens in logistics and contributes to that idea by proposing levels of logistics systems (Paper 1) focussed on three categories. Furthermore, the implications of those structural characteristics for indicators of energy efficiency have been identified (Paper 2) and the system boundaries extended from the last mile to include the first mile as well (Papers 2 and 4). As summarised in Table 5.3, all of those results concern structural characteristics relevant to improving energy efficiency in logistics systems. Moreover, they can be put into conversation with past work concerning, for example, system levels by McKinnon and Bilski (2014) and McKinnon (2016a), system boundaries by Kalenoja *et al.* (2011) and supply chain strategies by Pagh and Cooper (1998).

The system levels presented by McKinnon and Bilski (2014) and McKinnon (2016a) focus exclusively on levels of logistics activities and innovation. On the contrary, the research presented here added the level of areas within logistics systems and highlighted the importance of actors therein. Such an expansion of system levels follows the so-called “soft” systems thinking of Lindskog (2012) that stresses the human side of logistics. Although another systems framework in the literature, namely the sustainable scanning framework by Fabbe-Costes *et al.* (2011), also focusses on what is called *areas* in this thesis, that framework does not emphasise activities. At the same time, referring to the system boundaries identified by Kalenoja *et al.* (2011) has contributed to the understanding that any approach assessing energy efficiency needs to go beyond a company’s borders. In practice, the research’s interactive approach to that end can help to categorise who (i.e. which actors), what (i.e. which activities) and where (i.e. in which areas) within logistics systems the potential for improving energy efficiency can be identified. In turn, a model comprising system levels has been developed that extends the system boundaries from last-mile to first-mile logistics fulfilment while sustaining focus on energy efficiency.

Three structural characteristics relevant to energy efficiency in logistics systems in the last mile were identified: distribution structure, transport execution and household logistics capability. Moreover, those aspects of last-mile fulfilment were analysed in connection with possible strategies chosen by LSPs and shippers, including speculation and postponement. Taken together, those observations contribute to current knowledge about strategic planning for last-

mile fulfilment, especially as highlighted in the framework by Hübner *et al.* (2016b). In earlier scholarship, Pagh and Cooper (1998) identified supply chain speculation and postponement strategies in respect to logistics and manufacturing. Building upon their work, the research presented here involved applying their strategies as well as their logic to last-mile logistics fulfilment. In so doing, it has challenged the current understanding that the speculation strategy, which favours the transport of large quantities of goods and high fill rates, is the most energy-efficient approach. By comparison, the postponement strategy, according to which goods are stored centrally and forwarded only when a customer's order is received, embraces the use of a pull strategy. In contrast to both of those strategies, the interactive approach to capacity utilisation, though not involving most energy-efficient transport due to low fill rates, reduces redundant transport, especially from a systems perspective, by not shipping products that are not in demand. In that way, the interactive approach challenges the understanding that high fill rates should always be sought.

Following Liimatainen *et al.* (2015), who identified four trends shaping the future of energy efficiency and the emissions of road freight transport (i.e. energy and environmental concerns, the structural change of the economy, changes in consumer habits and changes in logistics practices and technology), a first proposition has been developed that highlights the structural characteristics of logistics systems that currently shape energy efficiency:

> **Proposition 1:** *Energy efficiency in logistics systems can be improved by identifying their structural characteristics as well as by extending the boundaries of the systems.*

Identifying such characteristics can help to elucidate energy efficiency in logistics systems and, in turn, environmentally sustainable development.

6.1.2 Interactive approach to capacity utilisation

The research presented herein has also extended the common view on how to improve energy efficiency in logistics—that is, by reducing the use of fossil fuels and transitioning to using alternative fuels—by underscoring that energy efficiency can also be improved by implementing logistics initiatives, including capacity utilisation, throughout logistics systems. In that way, the findings of the thesis contribute to logistics literature that has increasingly focussed on energy efficiency (Centobelli *et al.*, 2018; Halldórsson and Kovács, 2010; Kalenoja *et al.*, 2011). In promoting energy efficiency by improving capacity utilisation, capacity needs to be understood as a complex interaction of several components embedded in a wider system, and the causes and means of mitigating underutilised capacity need to be identified (Paper 1). According to the results presented in Chapter 5.2, an interactive approach to capacity utilisation also needs to be taken, for three major reasons.

First, capacity in the logistics system can be regarded as an interactive concept with several components, including equipment, operating rates, human resources, system capabilities and policies (Hayes *et al.*, 2005). Although capacity has traditionally been regarded as having static boundaries (Browne *et al.*, 2006; McKinnon and Ge, 2004), this thesis understands capacity as a complex interaction of several components embedded in a wider system (Hayes *et al.*, 2005; Wehner, 2018). From that standpoint, when components are unaligned or poorly coordinated—for example, due to limited interaction between suppliers and carriers or insufficient homogeneity between products and markets, as pointed out by Pfohl and Zöllner (1997)—underutilised capacity becomes evident.

Second, managing the interplay of components that constitute capacity has to focus on making use of underutilised capacity and reducing energy use by altering the requirements of the logistics

flow, such as by abandoning just-in-time delivery and using slow steaming, as highlighted by McKinnon (2016b). Instead of identifying individual factors of the energy-efficient management of supply chains—for example, collaboration (Wolf and Seuring, 2010), consolidation and standardisation (Aronsson and Huge-Brodin, 2006), the weight of goods and empty running (Piecyk and McKinnon, 2010)—energy efficiency should be achieved in logistics systems by following an interactive approach to capacity utilisation, as illustrated in the research, by acknowledging different system levels and their coordinated mobilisation. Of course, doing so requires going beyond the idea of simply increasing fill rates in vehicles, which can inadvertently increase the number of returns and unnecessary transport. Instead, utilising capacity needs to be viewed as an interactive and dynamic process. In that sense, the most pertinent questions ask why certain products are in demand and what consumers truly need.

Third, by adjusting a logistics system's boundaries by extending the scope of logistics services, new forms of capacity can be made available. Not only can new actors (e.g. bicycle couriers, taxi services and consumers as logistics service co-producers) can be included in logistics systems, but as suggested by Fabbe-Costes *et al.* (2011), organisations also need to cooperate across firms. After all, limitations in sustainability cannot be solved at only the level of the firm.

Considering all three of those reasons, the second proposition acknowledges the interactive nature of capacity, highlights the need to manage the interplay of components and takes new actors into account by adjusting the system boundaries:

> **Proposition 2:** *Energy efficiency in logistics systems can be improved by following an interactive approach to capacity utilisation.*

6.1.3 Maturation of LSPs towards environmental sustainability

Current literature on energy efficiency in logistics systems posits various categories of environmental sustainability as well as energy efficiency initiatives taken by LSPs (Centobelli *et al.*, 2017b; Colicchia *et al.*, 2013; Evangelista *et al.*, 2018). By extension, to redirect those initiatives more clearly towards environmental sustainability, taking an evolutionary perspective providing a stepwise approach could be fruitful. As posited in Paper 3, despite the need for LSPs to transition into environmentally sustainable organisations, research on maturity models their sustainable development has remained limited (Fabbe-Costes *et al.*, 2011) even if such models have been common in fields such as manufacturing (Baumgartner and Ebner, 2010; Machado *et al.*, 2017; Ngai *et al.*, 2013).

