THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

Reducing the environmental impact of food products logistics systems

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Abstract

This thesis addresses how to reduce two types of environmental impact generated in logistics systems: transport's impact on climate and food waste. In mitigating both these types of environmental impact, actors in food supply chains (FSC)—producers, wholesalers, and retailers—play important roles, for both causes of environmental impacts and improvement actions to moderate them emerge within their logistics systems. Therefore, the purpose of this research is to explore how actors in FSCs can reduce the environmental impact of their logistics systems in terms of both transport's impact on climate and food waste. The research focuses on two aspects of FSCs that can affect those impacts and hinder the implementation of improvement actions to reduce them: FSC characteristics (e.g., shelf life and temperature regime), which create conditions for food logistics systems, and performance variables (e.g., requirements regarding lead times and flexibility), which can conflict with actors' capacity to reduce environmental impacts in their logistics systems.

The thesis is a compilation of five studies: (1) a review of how food logistics literature has addressed food products and actors in FSCs in logistics research; (2) a study of primary and industrial producers that identifies FSC characteristics that can be used to describe logistics systems; (3) a study of a wholesaler's logistics system that proposes a framework for reducing transport's impact on climate in light of flow characteristics including FSC characteristics; (4) a study of an industrial producer's logistics system that proposes another framework, namely one for comparing improvement actions that can reduce transport's impact on climate; and (5) a study of industrial producers, wholesalers, and retailers that identifies improvement actions that can reduce the amount of food waste. Empirical data collection for the thesis was performed with case studies.

The results highlight eight FSC characteristics, regarding both supply chain flow and products, which can be used to describe actors' food products logistics systems. The results further clarify how those FSC characteristics and logistics performance variables influence the two types of environmental impact. To explain how actors in FSCs can reduce transport's impact on climate, two frameworks are developed: one for evaluating shipments' potential to lower transport's impact on climate, and the other for selecting improvement actions that can efficiently mitigate that impact. By extension, the thesis next identifies, describes, and analyses nine improvement actions to reduce food waste. Lastly, the thesis compares the two types of environmental impact, first in terms of how the FSC characteristics influence them, and second how they can be reduced by different improvement actions.

The thesis contributes to the fields of green logistics and food logistics by explaining how FSC characteristics influence both types of environmental impact, as well as by analysing and comparing improvement actions in food logistics systems. Its contributions to management include frameworks that can help actors in FSCs to identify, evaluate, and create suitable conditions for improvement actions in their logistics systems.

Keywords: Transport's impact on climate, food waste, food logistics systems, food supply chains, green logistics, food logistics

List of appended papers

This thesis is based on five appended papers:

Paper 1: Fredriksson, A. and Liljestrand, K. (2015), "Capturing food logistics: A literature review and research agenda", International Journal of Logistics Research and Applications, Vol. 18 No. 1, pp. 16–34.

Paper 2: Liljestrand, K. and Halldórsson, Á. (2015), "Characteristics of food supply chains: The case of seafood producers", a previous version of which was presented at the 19th EurOMA Conference, 1–5 July 2012, Amsterdam, Netherlands.

Paper 3: Liljestrand, K., Christopher, M. and Andersson, D. (2015), "Using a transport portfolio framework to reduce carbon footprint", International Journal of Logistics Management, Vol. 26 No. 2, pp. 296–312.

Paper 4: Liljestrand, K. (2016), "Improvement actions for reducing transport's impact on climate: A shipper's perspective", Transportation Research Part D: Transport and Environment, Vol. 48, pp. 393-407.

Paper 5: Liljestrand, K. (2016), "Logistics solutions for reducing food waste," in the review process of a scientific journal and a previous version of which was presented at the 20th Logistics Research Network Conference, 9–11 September 2015, Derby, UK.

Author contributions

Paper 1: The authors' names appear in alphabetical order. The second author designed the study in terms of selecting journals to review and search terms to use. Data analysis and the writing of the paper were divided equally between the authors.

Paper 2: The first author was primarily responsible for designing the study, collecting data, and analysing the empirical material. Both authors were responsible for identifying theoretical propositions and implications, as well as for writing the paper, in which the first author was primarily responsible for writing sections addressing the theoretical framework, case description, and analysis.

Paper 3: The first author was primarily responsible for designing the study and for collecting and analysing the empirical material. The first author created the theoretical framework and was primarily responsible for writing the paper, during which process the other authors provided feedback and helped to improve the paper.

Paper 4: I am the sole author of the paper.

Paper 5: I am the sole author of the paper.

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Kristina Liljestrand
Göteborg, October 2016

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1 Introduction

This thesis focuses on how actors in food supply chains (FSCs) can reduce the environmental impacts of their logistics systems, in order to contribute to food logistics and green logistics.

1.1 Background

Food is a matter of everyday life, with uses that range from fulfilling basic needs to satisfying lifestyle choices. With both commercial and political dimensions, food ranks among products that have been the subject of trade among individuals and countries for centuries. The World Bank estimates that the food and agriculture sector accounts for roughly 10% of the global GDP (Murray, 2007), and in terms of the global GDP in 2013, the sector is worth roughly USD 7.49 trillion (World Bank, 2014). Within the sector, FSCs link companies that handle foods as they are transformed from unprocessed raw materials to products for end consumers. In the European Union alone, more than 48 million people are employed in FSCs and therein generate an added value of roughly EUR 750,000 million per year (Martinez Palou and Rohner–Thielen, 2011).

In FSCs, logistics activities are used to ensure that food products reach end consumers. By definition, *logistics* is ‘the process of planning, implementing, and controlling procedures for the efficient and effective transportation and storage of goods including services, and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements’ (Council of Supply Chain Management Professionals, 2013, p. 117). In logistics systems, non-perishable products can decrease in value if they do not reach consumers in time, whereas perishable products simply have to be discarded. Logistics is therefore crucial in making products available for purchase in the right place, at the right time, and in the right quantity, which respectively form criteria known as *place utility, time utility*, and *quantity utility* (Coyle et al., 2008).

For actors in FSCs—that is, producers, wholesalers and retailers—providing customers with the right quantity of products on time and in the right place is, however, not always enough. In fact, of increasing concern in supply chains is whether logistics activities are executed to minimise their impact on the environment. To explain why low environmental impact matters in supply chains, Seuring and Müller (2008) identify pressures and incentives for sustainable supply chains, including laws and regulations, customer demands, stakeholder demands and preferences, competitive advantage, pressure from environmental and social pressure groups, and loss of reputation. Further, Dey et al. (2011) highlight four domains that explain why sustainability matters in logistics systems: international standards and regulations, brand value, misuse of resources, and government intervention. To reduce environmental impact in logistics systems, actors in supply chains generally tend to focus on mitigating transport’s impact on climate (e.g. Aronsson and Huge Brodin, 2006; Piecyk and McKinnon, 2010). In addition, actors in FSCs have to consider environmental impacts caused by food waste (e.g. Kaipia et al., 2013; Mena et al., 2011). In what follows, three of the incentives and domains identified by Seuring and Müller (2008) and Dey et al. (2011)—regulations, customer demands, and misuse of resources—are presented in relation to two types of environmental impact in food logistics systems: transport’s impact on climate and food waste.

First, pressure from the macro level can generate regulations that affect actors in supply chains (Dey et al., 2011; Seuring and Müller, 2008). For food waste—that is, food appropriate for human consumption that is discarded, whether kept past its expiration date or left to spoil—at least one third, or 1.3 billion tonnes, of food produced worldwide is wasted each year (Food and Agriculture Organization of the United Nations, 2013). Food waste significantly affects the environment by exacerbating energy consumption and resource use. Comparing the global greenhouse gas (GHG) emissions due to food waste with countries' total GHG emissions, only China's and the United States' total GHG emissions rank higher (Food and Agriculture Organization of the United Nations, 2013). In Sweden, food waste, excluding agricultural and fishing waste, reached 127 kg per person in 2012 (Swedish Environmental Protection Agency, 2013). In turn, the magnitude of food waste poses consequences for incentives generated at the macro level. For instance, the United Nations has set the goal of zero food waste (United Nations, 2014). In Sweden, the Swedish Environmental Protection Agency has likewise set a goal to reduce the weight of food waste in Swedish FSCs, excluding primary production, by at least 20% by 2020 compared to 2010 figures (Swedish Environmental Protection Agency, 2014).