The thesis's proposed maturity model for LSPs prescribes their gradual development, similar to what Baumgartner and Ebner (2010) have suggested. At the initial stage (Stage 0), LSPs are thought to not focus on energy efficiency or sustainability in the form of actions, internal processes or customer services, as exemplified by organisations that show little or no interest in improving their energy efficiency, as discussed by Introna *et al.* (2014). At Stage 1, the ad hoc stage, LSPs undertake some initiatives such as energy mapping and decarbonisation (e.g. Swedish law, 2014:266), although key performance indicators remain vague, actions and internal process are underdeveloped, and energy efficiency initiatives are seldom emphasised in service offerings. A similar conceptualisation appears in the first stage of the maturity model for sustainable operations proposed by Machado *et al.* (2017), who have posited that organisations needs to comply and conform with regulations before attending to more complex indicators and addressing the environmental effects of their operations. At Stage 2, at which LSPs are managed in isolation, the organisations clearly recognise sustainability, and isolated actions, processes and some services are mobilised within the organisation. Stage 2 thus comprises what Introna *et al.* (2014:113) have called "by projects" and what Cagnin *et al.* (2005:7) have dubbed being

"managed with no integration". Stages 3 and 4, respectively conceived as internal institutionalisation and external institutionalisation, are similar to the fourth and fifth stages in the model developed by Reefke *et al.* (2014); however, for LSPs, institutionalisation occurs internally before being scaled up to the external network. At Stage 4, the highest stage, sustainability is not an incremental offering on top of other services but integrated within the organisation in cooperation with suppliers and customers in all actions, processes and services. Above and beyond such efforts, achieving environmental sustainability requires other factors independent of LSPs, including purchase criteria for customers (Wolf and Seuring, 2010) and the implementation of widely accepted methods for measuring the environmental impact of logistics (Bask *et al.*, 2018).

The proposed maturity model for sustainable development contributes to literature describing other maturity models for LSPs and of course implies that LSPs need to continue maturing. Even if actions, internal processes and services are currently managed primarily in isolation, external institutionalisation should be pursued, so that those actions, processes and services align with the operations of suppliers and customers such that sustainability is realised by way of collaboration. To that end, the maturity model prescribes an evolutionary path and stepwise approach for LSPs as well as indicates the stage of maturity at which LSPs currently operate and how they can evolve into environmentally sustainable organisations. Encapsulated all of the above, the third proposition is thus:

> **Proposition 3:** *Energy efficiency in logistics systems can be improved when LSPs mature by aligning their actions, processes and services with suppliers and customers.*

6.1.4 Consumers as co-producers of logistics services

As the results in Table 5.3 show, the (end) consumer or household is a co-producer of logistics services and, as such, actively involved in determining energy efficiency. In particular, consumers play a decisive role in last-mile logistics fulfilment (Paper 2) and devote skills, time and other resources to both the last and first miles of supply chains (Papers 2 and 4). In the first mile, the household's role also requires transitioning from being a consumer only to also being a co-producer of the waste collection service and a supplier of the resource involved—that is, waste that can be recycled to a new raw material (Papers 4 and 5). Taken together, those circumstances cast consumers as active players in logistics systems and, in theory, align with the so-called "soft" school of systems perspectives described by Lindskog (2012). In the case of last-mile logistics fulfilment, by comparison, end consumers can assume either passive or active roles as exercising their household logistics capability (Paper 2).

Literature on SCM has started to acknowledge the importance of partnerships, relationships and value creation (Hoyt and Huq, 2000; Lusch *et al.*, 2010; Spekman *et al.*, 1998). Therein, the service, not the physical product, has been recognised as the fundamental basis of exchange (Vargo and Lusch, 2004). Following Premise 3 (see Table 2.1) that all resources and processes are distribution mechanisms for service provision, albeit without value in themselves, that logic can be transferred from supply chains to logistics systems, in which focus lies on providing logistics services. Operant resources, including skills, competences, knowledge and capabilities, are often intangible as well as dynamic and, in any case, act upon operand resources to produce effects (Lusch, 2011) and serve as the fundamental source of competitive advantage (see Premise 4 in Table 2.1). In contrast to goods-dominant logic that focusses on the value of the exchange of goods, service (-dominant) logic focusses on value in use. According to such logic, the creation of value in a reciprocal relationship between customers and providers (see Premise 1 in Table 2.1) is at the core of logistics services.

In the first-mile logistics of household waste collection, the household plays a dual role as the customer and the supplier of a resource in the process of value co-creation (Grönroos, 2011). From that perspective, the household's role can be regarded as an operand resource (Vargo and Lusch, 2008)—that is, a resource mobilised to fulfil a predefined expectation (Lusch, 2011). By extension, beyond the boundaries of traditional logistics systems, the consumer can become a prosumer by co-creating a service with companies (Halassi *et al.*, 2018).

In short, the household's role as a co-producer of logistics services, though originating in the context of the first mile, can be transferred to last-mile logistics fulfilment, hence the fourth proposition.

> **Proposition 4:** *Energy efficiency in logistics systems can be improved by engaging consumers as co-producers of logistics services.*

6.1.5 Energy efficiency as a value co-created in logistics systems

The result that households assume the role of co-producers of logistics services also suggests that households can be co-creators of value as waste re-enters the product cycle as a new resource for end users of recycled material (Paper 4). Moreover, households can be understood as co-creators of value when energy efficiency is viewed as a value co-created by providers and customers. By extension, such thinking informs service logic (Grönroos, 2006, 2011).

This thesis argues that energy efficiency can be understood as an operant and intangible resource (Lusch, 2011) with value. Energy efficiency also affords a competitive advantage, for it not only positively affects the environment by reducing the total energy consumed but also furnishes economic value. As emphasised in the book chapter, energy efficiency captures two of the three Ps of the triple bottom line: profit and planet (Halldórsson *et al.*, 2019b). At the same time, companies can integrate energy efficiency into their branding as sustainable or green organisations, if not both. Altogether, energy efficiency in logistics systems is a value for both customers and providers.

Beyond that, energy efficiency needs to be co-created by all actors in a logistics system. As Papers 1 and 3 revealed, it is difficult for logistics providers to implement energy efficiency measures if customers do not want to bear the costs of implementing those measures or do not actively ask for them. In either case, according to Bommer *et al.* (2001), an activity that does not create value for customers should be eliminated. However, in logistics, energy efficiency co-created between providers and customers is of value to all. Accordingly, if energy efficiency is a drawback for customers—for example, if intermodal transport means longer transport times—then customers need to agree to create it and may be more willing do so if it holds value. For that purpose, service blueprinting can be used to visualise services and thereby identify their components and modules that can be replicated to create services that customers perceive as being customised and that allow providers to achieve standardisation which in turn improves energy efficiency (Paper 5). Such visual aids can help to elucidate the customer and provider spheres described by Grönroos and Voima (2013) as well as the co-creation sphere in which energy efficiency as a value is co-created.

Therefore, the fifth and final proposition views energy efficiency as a value to both providers and customers:

> **Proposition 5:** *Energy efficiency in logistics systems can be improved by co-creating value with customers.*

6.1.6 Synthesis: Uniting the propositions in a conceptual framework

According to Pagell and Shevchenko (2014), the road to environmental sustainability requires changes in norms, measurements, methods and research questions, and the research conducted for this thesis has indeed identified potential changes in norms and measurements. Current norms were challenged by taking a holistic approach to logistics, operationalised in a model of system levels, as well as by taking an interactive approach to capacity utilisation and by casting end consumers in an active role in logistics fulfilment. In addition, knowledge about energy efficiency measurements has been expanded as an outcome of a qualitative assessment of energy efficiency. On top of that, Pagell and Shevchenko's (2014) call for expanding the focus of stakeholders has been answered by including perspectives from LSPs, their customers, end consumers, WSPs and governmental bodies (e.g. municipalities). Such results have also met the need to explore customers' perspectives, as identified in Gap 4 in the work of Centobelli *et al.* (2018). Furthermore, energy efficiency has been conceptualised as an operant, intangible resource with value for all actors that can be obtained via co-creation. Returning to the starting point of the research and the purpose of the thesis to expand understandings of how environmentally sustainable development can be facilitated by improving energy efficiency in logistics systems, the research contributes to such understandings by conceptualising energy efficiency in logistics systems in terms of three building blocks: structural characteristics, logistics initiatives and logistics services.

In reference to the three ways in which systems can react (i.e. change in variation, structural change and paradigmatic shift) delineated by Arbnor and Bjerke (2009), the results of the research suggest that radical changes are necessary to increase environmental sustainability. To reduce GHG emissions from the transport sector by at least 60% as of 2050 compared to 1990 (European Commission, 2011c), a radical shift is indeed needed. Arbnor and Bjerke (2009:109) have stated that a paradigmatic shift occurs only when a completely new model of the environment can treat a new situation. Such thinking is in line with Romme (2003), who has called for research that interrogates new systems or new states of existing systems. Environmentally sustainable systems require mostly the third type of change, a paradigmatic shift, because current systems cannot overcome the present challenges of high energy consumption and GHG emissions. Radical, innovative solutions that revolutionise entire systems are also supported in the literature; for instance, Halldórsson *et al.* (2009) have proposed a replacement strategy, in which traditional concepts are replaced by alternative approaches to cope with environmental and social developments. Starting with the notion of an integrated system by analysing such a system's current patterns from a systems perspective, however, the author realised that taking such approaches is not enough. According to the concept of service logic from marketing, value is created between providers and customers and needs not focus exclusively on costs and time but can be based upon environmentally friendly logistics solutions, energy efficiency and resource protection. To those ends, demands set by consumers need to change, which will impact logistics activities along entire supply chains. However, such a transformation can occur only via the education of consumers, who need to play active roles in logistics in order to co-create value so that logistics systems can enter into a new state via the process of environmentally sustainable development.

In line with the conceptual framework based on work by Cooper *et al.* (1997) and Lambert and Cooper (2000), improving energy efficiency in logistics systems via the three building blocks helps to operationalise the aim of energy efficiency in logistics systems by first viewing the system's structural characteristics, by next focussing on the provider side in logistics initiatives and by third attending to the customer side by prioritising the concept of service. The paradigmatic shift lies

within viewing logistics systems according to service logic (Grönroos, 2006, 2011) and actively involving end consumers in the process of performing logistics services.

Based on the proposed conceptual framework, Figure 6.1 summarises the research conducted in terms of the five propositions, all arranged in the provider and customer spheres described by Grönroos (2011), which highlight energy efficiency as a value co-created between logistics providers and customers. The conceptual framework in the figure has been developed with reference to Figure 2.8.

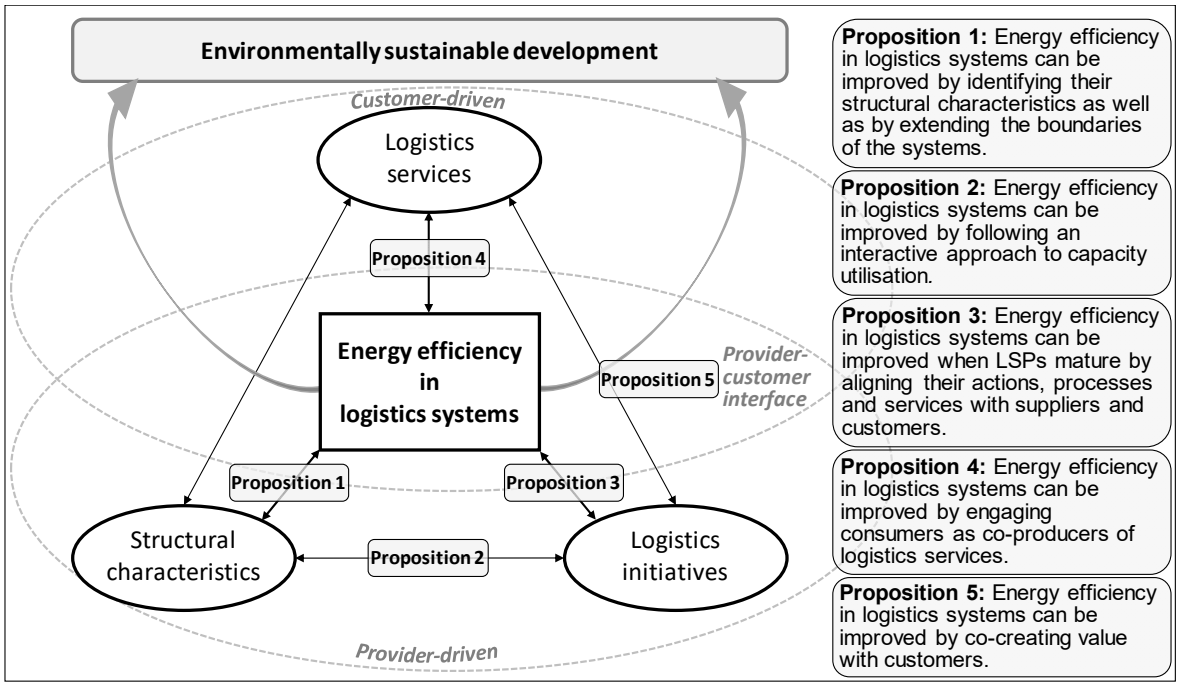


Figure 6.1: Summary of discussion in a conceptual framework

The exploratory power of the framework lies within the links between the three building blocks with energy efficiency in logistic systems as the focal element. Light has been shed on those links by answering the three research questions. The first link, an extension of the boundaries of logistics systems, unlocks new potential for energy efficiency by involving new actors and affords the possibility of including new logistics initiatives. In the second link, the maturation of LSPs to the stage of external institutionalisation, calls for the involvement of suppliers and customers and paves way for service innovations that can influence service designs. The third link is highlighted by structural characteristics that lay the groundwork for logistics services. Otherwise, offering certain services can in turn call for strategies that require certain structural characteristics to be in place.