In intense debates about global warming, transport's impact on climate is often highlighted as a factor that requires drastic improvement (e.g. Johansson, 2013). In general, emissions from transport have only marginally decreased in recent years (European Environmental Agency, 2012). In fact, GHG emission levels in relation to freight transport are particularly alarming; in 1990, GHG emissions (i.e., CO_2 equivalents) from light and heavy trucks and buses in Sweden accounted for 6.4% of total emissions, a figure that by 2011 had risen to 11% (Swedish Environmental Protection Agency, 2012). As part of that trend, the transport of food products is predominant; indeed, accounting for more than 15% of road tonne-km in Europe (Eurostat, 2009), food transport is a chief contributor to road freight emissions. To give a name to longer food transport distances that pose greater consequences for the environment, the term *food miles* has been used to describe transport distances from food products' primary producers to end consumers (Garnett, 2003). Ambitious goals have also been set to decrease GHG emissions caused by transport; for one, the European Union aims to reduce carbon emissions from transport by 60% by 2050 (European Commission, 2011). In effect, goals set to lessen the impact of either food waste or transport on the climate can promote incentives and regulations that affect actors in FSCs. As a result, for many observers, including Dey et al. (2011), 'carbon emission and other logistics regulations is not a matter of "if" but a matter of "when''' (p. 1252). This implies that proactive actors who reduce their logistics systems' environmental impact can reap the incentives early and be less affected by regulations that could be put into place.

Second, customer demands also drive efforts to reduce environmental impacts (Seuring and Müller, 2008). For example, heightened awareness of the environment among consumers increase the sale of organic products, which in Swedish retail rose from 4.9% in 2014 to 6.6% in 2015 (Ekoweb, 2016). Further, there has been frequent coverage of food waste in mass media, which suggests increased consumer awareness of the problem and by that create incentives for actors in the FSC to reduce it.

Third, opportunities to reduce food waste and transport's impact on climate can lower costs for actors in FSCs, which is linked to the domain of misuse of resources addressed by Dey et al. (2011). Simply put, since fewer products are discarded, less food waste means lower costs. Opportunities to lessen transport's impact on climate can also mean reduced logistics costs; for example, increasing the use of intermodal transport can lower transport costs, as well as transport's impact on climate (Janic, 2007). For FSC actors, cost reductions in areas with low profit margins can be highly important. For example, in Sweden, the profit margin of industrial food producers is far less than that of other manufacturing industries (Lindow, 2012). For industrial food producers seeking to increase profit margins, reducing logistics costs can therefore be pivotal.

1.2 Problem area

Despite the above rationale for why actors in FSCs should reduce the environmental impacts of their logistics systems, food transport's impact on climate continues to rise, and amounts of food waste are perceived to be staggering. This section describes two problems that actors in FSCs have to address in order to diminish those impacts and—namely, characteristics of food products and conflicting performance variables of their logistics systems—and, in doing so, problematize why high environmental impacts in food logistics systems persist.

In food logistics systems, food product characteristics complicate the application of solutions from non-food logistics systems, since as biodegradable consumables, food products need logistics systems that accommodate the nature of the products. The goal of focusing on food products takes support from Van Hoek (1999) and Cox et al. (2007), both of whom compare the food industry with the automotive industry. For example, Van Hoek (1999) points out that applying the concept of postponement in the food industry is limited to the final packaging and labelling of products, whereas 'companies in the automotive supply and clothing industry, in particular, apply postponement extensively' (p. 23). In relation to food waste, food characteristics can partly explain why waste occurs. As Mena et al. (2011) demonstrate, food characteristics such as short shelf life and the seasonality of supply are causes of food waste. By extension, other research indicates that food characteristics can restrict the potential of possible improvement actions for reducing transport's impact on climate. Intermodal transport, at least in the United Kingdom, is used for less than 1% of food products, measured in tonne-km, which is far less than for other products, whose figures hover around 6% (Garnett, 2003). One factor limiting the use of intermodal transportation is a set of demands put upon the transport system given the temperature regime that food products require. Eng Larsson and Kohn (2012) show that the lack of temperature-controlled trailers that accommodate the transport of temperature-sensitive food products can also pose a challenge. Those circumstances imply that when actors in FSCs want to reduce the environmental impacts of their logistics systems, they have to consider the characteristics of their food products, which partly explain why the impact occurs and can limit opportunities to make changes in logistics systems.

As described in Section 1.1, supply chain actors who lower the environmental impacts of their logistics systems can reap three distinct benefits: alignment with pressure from the macro level, alignment with consumer demands for more environmentally friendly products and reduced costs in their logistics systems. However, actors in FSCs have to consider other demands put upon the performance of their logistics systems. As Christopher (2011) states, 'The whole purpose of SCM [supply chain management] and logistics is to provide customers with the level and quality of service that they require and to do so at less cost to the total supply chain' (p. 42). He further defines *customer value* to be a function of four variables: quality and service, which contribute to customer value, and cost and time, which decrease customer value

(Christopher, 2011). In addition, Jonsson (2008) proposes six performance variables for logistics—customer service, costs, tied-up capital, flexibility, time, and the environment—each of which can at once align and conflict with the others. Consequently, actors who want to reduce the environmental impact of their logistics systems have to consider how changes to the systems will affect those variables. For example, even if a change can reduce environmental impacts and costs, it could nevertheless exacerbate other performance variables, including time and flexibility, and therefore be difficult to implement.

Taken together, the two problems of food product characteristics and conflicting performance variables in food logistics systems explain why it remains challenging for actors in FSCs to reduce the environmental impacts of their logistics systems. At the same time, both problems differ in how they relate to food products. On the one hand, food product characteristics are unique to food products, although other perishable products (e.g., flowers and blood) can have similar characteristics. On the other, conflicting performance variables are not limited to certain kinds of products, but can be a challenge for all actors seeking to reduce the environmental impacts of their logistics systems. As such, actors in FSCs face distinct challenges posed by food products, as well as challenges that actors in logistics systems for other products also confront.

1.3 Purpose

Considering the importance of reducing the environmental impacts caused by food logistics systems, this thesis assumes focuses on exploring how actors in food supply chains can reduce the environmental impact of their logistics systems:

The purpose is to explore how actors in FSCs can lower the environmental impact of their logistics systems, in terms of both transport's impact on climate and food waste.

Such a purpose stresses a focus on actors in FSCs who aim to lessen the environmental impacts of their logistics systems. More specifically, environmental impact is divided into two dimensions: transport's impact on climate and food waste. Accordingly, ways to lower environmental impacts are adressed in terms of improvement actions, defined as a combination of logistics activities that are put in place to adjust or alter the flow and/or the parameters used to manage the flow. Figure 1.1 illustrates the relationship among the three key concepts of food logistics, environmental impact, and improvement actions.

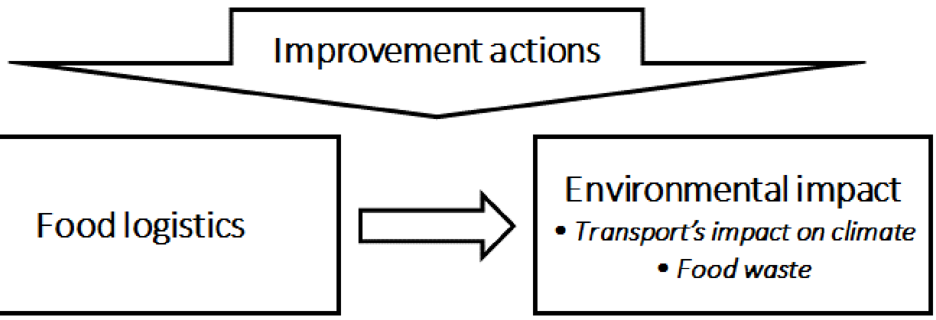

Figure 1.1 Research framework

The research presented here is driven by the phenomenon of environmental impact in food logistics systems, meaning that its purpose addresses a phenomenon, not a theoretical problem (cf. Schwarz and Stensaker, 2014). Nevertheless, describing a solid foundation of the phenomenon as corroborated by related literature remains critical, and to that end, the thesis draws upon two fields of research. First, it takes from the field of green logistics to stress the perspective of environmental impacts in logistics systems. Second, it applies work in food logistics to gain perspectives on food products and actors in FSCs.

1.4 Research questions

To achieve the stated purpose, four research questions have been formulated. First, RQ1 addresses food logistics and how characteristics of food products and actors up- and downstream in supply chains create conditions for actors' food logistics systems. Next, RQ2 and RQ3 concern the two types of environmental impact; RQ2 focuses on transport's impact on climate, whereas RQ3 focuses on food waste. Lastly, by combining the results of RQ2 and RQ3, RQ4 seeks to jointly analyse both types of environmental impact.

1.4.1 RQ1: Food supply chain characteristics

RQ1 addresses the context that FSC actors have to consider in reducing the environmental impacts of their logistics systems, namely by identifying characteristics that describe the logistics systems of food products. Given the wide spectrum of food products, it is critical to identify specific food characteristics that create conditions for logistics systems, including product shelf life (e.g. Romsdal et al., 2011) and temperature regime (e.g. Theodoras, 2006). However, not only do characteristics linked to food products have to be considered; among other important aspects to take into account is the stage of the FSC at which actors are positioned. Generally, key actors in FSCs range from primary producers upstream to industrial producers and wholesalers downstream, ultimately ending with retailers. By extension, the distinct roles of those actors, which require facing different challenges and engaging in specific interactions, are salient features of FSCs. For instance, as Taylor (2005) observes, depending on the stage in the supply chain, an actor needs to apply different operational improvements in order to cultivate a lean value chain. Other characteristics that are important to consider include lead time (e.g. den Ouden et al., 1996; van der Vorst et al., 2001) and demand variation (e.g. Taylor and Fearne, 2006). Characteristics not directly linked to products are referred to as *flow characteristics*. In this thesis, the term *food supply chain characteristics* (FSC characteristics) includes both product and flow characteristics.