In sum, this thesis suggests addressing energy efficiency in logistics systems by focussing on the three buildings blocks of structural characteristics, initiatives and services, all based on the framework from Cooper *et al.* (1997) and Lambert and Cooper (2000). More specifically, it proposes shifting existing logistics systems into a new state by extending the role of consumer to both customers and providers.

6.1.7 Summary of theoretical contributions

This section summarises how the results of an applied field such as logistics can be used to develop theory (Swanson, 2007). Because data were collected in collaboration with practitioners and the research questions and research were phenomenon-driven (Schwarz and Stensaker, 2014), the research was rooted in practice. At the same time, guided by the abductive approach,

theory was continuously aligned with the current body of knowledge. Together with a systems perspective and service logic in connection with service modularity and service blueprinting, the thesis also remains closely tied to academia.

As stated in Chapter 2.1, a *systems perspective* served as the theoretical perspective throughout the research. The perspective helped to depict the real world in its totality of interconnected parts and simplify it in a model (Arbnor and Bjerke, 2009) as well as underscore the complexity of logistics as a field. Results were produced with reference to service logic (Grönroos, 2006, 2011), which focusses on customers (Edvardsson and Olsson, 1996; Grönroos, 2006), and the value-in-use meaning of *value* (e.g. Grönroos, 2006, 2011; Vargo *et al.*, 2008). Service logic also helped to conceive end consumers and households as both customers and providers at once and, in that way, as recommended by Romme (2003), allowed generating knowledge by producing new systems or new states of existing systems. Pagell and Shevchenko's (2014) quest for changes in norms has been answered with the presentation of a normative framework based on the work by Cooper *et al.* (1997) and Lambert and Cooper (2000). By transferring the framework from an SCM context to a logistics context and by expanding understandings on how energy efficiency in logistics systems can be approached, this research contributes to theory on logistics.

Furthermore, in reference to Arbnor and Bjerke's (2009) proposal of to undertake radical change in order to realise a new state in which the real world can be pictured, the thesis suggests a change of the current logistics systems by borrowing a theory from a different field, namely service marketing, to increase the understanding of environmentally sustainable development of logistics through improving energy efficiency in logistics systems.

In addition to expanding understandings on the co-creation of energy efficiency in logistics services, Case Study II involved applying service blueprinting from literature on service marketing and applying it to the concept of service modularity from literature on operations management in the context of logistics services. Such a combination marks an innovation that contributes to understandings of service design, particularly of logistics services.

By taking a systems perspective, a common approach in logistics research (Aastrup and Halldórsson, 2008), as its underlying theory along with service logic from service marketing (Edvardsson and Olsson, 1996; Grönroos, 2006), the research benefitted from tools that allowed expanding understandings of how energy efficiency in logistics systems is created between actors. Drawing from the concept of service logic from marketing, it showed that value is created between providers and customers. Viewing energy efficiency as an operant as well as intangible resource with value is a further contribution to theory.

6.2 Managerial implications

This chapter provides an overview of managerial implications for practitioners, including logistics professionals on the provider side of the supply chain (i.e. LSPs), and actors on the customer side as well (i.e. shippers and municipalities). An overview of the implications appears in Table 6.1. In total, the managerial implications are fivefold and can be sorted into five topical categories: capacity utilisation, maturation of the logistics industry, provider–customer interface, blueprinting of logistics services and the modularity of logistics services.

First, capacity utilisation is a key logistics activity for improving energy efficiency. However, it concerns not only increasing the load factor of trucks but also using the full capacity of all resources involved in logistics services. Therefore, this thesis recommends using the model of system levels developed in Paper 1 and addressing the categories of activities, actors and areas when analysing capacity utilisation. Only when capacity utilisation on and across all system levels

is achieved—that is, only when a systems perspective on the whole logistics system and its environment is applied—can the full potential of energy efficiency be unleashed.

At the same time, capacity utilisation also has to be approached with caution. High utilisation rates do not always lead to energy efficiency. In trucks, for example, high fill rates can result from unnecessary detours taken to collect goods or high return rates from the over-ordering of products. Such effects can increase energy consumption instead of decreasing it. In addition, highly energy-efficient road freight transport can lower prices for customers and therefore the additional usage of transport in what is called the "rebound effect" (Sorrell *et al.*, 2009). Beyond that, energy-efficient road freight transport can make transport by road more attractive and, in turn, displace freight via other modes. In such cases, modes such as rail, which are more energy efficient, lose freight, which does not promote environmental sustainability. Therefore, it is important to view capacity in relation to the wider system and its interactivity with other components. Environmentally sustainable logistics can thus be described as a paradox, because problems solved by introducing new solutions can contribute to other problems.

Second, the maturation of the logistics industry is needed to foster environmentally sustainable development. Interviews with practitioners on the provider side revealed that it is often difficult for companies to be the first in any endeavour, because such pioneers pay high costs and fear that their customers will abandon them for competitors. Therefore, it is essential that the whole industry seeks to achieve environmentally sustainable development in a concerted effort. Due to market forces, such an effort is probably best enabled by state policy. Nevertheless, this thesis also advocates the implementation of energy efficiency initiatives, because by being energy efficient, value can be created for both providers and customers. Furthermore, it has been observed that although LSPs are obliged by Swedish law to map the energy use of their transport activities, energy mapping remains underdeveloped. To date, only the energy mapping of buildings has been sufficiently established. Therefore, knowledge about conducting the energy mapping of transport activities needs to be developed, because, as the adage goes, "You can only improve what you can see". Thus far, not even the industry developed for energy mapping, including external consultants hired by LSPs, is adequately familiar with the task and requires additional training and expertise in the field.

Third, concerning co-creation, energy efficiency is of value to both providers and customers that is co-created at the provider–customer interface, and for that reason, customers need to be included in the process of creating logistics services. Albeit foremost a theoretical implication, viewing the end consumer as a provider and customer clarifies that the actor needs to be involved in that process. By casting households in an active role in last- and first-mile logistics fulfilment, households can function as prosumers and contribute to actualising energy efficiency. To dramatically reduce energy consumption and venture beyond simple energy efficiency, consumers need to recognise that overconsumption in all areas has to stop. Meanwhile, practitioners need to recognise the necessity of involving and educating consumers and collaborating with them in co-production towards reaching the goal of increased circularity, amongst other targets. Awareness also needs to be raised by means of education and information exchange. The visibility of the environmental impact of logistics is therefore important. This year's Earth Overshoot Day, which marked when humanity's resource consumption for the year exceeded Earth's capacity to regenerate those resources, was reached on 29 July for world consumption and on 3 April for consumption in Sweden (Earth Overshoot Day, 2019).

Fourth, using the service blueprint as a hands-on tool can help to visualise logistics services for actors that subscribe to the idea that "You can only improve what you can see". Visualising

logistics service processes by borrowing tools from service marketing can therefore help to improve services and, in turn, energy efficiency.

Fifth, the modularity of logistics services can increase perceived customisation at the customer end and support standardisation at the provider end, both of which afford similarity and variety in services at the same time. Energy efficiency can also be improved by replicating energy-efficient components in other services.

All of the managerial implications of the research's findings are summarised in Table 6.1.

Table 6.1: Overview of managerial implications

Topic	Managerial implications	Support in the thesis
1. Capacity utilisation	Logistics managers need to view capacity utilisation beyond company boundaries and view their systems from a holistic perspective. Logistics systems need to work with suppliers and customers.	Model of system levels with the categories of activities, actors and areas (Paper 1) Causes of underutilised capacity and means of mitigation (Paper 1)
2. Maturation of the logistics industry	The logistics industry needs to pursue environmentally sustainable development as a unified force, ideally with the support of state policies. LSP need to strive for the highest sustainability maturity stage and align their actions, processes and services with suppliers and customers. LSP need encouragement to be early adopters of a high maturity stage (i.a. through incentives) Energy mapping of the transport activities is still underdeveloped, and this knowledge needs to be built up, so far only energy mapping of buildings is established.	Energy efficiency initiatives in the form of actions, internal processes and services (Paper 3) Maturity model (Paper 3)
3. Provider–customer interface	Providers need to involve, educate and collaborate with end consumers. Because energy efficiency is of value to both providers and customers, customers need to be included in the process of creating logistics services.	Framework of energy efficiency in last-mile logistics fulfilment focussed on household logistics capabilities (Paper 2) Applying service logic in the context of logistics (Papers 4 and 5)
4. Blueprinting of logistics services	The service blueprint is a hands-on tool for visualising the service process. Visualising the service process can help to improve the service and, in turn, energy efficiency.	Connecting service blueprinting with service modularity (Paper 5)
5. Modularity of logistics services	Modularity helps to increase perceived customisation at the customer end and maintain standardisation at the provider end.	Modularity of logistics services (Paper 5) Principles for the energy-centric design of logistics services (Paper 5)

7 Conclusion

This chapter presents the concluding remarks and limitations of the research conducted for the thesis as well as offers some suggestions for future studies on environmental efficiency in logistics systems.

7.1 Concluding remarks

The research addressed how the understanding of environmental sustainability can be increased by improving energy efficiency in logistics systems. By conducting five studies, which resulted in five papers and a book chapter, all three research questions could be answered (see Chapter 5) and propositions drawn (see Chapter 0).

By answering the first research question, concerning characteristics, structural characteristics relevant to improving energy efficiency could be identified at the levels of logistics systems and in the actors in the logistics service triad. The system levels can be summarised in three categories—activities, actors and areas—and the mobilisation of initiatives across the levels is important to unlocking more potential for improvement. In that context, an assumption challenged throughout the research (Alvesson and Sandberg, 2013) was that altering technology and replacing the fuel type can allow sufficient environmental sustainability. On the contrary, as revealed during the interviews, all biofuel available in Sweden is currently being used, and in any case, such use will not resolve the problem of GHG emissions. Furthermore, electrification alone is not a sufficient solution, because it will force different industries to compete for the same energy resource. On a different topic, the household's role in logistics systems was revaluated with reference to the service triad. Therein, consumers were found to contribute to energy efficiency by taking an active role. Because household logistics capabilities involve skills, engagement and resources at the household level, households become both customers and providers of logistics services in co-production with LSPs.

The second research question, concerning initiatives, addressed how initiatives of LSPs can contribute to environmentally sustainable development, assessed through actions, internal processes and services. In addition, a sustainability maturity model of LSPs was proposed to evaluate their sustainability-oriented efforts in a structured way, to assess their maturity level and to propose a path forward. Currently, the logistics industry lags behind the manufacturing industry in applying tools to facilitate sustainability. Because a change is needed that can be initiated by LSPs, LSPs need to reassess their actions and internal processes in order to facilitate environmentally sustainable development inside-out via their service offerings. For example, one action investigated in detail was capacity utilisation, especially the causes and means of mitigating unutilised capacity in logistics systems. Such means of mitigation taken at the system level of activities include off-peak delivery, route planning, real time tracking, real-time tracking, consolidation, information sharing and the standardisation of material handling and procedures. In the category of actors, by contrast, means of mitigation include better reporting and following up on emissions, expanding delivery time frames and the education of all actors involved in the system. Last, in the category of areas, the means of mitigation can be summarised as decelerating supply chains, decreasing the demand for just-in-time deliveries and spreading out pickup points. By taking an interactive approach, the research revealed that capacity extends throughout all levels of logistics systems: products, their packaging, their sizing for pallets, the capacity utilisation of trucks and warehouses, the ability of actors to adapt to time slots and other demands.

Last, concerning service design, the third research question interrogated how logistics services improve energy efficiency in logistics systems. By using the service blueprint as a tool, service

offerings were evaluated, and relationships between components and modules, as well as between customers and providers, were made visible. Energy efficiency was shown to be possible by making energy-efficient components standard across several service offerings. Nevertheless, new business models are needed to facilitate those new services, and energy efficiency objectives need to be implemented when designing logistics services. At the same time, the creation of new and innovative service offerings should include customers and consumers more actively.

7.2 Limitations

Three major limitations of the research concerned data collection, the research focus on the point of consumption and the application of concepts.

First, collecting empirical data primarily from professionals (i.e. logistics managers at LSPs and shippers) working in southern Sweden presented some drawbacks. By prioritising empirical evidence from professionals, the end consumer was under-represented in the data despite being one of the three actors in the service triad. Even then, data representing end consumers were collected from other actors. The principal reason for not collecting data by interviewing or surveying end consumers was the difficulty of including the opinions of millions of private citizens scattered across the research context. Instead, professionals were chosen because they are knowledgeable, often already consider end consumers' demands in their daily businesses and could be engaged in more focussed interviews. At the same time, the data provided by professionals have to be interpreted with caution, because they are subjective and reflect personal motivations and beliefs. Beyond that aspect of data collection, data were collected in southern Sweden. Although most of Sweden's residents live in that part of the country, the findings do not necessarily represent Sweden's rural areas or other northern and mid-European countries. Nevertheless, challenges in urban areas concerning last- and first-mile fulfilment are transferable to urban areas in other countries, findings from the context of southern Sweden can be transferred to other northern and mid-European context, and similarities with other geographical regions may be drawn.

Second, by focussing on and around the point of consumption, the research remained limited to that specific supply chain setting. To draw conclusions that are valid for entire supply chains, it would be necessary to adopt a more holistic focus in future studies that unites upper tiers with lower tiers, or vice versa, to reach a circular understanding.

Third, a limitation in the application of certain concepts arose. Although (end) consumers are the same as customers in many situations, the latter is not equivalent to the former, because an LSP's customer can be a shipper or any other actor in the supply chain. The problem with using the terms *customer* and *consumer* surfaced especially while discussing the service triad. Furthermore, the term *end consumer* does not suit research on first-mile logistics, in which consumers do not consume products or services but instead operate as suppliers. Accordingly, that actor was referred to as the *household* in Case Studies I and II. Other limitations regarding vocabulary that derived from the triadic relationship were reconciled as best as possible in the corresponding chapters.