Although food logistics research has addressed such FSC characteristics, seldom has it identified a larger set of FSC characteristics. An exception is Romsdal (2014), who identifies a set of FSC characteristics, however, she does so from the perspective of production. Since the present thesis focuses on logistics systems and necessitates a compilation of FSC characteristics from the logistics perspective, RQ1 seeks to identify FSC characteristics that can be used to analyse the logistics systems of food products:

RQ1: What food supply chain characteristics can be used to describe logistics systems of food products?

Since the FSC characteristics identified here provide a foundation for understanding why the two types of environmental impact occur, the results of RQ1 are used in answering RQ2–RQ4.

1.4.2 RQ2: Transport’s impact on climate

When considering how actors in FSCs can reduce their transport’s impact on climate, it is pivotal to understand both why that impact occurs and what different improvement actions are available to lessen it.

To elucidate the sources of impacts on climate, several frameworks in the field of green logistics examine the linkage between those impacts and logistics systems. All of them describe complex settings in which actors can influence several variables to reduce those impacts (e.g. Aronsson and Huge Brodin, 2006; Nielsen et al., 2003; Piecyk and McKinnon, 2010; Wu and Dunn, 1995). For one, Piecyk and McKinnon (2010) identify a set of seven variables that can be modified to reduce logistics systems’ impact on climate: handling, average haul length, modal split, average load, average percentage of empty runs, fuel efficiency, and fuel carbon intensity.

In considering the characteristics of food products in the linkage between logistics systems and transport’s impact on climate, three of the frameworks acknowledge that product characteristics have to be accommodated. Namely, Wu and Dunn (1995) highlight material selection and product design, Aronsson and Huge Brodin (2006) stress product design, and Piecyk and McKinnon (2010) identify six product-related factors that influence road freight demand and thus the environment: the use of space-efficient packaging-and-handling equipment, product designs that are sensitive to logistical requirements, the use of shelf-ready packaging, the import of goods in store-ready format, the miniaturisation of products, and products’ value density. Altogether, although the three frameworks stress that products influence how transport in logistics systems affects the climate, they do not consider the characteristics of food products. However, when determining ways to lessen transport’s impact on climate in food logistics systems, it is necessary to consider the influence of FSC characteristics, which should be further investigated.

Improvement actions for reducing transport’s impact on climate have also been studied in the field of green logistics—for example, increasing the load factor (e.g. Palmer and McKinnon, 2011; Santén, 2012; Ülkü, 2011) and implementing intermodal transport (e.g. Eng Larsson and Kohn, 2012; Puettmann and Stadtler, 2010). Although some of those improvement actions have been studied in the logistics systems of food products, research has yet to demonstrate how actors in FSCs, while considering FSC characteristics, can evaluate those actions to alter their systems as a means to reduce transport’s impact on climate.

As the above paragraphs indicate, green logistics research offers conceptual frameworks and empirical studies that treat transport’s impact on climate, both in terms of why it occurs and what sorts of improvement actions can reduce it. However, how FSC characteristics influence transport’s impact on climate and improvement actions for mitigating that impact in food logistics systems requires further development in research. In response, RQ2 is twofold; it addresses how FSC characteristics influence transport’s impact on climate and how improvement actions in food logistics systems can mitigate that impact.

RQ2a: How do food supply chain characteristics influence transport’s impact on climate?

RQ2b: How can improvement actions in food logistics systems reduce transport’s impact on climate?

The results of both parts of RQ2 are also used to answer RQ4.

1.4.3 RQ3: Food waste

To determine how actors in FSCs can reduce food waste, it is important to understand both why such waste occurs and what different improvement actions are available for reducing it. Even if food waste constitutes an environmental impact, literature addressing it leans more on research in food logistics than in green logistics.

Several authors have provided insights into why food waste occurs. Among them, Mena et al. (2011) present a framework for identifying causes of food waste deriving from three root causes: megatrends, natural constraints, and management. In follow-up research, Mena et al. (2014) examine a multitier network in order to extrapolate a set of propositions for identifying management practices that can trigger food waste in areas such as supply and demand management, availability and inventory management, quality and process control, shelf-life management, and packaging and labelling. Romsdal et al. (2015) furthermore identify key drivers of food waste, including unsuitable packaging, inappropriate temperature regime, and poor stock management.

Concerning improvement actions for reducing food waste, studies have proposed actions that can be implemented in logistics systems. For instance, Kaipia et al. (2013) show that more efficient information sharing and changes to information and material flows (e.g., implementing make-to-order flows) can decrease the amount of food waste, whereas Rijpkema et al. (2014) demonstrate how food waste can be reduced by analysing the cost of shelf-life losses in determining ordering policies. Further, literature on food logistics has pinpointed areas of logistics linked to food waste, including shelf-life management (Hafliðason et al., 2012; Sahin et al., 2007), quality management (Ottesen, 2006), and demand management (e.g. Taylor, 2006; Taylor and Fearne, 2009). Although previous papers provide in-depth descriptions of improvement actions for reducing food waste, no research has investigated multiple improvement actions in conjunction. Since logistics is deemed relevant to decreasing food waste, such an overview is necessary. Therefore, by applying a similar logic as applied in RQ2, RQ3 addresses first how FSC characteristics influence food waste, and second, how food waste in logistics systems can be lessened by offering an overview of logistics improvement actions for reducing food waste. The research includes how FSC characteristics influence food waste, even if causes have been covered in previous literature, since studying improvement actions removed from the causes is not considered feasible.

RQ3a: How do food supply chain characteristics influence food waste?

RQ3b: How can improvement actions in food logistics systems reduce food waste?

The results of both parts of RQ3 are also used to address RQ4.

1.4.4 RQ4: Combining two types of environmental impact

Although RQ2 focuses on transport’s impact on climate and RQ3 focuses on food waste, the purpose of the thesis, however, is to investigate how actors in FSCs can lower their logistics systems’ environmental impacts in terms of both transport’s impact on climate and food waste. To examine ‘both’ in the purpose, RQ4 concentrates on how actors in FSCs can consider both types of environmental impact in tandem, which is a significant task for at least one major reason. Faced with incentives to reduce both transport's impact on climate and food waste in their logistics systems, actors in FSCs might also face conflicts between improvement actions for each type of environmental impact. For one, improvement actions for reducing transport's impact on climate can entail creating larger, more efficient logistics systems that take advantage of scale benefits achieved by implementing intermodal transport (e.g. Craig et al., 2013; Eng Larsson and Kohn, 2012), using larger vehicles (e.g. Leach et al., 2013; Rodrigues et al., 2015), and increasing load factors (e.g. McKinnon et al., 2015; Santén and Rogerson, 2014), to name a few improvement actions. For actors in FSCs, realising those scale benefits can imply larger, fewer shipments; however, improvement actions for reducing food waste are somewhat different. As Kaipia et al. (2013) show, more efficient information sharing and adaptions of information and material flows (e.g., implementing make-to-order flows) can lower the amount of food waste. To that end, Rijpkema et al. (2014) add that food waste can be lessened by taking the cost of shelf-life losses into consideration when determining ordering policies. In all, a summary term for what logistics systems require to reap the benefits of such improvement actions is *responsiveness*: supply chains need to be able to react quickly to changes in demand and supply, as well as to adapt. For transport activities, however, such accommodations can expand the demands placed on just-in-time deliveries and shorten lead times for orders (cf. Piecyk and McKinnon, 2010). As a result, reconciling demands needed for scale benefits in order to reduce transport's impact on climate with demands placed upon responsive supply chains in order to reduce food waste can be challenging. Noting a similar contradiction, Romsdal (2014) concludes that though FSCs require responsiveness from food producers, the production system is nevertheless 'focused on efficiency through exploitation of scale benefits' (p. 4).

Literature addressing improvement actions to reduce transport's impact on climate generally emerges in green logistics, whereas literature addressing food waste tends to emerge in food logistics. As such, literature combining the fields is scarce. In this thesis, however, it is necessary to combine the fields in order to further investigate how actors in FSCs can reduce both transport's impact on climate, which is linked to transport activities, and food waste, which is linked to food products. Therefore, RQ4 addresses both types of environmental impacts together:

RQ4: How can addressing transport's impact on climate and food waste jointly contribute to reducing the environmental impact of food logistics systems?

1.5 System description

Since this thesis examines how actors in FSCs can mitigate the environmental impact of their logistics systems, it is important to address what a logistics system encompasses. To that end, the thesis describes a system of five components—system objectives, logistics activities, food products, actors, and the system's environment—inspired by Churchman (1968) framework for describing systems.

Figure 1.2 illustrates the system's description. The upper part of the figure depicts four stages of FSCs needed to address the actors in focus—namely, primary producers, industrial producers, wholesalers, and retailers. By contrast, the lower part shows components in focus in each actor's logistics system: the objective of the system, the food products that constitute the flow, and logistics activities. The lower part also illustrates that the environment of the logistics system includes actors both up- and downstream in FSCs.

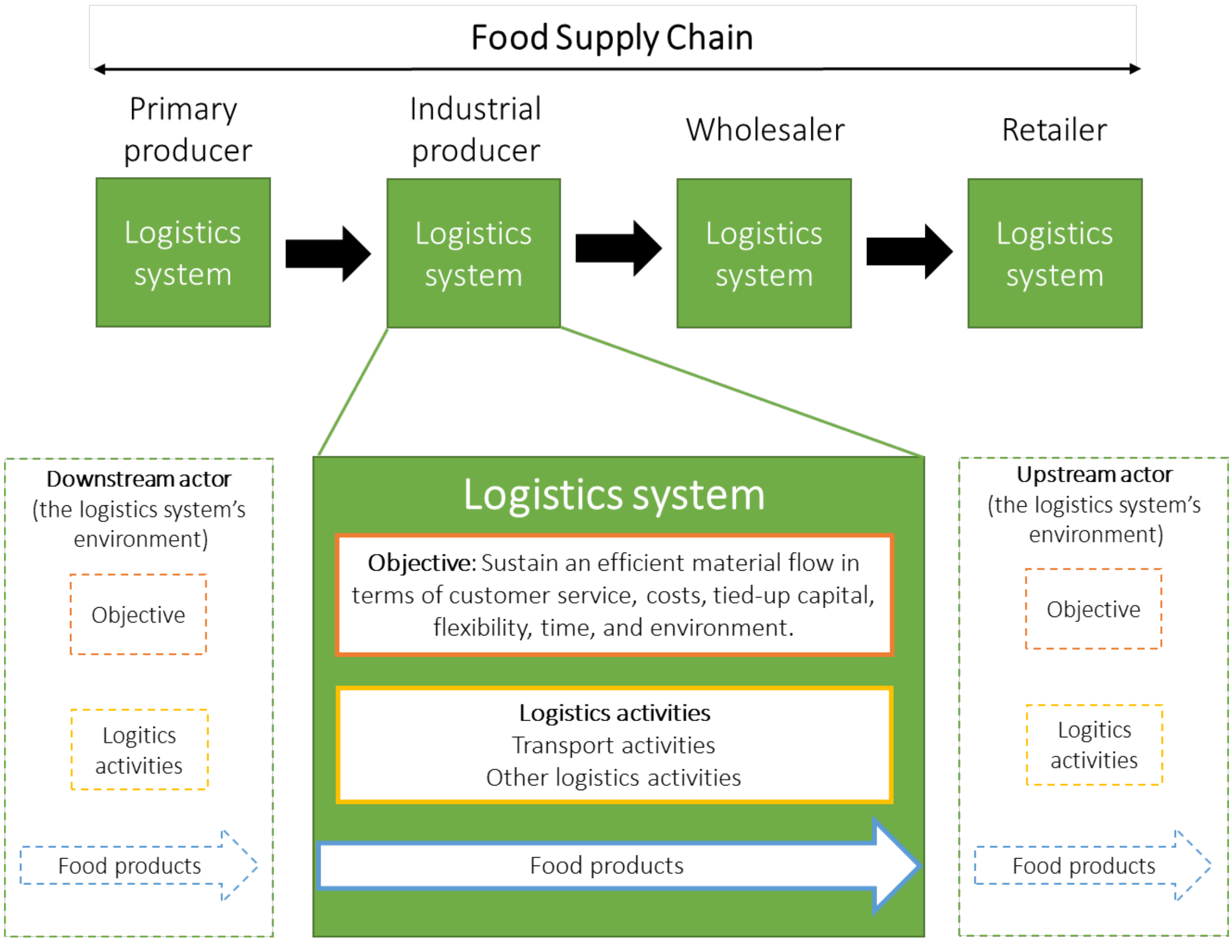

Figure 1.2 System description

1.5.1 System objectives

In any logistics system, since decisions are made at different levels, when defining the system's objectives, it is critical to discuss at which levels certain decisions are made. McKinnon and Woodburn (1996) present a framework that defines four levels of logistics decision making: (1) decisions about the structure of the logistics system, (2) decisions about the pattern of sourcing and distribution, (3) decisions about scheduling the product flow, and (4) decisions about managing transport resources. At the first level, decisions specifically concern the number, location, and capacity of factors, which are relatively fixed in the short term. At the second level, the supply and customer base are identified, whereas at the third level, the product flow is developed, which involves determining factors such as shipment size and frequency. Lastly, at the fourth level, the transport resources (e.g., transport mode and vehicle type) to be used are determined. Accordingly, the answer to RQ1 identifies FSC characteristics that can be related to the first three decision-making levels. In answering RQ2 and RQ3, which address the two types of environmental impact, the first part of the questions seeking to identify how FSC characteristics influence the two types of environmental impact also draw upon the first three levels. In addition, RQ2 focuses on transport activities and thus also encompasses fourth-level decisions in describing the system's environment, which exists within the boundaries of transport providers' systems. To elaborate upon ways to reduce the two types of environmental impact—that is, to answer the second parts of RQ2 and RQ3—the focus falls strictly upon adapting the material flow—in other words, it addresses the third level. Lastly, since RQ4 is a synthesis of the other research questions, it applies the same system levels as they do.

Along with defining decision-making levels, the system's objectives in this thesis are based on the six logistics performance variables—customer service, costs, tied-up capital, flexibility, time, and the environment (Jonsson, 2008)—presented in Section 1.2. The objectives address how actors can balance those variables in order to create efficient logistics systems.

Altogether, the objectives of the systems described here are to sustain an efficient material flow in terms of customer service, costs, tied-up capital, flexibility, time, and the environment. The first part—to sustain an efficient material flow—concerns how actors in FSCs can alter the logistics system at the third level in McKinnon and Woodburn (1996) framework. By contrast, the second part, which treats customer service, costs, tied-up capital, flexibility, time, and the environment (Jonsson, 2008), relates to ways in which actors can strike a balance among the six performance variables.

1.5.2 Logistics activities

Several logistics activities can be studied in logistics systems: demand forecasting, inventory control, material handling, order processing, parts and service support, procurement, packaging, traffic and transport, and warehousing and storage, among others (Lambert et al., 1998). Some of those activities, including warehousing and transport, can relate to the physical flow, whereas others (e.g., demand forecasting) relate to the information flow. To examine ways to reduce transport's impact on climate (RQ2), this thesis focuses on transport activities; however, if other logistics activities influence those transport activities, then they activities are included as well. By contrast, logistics activities used to reduce food waste (RQ3) cannot be specified here, since the corresponding improvement actions and, in turn, the logistics activities involved cannot be identified without the empirical material. Among its limitations, the thesis does not focus on production, even though production can also operate as a logistics activity.

Some logistics activities can be altered in light of decisions made at all four levels of McKinnon and Woodburn (1996) framework. In this thesis, however, they are addressed only in relation to decisions made at level 3—in other words, decisions about the material flow.

1.5.3 Food products

The unit of analysis in this thesis is the flow of food products in logistics systems of FSCs. Since food waste is linked to products and since transport's impact on climate is linked to a given activity, the flow of food products has to be described differently for the two types of environmental impact. Concerning transport's impact on climate, the flow of products is described in terms of shipments, which is a common term for describing product flows in relation to transport activities. Conversely, for food waste, the flow is described in terms of products. In applying a similar differentiation of the unit of analysis, Ramstedt and Woxenius (2006) state that a logistics system usually focuses on items (i.e., products), whereas a transport system focuses on consignments (i.e., shipments). In this thesis, no limitation is made regarding what food products can be studied, and products suitable to addressing each type of environmental impact are identified in Chapter 4.

1.5.4 Actors in food supply chains

To reduce the environmental impact of food logistics systems, it is pivotal to consider whose perspective is taken—that is, who is responsible for the problem at hand. This thesis addresses actors who are responsible for products throughout FSCs: *primary producers*, *industrial producers*, *wholesalers*, and *retailers*. Primary producers are farmers who either grow or breed raw materials; industrial producers are manufacturers who perform some kind of value-adding activity to the raw material, as well as package the food product in consumer packaging; wholesalers are distributers who store and convey products between industrial producers and retailers; and retailers sell products to consumers through food stores. Another term applied in this thesis is *FSC stage*, which is used to describe several actors at the same stage n in the FSC. More specifically, those stages are *primary production*, *industrial production*, *wholesaling*, and *retailing*.