7.3 Future research

To further expand understandings of how environmentally sustainable development achieved by improving energy efficiency in logistics systems, additional research is needed. With reference to this thesis, six avenues for future studies are suggested in what follows.

First, future research should focus on logistics fulfilment in the last mile given its potential for different distribution options. In Paper 2, six fulfilment options were investigated in terms of their characteristics of energy efficiency. However, that range of options is far from exhaustive, for other options and hybrid forms could be analysed in terms of their characteristics in that domain as well. Furthermore, because the research was qualitative, a quantitative validation of its results could be revealing. Finally, due to high numbers of returns, an investigation into the energy efficiency of reverse logistics also stands to offer opportunities for future research.

A second avenue is research on first-mile logistics fulfilment. After all, scholarship on waste logistics remains under-represented in the literature, and many problematic areas contain abundant potential for new findings. Extending such work could in turn contribute to research on circular economies, a research field that is in line with environmental sustainability. In addition, a quantitative validation to compare the energy efficiency of waste collection in the first mile with the quality of waste could prove to be fruitful.

Third, in relation to the mentioned limitations, the research presented herein could be extended to other settings of supply chains. To gain a circular understanding and thus further contribute to environmentally sustainable development, focus could be extended from the point of consumption to the entire supply chain. Such efforts could further apply the framework based on work by Cooper *et al.* (1997) and Lambert and Cooper (2000) and originating from SCM. Furthermore, the adjustment of system boundaries calls for new business models as approaches towards shared and open economies continue emerging (Pan *et al.*, 2015).

A fourth avenue is to advance research on the service triad. In the literature, three dyadic relationships are investigated, not a single holistic triadic one that captures all three actors at the same time. However, as this thesis has shown, taking a holistic perspective is important. Furthermore, while writing the thesis, the author several times reached a point at which the commonly used term *customer* seemed applicable only in dyadic relationships, whereas in triadic ones, it does not clearly refer to one actor and, in that case, invites confusion. A clear-cut term is thus missing from the literature, which presents an opportunity for conceptual research. As an offshoot of this avenue, research that extends the triad or examines actor networks could reveal opportunities for improving energy efficiency as well.

Fifth, one of the least travelled avenues is research on service modularity, not only by itself but also in connection to service blueprinting and especially in tandem with scholarship on the energy efficiency of logistics services. Studying service modularity by using the hands-on tool of service blueprints has proven quite useful. Therefore, combining service blueprints from literature on service marketing and service modularity from literature on operations management presents outstanding opportunities for future research, especially in logistics.

Last, a sixth avenue of research should be investigating social or economic aspects of sustainable development, because this thesis focussed exclusively on environmental aspects operationalised as energy efficiency. As stated at the outset of the thesis, the definition of *sustainable development* as articulated in its most influential source (Brundtland, 1987) captures several facets that have yet to be thoroughly examined.