Three topics are addressed in relation to actors in FSCs: 1) the perspectives of actors at each stage in Sweden, 2) differences among the stages in FSCs that are significant in this thesis, and 3) limitations regarding actors in FSCs.

FSCs in Sweden: In primary production, there were 110,644 companies in Sweden in 2015: 108,918 farmers[1] and 1,726 fisheries[2] (SCB, 2016). Most of those companies had no employees (102,343 companies). Of the 8,301 companies with at least one employee, 7,918 had up to nine employees, 379 companies had 10 to 99 employees, and four companies had more than 100 employees.

In industrial production, there were 4,020 companies in Sweden in 2015: 3,593 food producers[3] and 427 beverage producers[4] (SCB, 2016). Many of those companies (2,013) also lacked employees. Of the 2,007 companies with at least one employee, 1,307 had up to nine employees, 625 companies had 10 to 99 employees, and 75 companies had more than 100 employees. Beyond Swedish industrial producers, the import of food products in Sweden—which in 2014 totalled 119 billion SEK (Strandberg and Enhäll, 2015)—implies that Swedish wholesalers also purchase from foreign producers.

In Sweden, the stages of wholesaling and retailing are integrated within retail groups. Three actors control 87% of the market, the rest of which is controlled by three smaller retail groups (DLF, 2016). In all, the six retail groups owned 3,305 stores in Sweden in 2015 (DLF, 2016). Compared to other EU member states, Sweden and other Nordic countries have the highest market concentration of food wholesalers (Lindow, 2012). It should be stressed, however, that even if the stages are integrated in the same companies, it remains possible to study them separately.

An analysis of the number of companies and their sizes shows clear differences among the stages of FSCs. Regarding the number of companies, the FSC is narrowed downstream from primary producers (110,644 companies) to industrial producers (4,020 companies) and ultimately to wholesalers and retailers (six companies). Regarding industrial producers, there

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[1] SNI code 01
[2] SNI code 03
[3] SNI code 10
[4] SNI code 11

are also several international producers delivering to wholesalers. In terms of physical distribution, however, FSCs widen as they move downstream, for a total of 3,305 retailer stores in Sweden.

Differences among the stages: Even if actors share the challenge of having to reduce the environmental impact of their logistics system, they are clearly different from each other. Two major differences that especially affect sampling for this thesis are number of food products and responsibility for logistics activities.

Differences in food products emerge in how many products actors at different stages handle in their logistics systems. Since each producer often handles a limited amount of products, all in the same product category, to study certain products in-depth, it can be feasible to focus upstream in FSCs. Conversely, to capture the challenge of having a wide variety of products, it can be more feasible to focus downstream in FSCs, particularly on wholesalers and retailers with a large assortment of products.

Meanwhile, differences in logistics activities emerge in actors' responsibilities for different logistics activities—for example, the requisite amount of transport activities. As the Incoterm Ex Works increases (Potter et al., 2007), wholesalers might assume responsibility from industrial producers for transport activities between industrial producers and wholesalers. At the same time, wholesalers are also responsible for transport activities to stores, which implies that retailers have little responsibility for transport activities. To study transport's impact on climate, it can therefore be feasible to study wholesalers or food producers, who do not apply Ex Works for transport activities to wholesalers. As such, to best capture the underlying challenges posed in answering each research question, differences among stages in FSCs can require the study of actors at different levels in FSCs (Section 4.1.2).

Limitations: Two limitations in this thesis concern actors in FSCs. The first relates to the flow of food products among actors, which in this thesis is illustrated as a streamlined process among the four stages. However, that depiction is a simplification on two counts. One, other possible actors (e.g., caterers) are excluded from the sample. Second, it is possible to skip steps in FSCs; in some cases, wholesalers and even retailers can buy directly from primary producers (cf. Bourlakis and Weightman, 2004), the different possible flows of which are not addressed in this thesis. The second limitation addresses actors who do not own food products but nevertheless influence the FSCs—for example, transport providers and macro-level actors (e.g., governments).

1.5.5 Environment of the system

Although this thesis focuses on the logistics systems of single actors, the environments of logistics systems of actors up- and downstream in supply chains influence those systems. As such, their systems can be evaluated in light of the same components: the system's objective, the food products that constitute the flow, and logistics activities. FSC characteristics (RQ1) encompass characteristics of products and the flow, in both the logistics system in focus and the logistics systems of actors up- and downstream in FSCs, and can thus help to describe the environments of logistics systems.

1.6 Outline

This chapter has introduced the research topic of the thesis, formulated the purpose and research questions, and described the systems studied. By extension, Chapter 2 presents a review of literature in food logistics and green logistics in order to position the research in those fields and further motivate the purpose and research questions. Next, Chapter 3 presents a conceptual framework for analysing the research questions, Chapter 4 describes the research design, and Chapter 5 summarises papers that provide the basis of the empirical material. After Chapter 6 reveals the analysis of the four research questions, Chapter 7 provides the discussion. Lastly, Chapter 8 offers the overall conclusions of the thesis.

2 Literature review

Since this thesis builds upon two streams of logistics research—namely, food logistics and green logistics (Figure 2.1)—this chapter has three aims. First, it briefly defines and describes the fields of food logistics and green logistics. Second, it positions the thesis amid those fields. Third and lastly, it further motivates the purpose and research questions of the thesis.

To achieve those aims, this chapter is divided into three sections. Sections 2.1 and 2.2 describe the areas of food logistics and green logistics based on reviews of literature in each field. Thereafter, Section 2.3 describes the intersection between the fields, which is termed *green food logistics*. Since no literature reviews have been conducted on this topic, a structured literature review is also presented in Section 2.3, primarily to motivate the purpose and research questions already informed by narrative reviews (cf. Bryman and Bell, 2011) articulated in Chapter 1. By complementing the narrative review with a structured review, arguments for the research based on the narrative review can be strengthened, largely by ensuring that the same needs can be identified in a structured review.

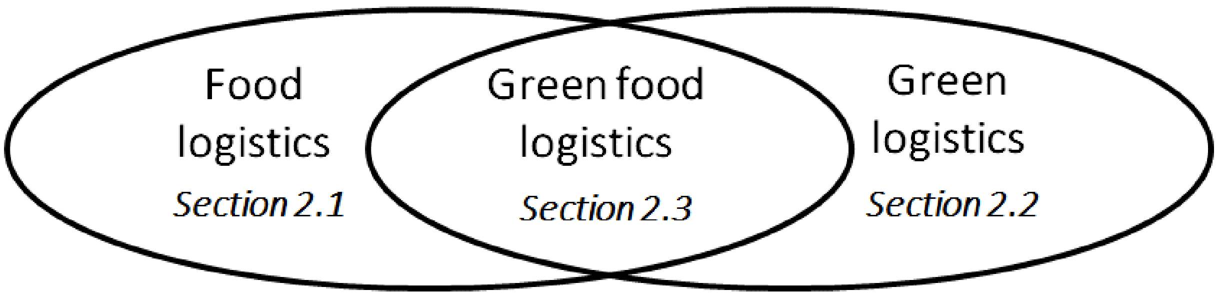

Figure 2.1 Overlap of food logistics and green logistics

2.1 Food logistics

Four published reviews of research on food logistics (Table 2.1) have been identified. Although the most recent review on the topic was cowritten by the author of this thesis, it was nevertheless included here, because its results lay the foundation for positioning the thesis amid other research and strengthen the motivation of the research questions.

The reviews differ in the degree to which they treat logistics and in terms of what food products they address. Regarding the degree of logistics treated, Fredriksson and Liljestrand (2015) take a logistics perspective, whereas Cunningham (2001), Rajurkar and Jain (2011), and Shukla and Jharkharia (2013) take a supply chain management (SCM) perspective. By contrast, in terms of products addressed, Cunningham (2001), Rajurkar and Jain (2011), and Fredriksson and Liljestrand (2015) all take a broad perspective that imposes no limitations on products included, whereas Shukla and Jharkharia (2013) focus exclusively on fruits, vegetables, and the non-food product category of flowers. Since logistics and SCM are related concepts (cf. Lummus et al., 2001) and since fruits and vegetables are an important product group within food logistics, all four abovementioned literature reviews can enlighten current understandings of food logistics.

Table 2.1 Literature reviews on food logistics

Author(s)	Scope and findings
Cunningham (2001)	Having identified 123 peer-reviewed journal articles on agri-food chain management from a database search, the author found that further research is needed in industries such as fisheries, as is more global distribution of research, particularly in the developing world: ‘Many of the opportunities for the agri-food industry to benefit from chain management research are yet to be explored’ (p. 212).
Rajurkar and Jain (2011)	Having identified 134 peer-reviewed journal articles on food supply chains from a database search, the authors found that further research is needed, with different scopes and methods, particularly regarding leaner, more agile supply chain strategies, suitable planning, and scheduling systems that can effectively manage operations, as well as about approaches for reducing food wastage and applications for advanced programming techniques; more experimental research is also generally recommended.
Shukla and Jharkharia (2013)	Having identified 86 peer-reviewed journal articles on supply chains handling fresh products (i.e., fruits, flowers, and vegetables) from a database search, the authors found that the top interests of research are consumer satisfaction and revenue maximisation, that studies on post-harvest waste reduction have not been a priority, and that most literature is ‘fragmented and in silos’ (p. 114).
Fredriksson and Liljestrand (2015)	Having identified 104 peer-reviewed journal articles on food logistics from a structured literature review in nine highly ranked logistics and supply chain management journals, the authors describe how logistics activities have been studied with a focus on food, how food logistics can be defined, and which aspects of food logistics require more attention in logistics research.

In what follows, a definition of *food logistics* is presented, and the thesis’s research is positioned among food logistics studies in relation to the results of the literature reviews.

2.1.1 Definition of food logistics

Interest in food logistics and food SCM has increased in recent years, and the literature reviews identified indicate an upward trend in publications on the topics (Fredriksson and Liljestrand, 2015; Shukla and Jharkharia, 2013). Of the four reviews, however, only Fredriksson and Liljestrand (2015) propose a definition of *food logistics*: that which ‘analyses logistics activities within a food supply chain context by problematising food product characteristics and by examining the constellation of food supply chain [FSC] actors’ (p. 13). That definition adheres well with the view of food logistics in this thesis, given its emphasis on the importance of considering both food products characteristics and actors in supply chains.

2.1.2 Position in the field

To position the research of this thesis among earlier studies on food logistics, in what follows three aspects of the above definition of *food logistics* are described (Fredriksson and Liljestrand, 2015): logistics focus, actors in the supply chain, and product type. Environmental impact within food logistics literature is also analysed, given its importance to this thesis. Altogether, the analysis is based on findings of the four literature reviews described in Table 2.1.

Logistics: Three of the reviews address a focus on logistics and SCM. First, Rajurkar and Jain (2011) divide the supply chain process into 10 categories, among which supplier relationship management was the most common (48%), followed by product development and commercialisation (29%) and customer relationship management (26%). Second, Shukla and Jharkharia (2013) delineate five categories to clarify how the 86 papers address SCM issues: demand forecasting (16 papers), production planning (19 papers), inventory management (4 papers), transport (12 papers), and others (35 papers). Lastly, Fredriksson and Liljestrand (2015) divide the papers according to four logistics activities: procurement (11 papers), production (6 papers), distribution (33 papers), and relationship management (54 papers). According to those categories, this thesis primarily contributes to the activity of distribution. However, aspects related to procurement and relationship management could also be relevant to the studies of food waste, since, as discussed in Section 1.5, it is difficult to pinpoint before data collection exactly which logistics activities are involved.

Actors: The two reviews that discuss the perspective of actors conclude that taking a supply chain perspective is common, and both reviews identify more than two stages of supply chains. On the one hand, Fredriksson and Liljestrand (2015) divide the actor perspective among four types of actor: single actors (42 papers), dyads (16 papers), networks (i.e., having at least three stages of the supply chain, 30 papers), and industries (16 papers). The single actor category is further divided into primary producers (4 papers), industrial producers (26 papers), wholesalers (2 papers), and retailers (10 papers). On the other hand, Rajurkar and Jain (2011) analyse papers that address more than two stages of supply chains and, as consistent with Fredriksson and Liljestrand (2015), conclude that it is more common to take a network or supply chain perspective—that is, one considering at least three stages of the supply chain—than a dyad perspective. The perspective prioritised in this thesis is that of single actors in FSCs. However, since literature on food waste stresses the importance of applying a supply chain perspective (Lindbom et al., 2013; Mena et al., 2011), the thesis's scope is also extended to several actors in FSCs, particularly in relation to answering RQ3 about food waste. By extension, the question of which actors in FSCs should be studied to best answer the research questions is addressed in terms of sampling in Section 4.1.2, since not only do stages in FSCs pose different challenges, but also it is important to find actors who can illuminate challenges identified in each research question.

Types of food products: Three reviews investigate the types of products or food industries that the literature has addressed, ultimately showing that it is more common to include a range of products and not limit the scope of supply chains to certain products. Cunningham (2001) shows that more than half of the papers (55%) in his review address several food sectors, followed by only horticulture (15%) and beef and lamb (15%). In their review of 86 papers, Shukla and Jharkharia (2013) reveal that 48 of them address all agri-fresh products (e.g., vegetables, fruits, and flowers), 16 address all vegetables, two address all fruits, four address all flowers, and 16 address specific products. Consequently, Fredriksson and Liljestrand (2015) results are in line with those of previous research. Of the 104 papers that they identified, 64 address a mix of products, followed by meat (11 papers) and vegetables and fruits (10 papers). The results of those reviews indicate that many papers have not focused on food characteristics, given its difficulty when a wide range of products are involved.

At the same time, those three reviews address the need for further research in relation to products and product characteristics. Cunningham (2001) stresses that research is needed for industries such as fisheries, which is identified as the most neglected sector of all sectors reviewed. Taking another perspective, Shukla and Jharkharia (2013) underscore that more studies are needed for particular products, by explaining, ‘Classification according to the produce shows that, in a majority of the cases all the agri-fresh produce is assumed as a single commodity, with only limited attention to the individual product characteristics. It is very important to study the produce at the individual level given its perishable and seasonal nature’ (p. 142). From a different angle, Fredriksson and Liljestrand (2015) conclude that since focus more often falls on actors in food logistics than on food characteristics, as studies’ of mixed products demonstrate, research in food logistics cannot be easily transferred to specific product groups. Accordingly, they identify a need for research on how specific product characteristics pose requirements for logistics and for transferability among products. All of the above findings explain the motivation for posing RQ1 about FSC characteristics—a question seeking to identify FSC characteristics that can be used to describe the logistics systems of food products. Furthermore, the results emphasise the importance of carefully considering products that can best illustrate challenges underlying the research questions, which is considered in greater depth in Chapter 4.

Types of environmental impact: Interestingly, none of the literature reviews address how different types of environmental impact are addressed in food logistics literature. Rajurkar and Jain (2011) show that 10% of papers in their review address the impact on the environment, but do not elaborate upon the ways in which those papers address the impact. Three literature reviews, however, indicate that environmental concerns need greater focus in food logistics. For instance, Fredriksson and Liljestrand (2015) state that ‘in relation to distribution, researchers have been giving more attention in recent years to the environmental impact of food products as well as sustainability issues . . . but more knowledge is required to understand how environmental and sustainability concerns affect food logistics’ (p. 14). Furthermore, Rajurkar and Jain (2011) identify that approaches for reducing food waste require further research, and on the same topic, Shukla and Jharkharia (2013) state that ‘post-harvest waste reduction is a secondary objective with the primary concern towards revenue increment in almost all the papers’ (p. 139), which leads them to urge more research on the topic. Those findings—in short, that environmental aspects need to be considered in food logistics—further justify the purpose of this thesis and its research questions, particularly RQ3 about food waste.

In conclusion, regarding logistics and actors, this thesis arguably does not apply a novel perspective, since distribution and both single and multiple actors in supply chains have been addressed in earlier research. However, the research is novel insofar as it, unlike most studies, additionally considers environmental aspects. Furthermore, the results of the literature reviews generally support the purpose of the thesis and its research questions.

2.2 Green logistics

To define *green logistics* and position the thesis in that field, 10 literature reviews on green logistics have been identified, though not all of them focus solely on green logistics. In fact, some extend their scope of environmental issues to sustainability, which is defined in terms of social, environmental, and economic areas and often referred to as the triple bottom line (TBL), a concept that promotes balance among economic, environmental, and social aims (Elkington, 1998). As a result, environmental aspects receive attention in the reviews, thereby allowing the reviews to position the environment aspects within the broader perspective of sustainability.

Furthermore, all 10 reviews adopt a scope of SCM instead of logistics; however, logistics and SCM are related concepts (cf. Lummus et al., 2001), meaning that findings of either are valuable to the logistics perspective. Table 2.2 summarises the focus and findings of the 10 reviews.