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Appendices

Appendix A: Service blueprints

Service Blueprint: Service 1

Collection at apartment houses of

(a) food waste

(b) residual waste

Service Blueprint: Service 2

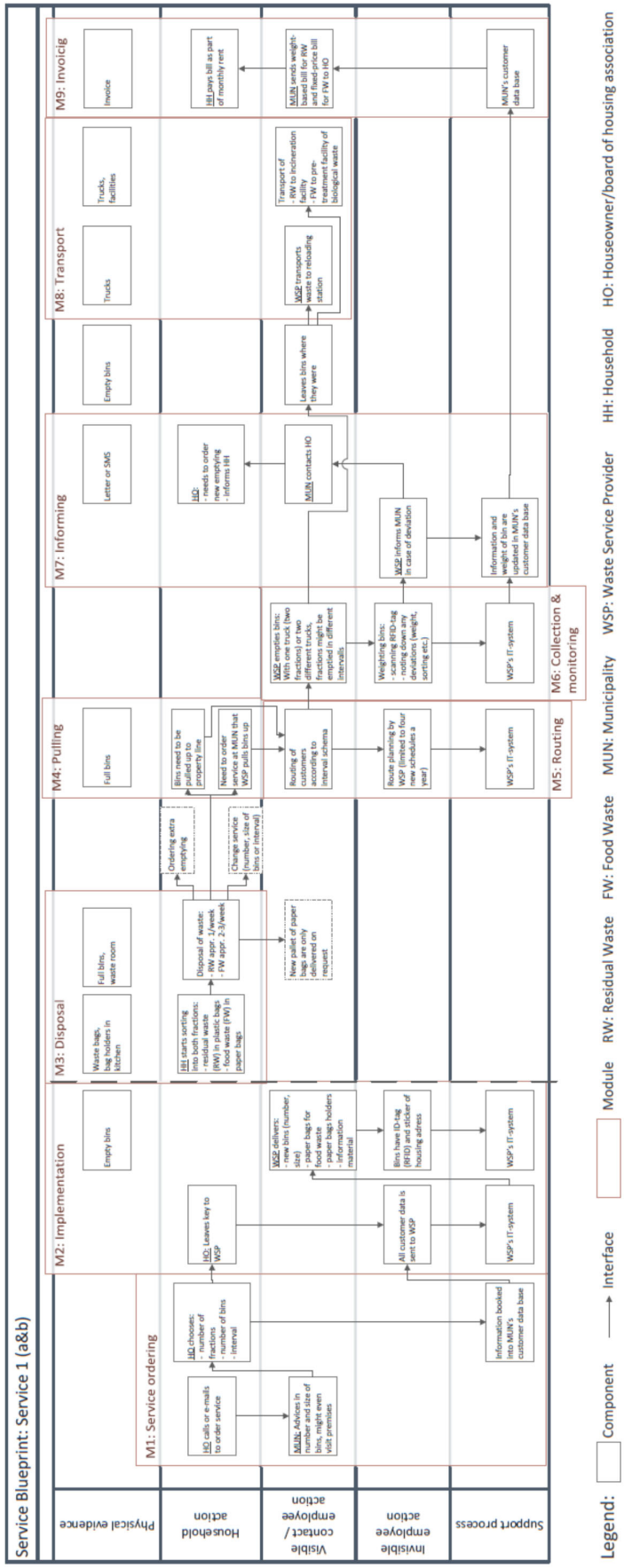
Collection at one-family houses of

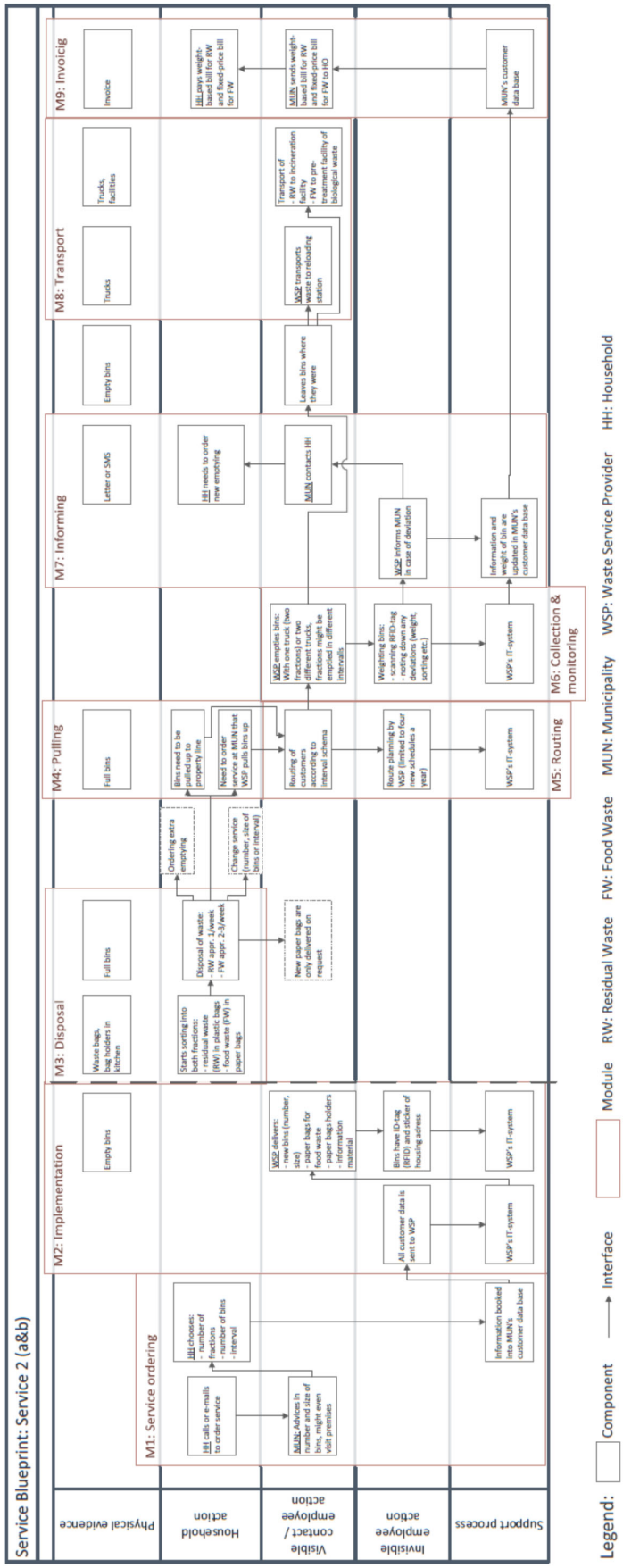
(a) food waste

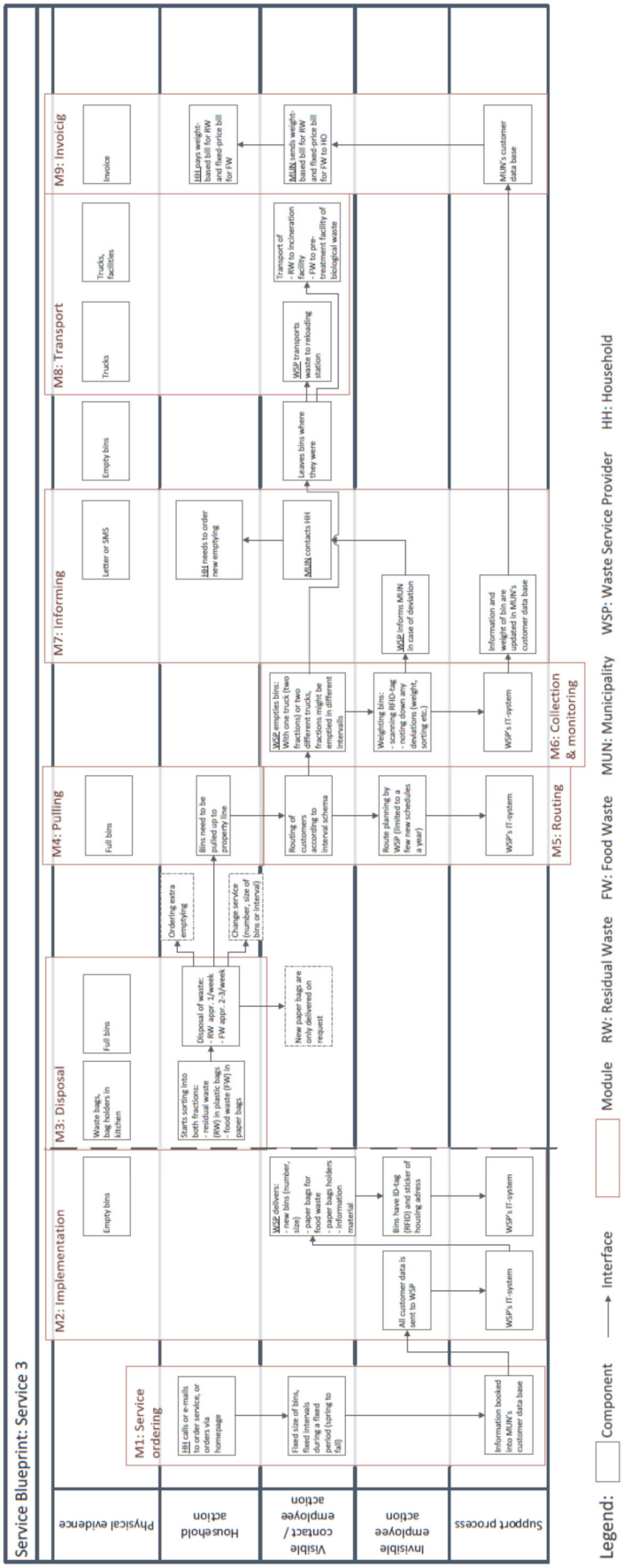
(b) residual waste

Service Blueprint: Service 3

Collection at one-family houses of gardening waste


Service Blueprint: Service 1 (a&b)
Physical evidence
Household action
Visible contact / employee action
Invisible employee action
Support process
M1: Service ordering
M2: Implementation
M3: Disposal
M4: Pulling
M5: Routing
M6: Collection & monitoring
M7: Informing
M8: Transport
M9: Invoicig
HO calls or e-mails to order service
HO choosses:
- number of fractions
- number of bins
- interval
MUN: Advises in number and size of bins, might even visit premises
Information booked into MUN's customer data base
HO: Leaves key to WSP
All customer data is sent to WSP
WSP's IT-system
Empty bins
WSP delivers:
- new bins (number, size)
- paper bags for food waste
- paper bags holders
- information material
Bins have ID-tag (RFID) and sticker of housing adress
Waste bags, bag holders in kitchen
Full bins, waste room
HH starts sorting
Into both fractions:
- residual waste (RW) in paper bags
- food waste (FW) in paper bags
Disposal of waste:
- RW appr. 1/week
- FW appr. 2-3/week
Ordering extra emptying
Change service (number, size of bins or interval)
New pallet of paper bags are only delivered on request
Full bins
Bins need to be pulled up to property line
Need to order service at MUN that WSP pulls bins up
Routing of customers according to interval schema
Route planning by WSP (limited to four new schedules a year)
WSP's IT-system
WSP empties bins:
With one truck (two fractions) or two different trucks, fractions might be emptied in different intervals
Weighting bins:
- scanning RFID-tag
- notice deviations (empty, deviations (weight, sorting etc.)
WSP's IT-system
Letter or SMS
HO:
- needs to order more emptying
- informs HH
MUN contacts HO
WSP informs MUN in case of deviation
Information and weight of bin are updated in MUN's customer data base
Empty bins
Leaves bins where they were
Trucks
WSP transports waste to reloading station
Trucks, facilities
Transport of
- RW to incineration facility
- FW to pre-treatment facility of biological waste
Invoice
HH pays bill as part of monthly rent
MUN sends weight-based bill for RW and flat-rate bill for FW to HO
MUN's customer data base
Legend:
Component
Interface
Module
RW: Residual Waste
FW: Food Waste
MUN: Municipality
WSP: Waste Service Provider
HH: Household
HO: Houseowner/board of housing association