Table 2.2 Literature reviews on green logistics

Author(s)	**Scope and findings**
Srivastava (2007)	Having reviewed literature that analyses the importance of green supply chain management (GSCM), green design, and green operations, the author construct a timeline of how research on the topic has developed.
Seuring and Müller (2008)	Having devised a conceptual framework for sustainable supply chain management (SSCM) with the help of a literature review with three focuses—namely, triggers for SSCM, supplier management of risks and performance, and supply chain management (SCM) for sustainable products—the authors show that research is dominated by green and environmental issues.
Carter and Rogers (2008)	Having engaged conceptual theory building for SSCM with the help of a literature review, the authors generate proposals for the relationship among the integration of sustainability, SCM, and long-term economic success.
Sarkis et al. (2010)	Having categorised and reviewed GSCM-related literature in terms of nine broad organisational theories, the authors demonstrate that researchers of GSCM have begun to apply numerous organisational theories.
Carter and Easton (2011)	Having analysed literature in terms of topic, industry, theoretical lens, methodology, and analysis, the authors reveal that SSCM has developed from research in social and environmental fields, ranges in perspective from corporate social responsibility to the triple bottom line (TBL), and has emerged as a theoretical framework.
Dey et al. (2011)	Having explored the current state of sustainability-oriented efforts in SCM, specifically in supply chain logistics operations, the authors show that logistics is an important part of any sustainable strategy, given the magnitude of costs involved and opportunities to reduce inefficiency and carbon footprints.
Winter and Knemeyer (2013)	Having examined the integration of sustainability and SCM in journal articles on operations and production, society and the environment, and logistics and SCM, it is pointed out that research focused on a single aspect of TBL (i.e., environmental, social, or economic) is more common than research focused on multiple aspects, as well as that qualitative designs are the most prevalent in either kind of research.
Ahi and Searcy (2013)	Having identified and analysed definitions of *GSCM* (i.e., 22 definitions) and *SSCM* (i.e., 12 definitions), the authors identify several differences among the definitions, particularly regarding their views on and inclusion of aspects related to the environment, efficiency, and performance.
Touboulic et al. (2015)	Having investigated theoretical perspectives in SSCM, the authors find that theory building in SSCM is rare and that theories applied most commonly use a few imported macro theories (e.g., a resource-based view, stakeholder theory, and institutional theory). The authors thus propose developing theory for the field—for example, by testing theories from various disciplines other than those frequently used at present—and moving beyond the exploration of drivers and barriers to instead focus on the implementation of SCM.
Fahimnia et al. (2015)	Having conducted a bibliometric network analysis of GSCM-related literature to identify influential works, authors, and emergent areas, a concentration of influential studies are identified among a few scholars and that the field continues to mature as authors expand it in various ways. Five major research clusters are identified: theory development, measurement and evaluation, barriers to practical applications, mathematical modelling and optimisation, and hypothesis, theory, and factor testing.

In what follows, a definition of *green logistics* is presented, and the thesis is positioned within the field of green logistics in relation to the results of the literature reviews.

2.2.1 Definition of green logistics

Interest in green logistics, as well as in GSCM and SSCM, has increased in recent years, and most up-to-date literature reviews indicate an upward trend in publications on the topic (Fahimnia et al., 2015; Touboulic et al., 2015). For instance, Touboulic et al. (2015) identify 308 papers in 15 peer-reviewed journals, and Fahimnia et al. (2015) identify 884 papers from the database Scopus. That the field is growing implies that a range of definitions for *green logistics* and its related concepts are available. Indeed, Ahi and Searcy (2013) literature review lists 22 definitions of *GSCM* and 12 definitions of *SSCM*, with clear differences, particularly regarding their views on and inclusion of aspects related to the environment, efficiency, and performance. Accordingly, they conclude that it is crucial for researchers to clearly identify views on green logistics and their position of research in the field. For instance, in this thesis, McKinnon et al. (2015) definition of *green logistics* is used: 'The study of the environmental effects of all the activities involved in the transport, storage and handling of physical products as they move through the supply chains in both forward and reverse directions. It assesses the nature and scale of these effects and examines the various ways in which they can be reduced' (p. 4). That definition aligns well with the thesis, since it addresses several concepts of the thesis that are important to define, including environmental effect (i.e., environmental impact), logistics activities, supply chain (i.e., what stages of supply chains are studied), the nature of supply chain effects (i.e., which RQ2a and RQ3a address), and ways to reduce those effects (i.e., as RQ2b and RQ3b address).

2.2.2 Position in the field

To position the present research among earlier studies addressing green logistics, in what follows three aspects of the definition of *green logistics* are described (McKinnon et al., 2015): type of environmental impact, actors in the supply chain, and logistics activities. Considering that green logistics is here studied in the context of food, the following also addresses how the reviews have examined product types, if at all.

Logistics: Literature reviews have tended to not address logistics activities or similar terms such as logistics functions. Srivastava (2007) divides research on GSCM by topic, including the importance of GSCM, green design (e.g., life cycle assessment, or LCA), and green operations. Although the research of this thesis would be positioned within green operations according to that delineation, that topic covers a wide spread of work with varying perspectives. Therefore, it is difficult to position this thesis in relation to previous research on green logistics in terms of its focus on logistics.

Actors: In addressing how actors have been studied in research on SSCM, Carter and Easton (2011) show that the most common unit of analysis is a firm (62%) or, to a far lesser extent, an individual (21%), whereas studies of dyads or more than two actors in supply chains account for only 4% of the papers. That finding is arguably surprising, given that many of the papers aspire to contribute to SCM. Although the primary perspective of this thesis is that of individual firms, namely in terms of individual actors in FSCs, since literature regarding food waste stresses the importance of applying a supply chain perspective (Lindbom et al., 2013; Mena et al., 2011), its scope is also extended to supply chains to answer RQ3 about food waste.

Types of environmental impact: Of the nine reviews summarised in Table 2.2, six take the broader perspective of sustainability (Carter and Rogers, 2008; Carter and Easton, 2011; Dey et al., 2011; Seuring and Müller, 2008; Touboulic et al., 2015; Winter and Knemeyer, 2013), whereas three limit their scope to environmental issues (Fahimnia et al., 2015; Sarkis et al., 2010; Srivastava, 2007); no review focuses solely on economic or social issues. Results in the literature reviews, however, are quite dissimilar; four reviews show that many papers focus on environmental concerns, but that few include more than two aspects of the TBL (Carter and Easton, 2011; Seuring and Müller, 2008; Touboulic et al., 2015; Winter and Knemeyer, 2013). By contrast, the reviews rarely discuss what kinds of environmental impact are addressed in reviewed papers. Fahimnia et al. (2015) summarise the most commonly used terms in 884 paper titles—for instance, *life cycle* (50 papers), *energy* (50 papers), *carbon* (40 papers), *water* (25 papers), and *closed loop* (23 papers)—which can help to distinguish types of environmental impact studied. However, since the terms *green* (249 papers) and *environmental* (151 papers) are even more common, arguably many titles do not mention types of environmental impact studied, meaning that probably more papers address the different types of environmental impact than their titles indicate. In this thesis, two types of environmental impact are addressed. First, the impact on climate is common to address within green logistics. Second, it addresses food waste, and for this environmental impact no references to that topic appear in the literature reviews, given its association with only one broad product type. Taken together, the thesis thus examines one commonly addressed environmental impact and one that is more novel within green logistics.

Types of food products: Two reviews address which kinds of industry have been studied in relation to green logistics. First, concerning SSCM, Carter and Easton (2011) show that the most common trend is to apply a multi-industry perspective (49%), although among specific industries, transport (21%) and consumer products (14%) are the most common, whereas the food and beverages industry accounts for only 3% of the papers. In relation to research on specific industries, they state that ‘researchers should carefully select individual industries with the goals of identifying specific types of sustainability activities that are germane to those industries’ (p. 55). Second, Fahimnia et al. (2015) indicate a similar interest in food in their summary of the most commonly used words in 884 paper titles, among which *food* is mentioned in 44, or 5%, of the titles. That trend implies that papers have treated food products in relation to green logistics, though the reviews do not indicate the extent of the focus on food characteristics in particular.

In sum, this thesis follows earlier research in some aspects—for example, by addressing the impact on climate and focusing on single actors. By contrast, its novelty lies in incorporating a perspective on food products, in including food waste as a type of environmental impact, and addressing several stages in supply chains is critical in relation to food waste.

2.3 Food logistics and green logistics combined

Literature reviews on food logistics and green logistics indicate that some authors have addressed combinations of the fields. To gain better insight into those authors’ studies, this section presents research that combines food logistics and green logistics in a structured literature review of the same literature identified in Fredriksson and Liljestrand (2015) structured review, which covers nine highly ranked, peer-reviewed logistics and SCM journals, with two changes. One, the *British Food Journal* is included to incorporate an opposite view on how food science conceives logistics. Two, the publication timespan is expanded to address all papers published until the end of 2015.

In total, 25 papers were identified that address a combination of food logistics and green logistics. The topic has generated increased interest, for 14 of those 25 papers were published in the last 3 years (Figure 2.2). The peak in 2013 was due to a special issue of the *British Food Journal* on corporate social responsibility (CSR) in food and agriculture, which contributed three papers to this analysis.