Service Blueprint: Service 2 (a&b)
Physical evidence
Household action
Visible contact / employee action
Invisible employee action
Support process
M1: Service ordering
M2: Implementation
M3: Disposal
M4: Pulling
M5: Routing
M6: Collection & monitoring
M7: Informing
M8: Transport
M9: Invoicig
HH calls or e-mails to order service
HH chooses:
- number of fractions
- number of bins
- interval
MUN: Advices in number and size of bins, might even visit premises
Information booked into MUN's customer data base
Empty bins
WSP delivers:
- new bins (number, size)
- paper bags for food waste
- paper bags holders
- information material
All customer data is sent to WSP
WSP's IT-system
Bins have ID-tag (RFID) and sticker of housing address
Waste bags, bag holders in kitchen
Full bins
Starts sorting into bags for:
- residual waste (RW) in plastic bags
- food waste (FW) in paper bags
Disposal of waste:
- RW appr. 1/week
- FW appr. 2-3/week
Ordering extra emptying
Change service (number, size of bins or interval)
New paper bags are only delivered on request
Bins need to be pulled up to property line
Need to order service at MUN that WSP pulls bins up
Routing of customers according to internal schema
Route planning by WSP (limited to four new schedules a year)
WSP empties bins: With one truck (two fractions) or two different trucks, fractions might be emptied in different intervalls
Weighting bins:
- scanning RFID-tag
- noting down any deviations (weight, sorting etc.)
Letter or SMS
HH needs to order new emptying
MUN contacts HH
WSP informs MUN in case of deviation
Information and weight of bin are updated in MUN's customer data base
Empty bins
Leaves bins where they were
Trucks
WSP transports waste to reloading station
Trucks, facilities
Transport of
- RW to incineration facility
- FW to pre-treatment facility of biological waste
Invoice
HH pays weight-based bill for RW and fixed-price bill for FW
MUN sends weight-based bill for RW and fixed-price bill for FW to HO
MUN's customer data base
Legend:
Component
Interface
Module
RW: Residual Waste
FW: Food Waste
MUN: Municipality
WSP: Waste Service Provider
HH: Household


Service Blueprint: Service 3
Physical evidence
Household action
Visible contact / employee action
Invisible employee action
Support process
M1: Service ordering
M2: Implementation
M3: Disposal
M4: Pulling
M5: Routing
M6: Collection & monitoring
M7: Informing
M8: Transport
M9: Invoicig
HH calls or e-mails to order service, or orders via homepage
Fixed size of bins, fixed intervals during a fixed period (spring to fall)
Information booked into MUN's customer data base
Empty bins
All customer data is sent to WSP
WSP's IT-system
WSP delivers: - new bins (number, size) - paper bags for food waste - paper bags holders - information material
Bins have ID-tag (RFID) and sticker of housing adress
WSP's IT-system
Waste bags, bag holders in kitchen
Full bins
Starts sorting into both fractions: - residual waste (RW) in plastic bags - food waste (FW) in paper bags
Disposal of waste: - RW appr. 1/week - FW appr. 2-3/week
Ordering extra emptying
Change service (number, size of bins or interval)
New paper bags are only delivered on request
Full bins
Bins need to be pulled up to property line
Routing of customer according to interval schema
Route planning by WSP (limited to a few new schedules a year)
WSP's IT-system
WSP empties bins: With one truck (two fractions) or two different trucks, fractions might be emptied in different intervalls
Weighting bins: - scanning RFID-tag - noting down any deviations (weight, sorting etc.)
WSP informs MUN in case of deviation
Information and weight of bin are updated in MUN's customer data base
Letter or SMS
HH needs to order new emptying
MUN contacts HH
Empty bins
Leaves bins where they were
Trucks
WSP transports waste to reloading station
Trucks, facilities
Transport of - RW to incineration facility - FW to pre-treatment facility of biological waste
Invoice
HH pays weight-based bill for RW and fixed-price bill for FW
MUN sends weight-based bill for RW and fixed-price bill for FW to HO
MUN's customer data base
Legend:
Component
Interface
Module
RW: Residual Waste
FW: Food Waste
MUN: Municipality
WSP: Waste Service Provider
HH: Household

Appendix B: Additional material

Halldórsson, Á., Sundgren, C. & Wehner, J. (2019), "Sustainable supply chains and energy: Where 'planet' meets 'profit'", Sarkis, J. (ed.) *Handbook on the sustainable supply chain*, Edward Elgar, Northampton, MA, 444 pp.

A summary of this book chapter appears in Chapter 4.6 of the thesis. The first author led the planning and coordination of the book chapter, whereas all authors contributed equally to its writing.

Energimyndighet (2016), Guide for energy mapping in the transport industry – ways of producing an energy mapping according to the law (2014: 266) on energy mapping in large companies, [original language title] Vägledning för energikartläggning i transportindustrin – arbetssätt för att ta fram en energikartläggning enligt lag (2014:266) om energikartläggning i stora företag, EKL. Statens energimyndighet (ER 2016:08), ISSN 1403-1892, pp. 1-47.

In this how-to guide, the Swedish Energy Agency describes how large companies can conduct energy mapping in their efforts to comply with Swedish law (2014:266). Wehner served as a contributor to the guide, not as an author.

Wehner, J., Halldórsson, Á. & Lumsden, K. (2015), "Energy efficiency by utilising overcapacity in the logistics system?", pp. 1-9.

This paper was published in the proceedings of the 20th annual conference of the Logistics Research Network (LRN 2015) held on 9–11 September 2015 in Derby, United Kingdom. The first author was responsible for data collection under the advisement of the other authors. The first and second authors contributed equally to the paper's planning, data analysis and writing, whereas all authors developed the theoretical framework.

Later, the first author revised the paper to be appended to her licentiate thesis in August 2017. The paper contributes to logistics literature by providing an overview of the body of knowledge on energy efficiency in logistics and freight transportation, by pointing out different system boundaries in logistics and by highlighting pathways for improving energy efficiency by utilising available and unavailable capacity.