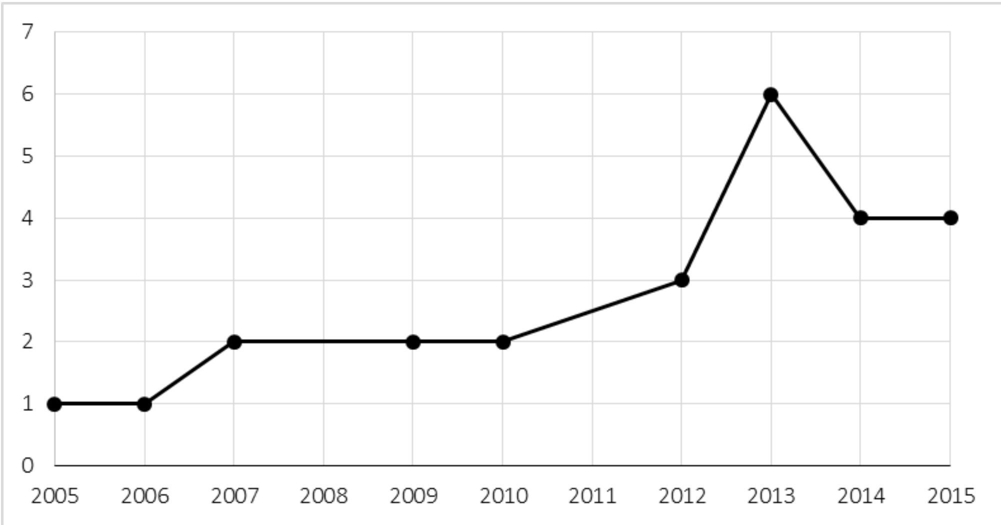

Figure 2.2 Number of papers identified that address the combination of food logistics and green logistics

Table 2.3 provides an overview of the papers identified: first by topic, with a few words describing the content of the papers, and then in terms of four categories, which are the same used to position this thesis among research in food logistics and green logistics. Two clarifications are necessary, however. First, the category of logistics is subdivided into the aspects of SCM, procurement, production, and distribution. According to Christopher (1998), logistics can be classified into procurement, production, or distribution; however, to encompass papers that study relationship management and supply chain design, the category of SCM is included as well. Since many papers address SCM-related topics, SCM is also included as a subcategory, even if logistics is often conceived as a subcategory of SCM (cf. Larson et al., 2007). Second, the last category in the final column differentiates an environmental from a sustainable focus, since many papers claim a sustainable focus that encompasses an environmental impact. By analysing not only the environmental but also the sustainable focus, the thesis clarifies how environmental issues are conceived in the bigger picture. Several papers address CSR, a topic that has always focused on societal issues but that has nevertheless developed into a broader concept that includes all parts of the TBL. Forsman-Hugg et al. (2013) define seven key dimensions of CSR in FSCs: environment, product safety, corporate nutritional responsibility, occupational welfare, animal health and welfare, local market presence, and economic responsibility. Since those dimensions address all parts of the TBL, including environmental aspects, papers that focus on CSR are also included.

Table 2.3 Literature on the combination of food logistics and green logistics

Author(s)	**Topic**	**Logistics**	**Food product(s)**	**Actor(s)**	**Environment-and sustainability-related focus**
Hamprecht et al. (2005)	Supply chain controls	SCM	N/A	Food producers	Sustainability (Environment – not specified)
Vasileiou and Morris (2006)	Supply chain sustainability	SCM	Fresh potatoes	Primary producers, merchants, and retailers	Sustainability (Environment: land and soil quality, irrigation water, and climate)
Aramyan et al. (2007)	Measuring supply chain performance	SCM	Tomatoes	Primary producers, wholesalers and retailers	Sustainability (Environment: energy use, water use, and emissions)
Setthasakko (2007)	Determinants of corporate sustainability	SCM	Frozen seafood	Industrial producers	Sustainability (Environment: not specified)
Pullman et al. (2009)	Sustainability practices and performance outcomes	SCM	Food and beverages	Industrial producers	Sustainability (Environment: facility resource conservation, waste recycling and reuse, and land management)
Spence and Bourlakis (2009)	Corporate social responsibility (CSR) and supply chain responsibility	SCM	N/A	Retailers, with a view on supply chains	Sustainability (Environment: organic farming)
Haverkamp et al. (2010)	Environmental management performance	SCM	Food and beverages	Industrial producers	Environment (Unspecified)
Oglethorpe and Heron (2010)	Operational choices for a climate-conscious agenda	Production and distribution	Various products (e.g., sausage and bread)	N/A	Environment (Life cycle assessment [LCA] and impact on climate)
Svensson and Wagner (2012)	Sustainable business cycles	Procurement, production, and distribution	Dairy	Primary and industrial producers	Sustainability (Environment: unspecified)
Fearne et al. (2012)	Sustainable value chain analysis	SCM	Theoretical		Sustainability (Environment: unspecified)
Soosay et al. (2012)	Sustainable value chain analysis	SCM	Wine	Primary producers, industrial producers, retailers and consumers	Environment (LCA)

Sodano and Hingley (2013)	CSR and state and private intervention	SCM	Theoretical		Sustainability (Environment: impact on climate)
Forsman-Hugg et al. (2013)	CSR for FSCs	SCM	Bread, chicken, and margarine	Primary producers, industrial producers and retailers	Sustainability (Environment: energy use, climate change, water eutrophication, and ecological cultivation)
Wiese and Toporowski (2013)	CSR and agency theory	SCM	Palm oil, chickens and eggs	N/A	Sustainability (Environment: cultivation)
Banterle et al. (2013)	Environmental certification in FSCs	SCM	Fruits, vegetables, and fish products	N/A	Social and environment (Waste, emissions, water, energy, biodiversity, and transport)
Marques Vieira et al. (2013)	Value in organic FSCs	SCM	Organic products	Producers, wholesalers, retailers, and consumers	Environment (Organic)
Kaipia et al. (2013)	Generating sustainable FSCs with waste reduction	SCM	Milk, fish, and poultry	Primary and industrial producers, wholesalers, and retailers	Environment (Food waste)
Menozzi (2014)	Sustainability of cultivation and production	Production	Extra virgin oils	Producers and consumers	Sustainability (Environment: organic)
Manzini et al. (2014)	Comparing container-based solutions	Distribution	Edible oils	N/A	Environment (LCA) and social (Quality and safety)
Rijpkema et al. (2014)	Sourcing strategies for perishable FSCs	Procurement and distribution	Straw-berries	Primary producers and wholesalers	Economic and environment (Food waste)
García-Arca et al. (2014)	Implementing sustainable packaging logistics	Distribution	Frozen seafood	Producers and retailers	Environment (Material selection and food waste) and economic
Matopoulos et al. (2015)	Resource-efficient agri-FSCs	SCM	Theoretical		Environment (Greenhouse gas emissions, carbon footprint, and water footprint)
Bottani et al. (2015)	Logistics efficiency via pooled management	Distribution	Tomatoes	Producers	Environment (Climate change, the ozone layer, particulates, and fossil depletion) and economic

Bloemhof et al. (2015)	Sustainability assessment of FSCs	SCM	Several products	Primary producers, industrial producers, retailers, food service providers, and logistics service providers	Sustainability (Environment: food waste, energy, CO_2 emissions, and water use)
McCarthy et al. (2015)	LCA in FSCs	Production	Poultry	Primary and industrial production	Environment (LCA)

Topics and logistics: Many papers take sustainability as their topic (Aramyan et al., 2007; Bloemhof et al., 2015; García-Arca et al., 2014; Kaipia et al., 2013; Menozzi, 2014; Pullman et al., 2009; Setthasakko, 2007; Soosay et al., 2012; Svensson and Wagner, 2012; Vasileiou and Morris, 2006). Another distinct topic is CSR, as four papers exemplify (Forsman-Hugg et al., 2013; Sodano and Hingley, 2013; Spence and Bourlakis, 2009; Wiese and Toporowski, 2013). Regarding focuses within logistics, a prevalent issue is SCM, as 17 papers demonstrate; a few other papers focus on procurement (2 papers), production (4 papers), and distribution (6 papers). This thesis, with its primary focus on the environmental impact in distribution, therefore contributes to the combination of food logistics and green logistics, since a few papers reviewed address distribution-related issues.

Actors: By type of actor, producers are the most common in the studies; 17 papers address producers, both primary and industrial, whereas four papers address wholesalers, and nine papers address retailers. Three other papers treat consumers and another concerns logistics service providers. Eleven of the papers focus on more than one actor, typically because they address SCM. By comparison, the primary perspective of this thesis is that of single actors in FSCs. Furthermore, since literature regarding food waste stresses the importance of applying a supply chain perspective (Lindbom et al., 2013; Mena et al., 2011), the scope is extended to supply chains in relation to RQ3 (i.e., food waste). The question of which actors in FSCs are studied in order to best address the research questions is answered in relation to sampling in Section 4.1.2.

Types of food products: In terms of products, 17 papers focus on specific products, whereas five others either address several products or do not specify which products they include. These results contradict those of literature reviews in food logistics, in which it is most common to either address food products in general or include many products (Cunningham, 2001; Fredriksson and Liljestrand, 2015; Shukla and Jharkharia, 2013).

Types of environmental impact: The following paragraphs present a description of what kinds of environmental impact have been addressed. First, the number of papers that address sustainability versus environmental impact are identified, and second, papers including the same kinds of environmental impact addressed in this thesis are analysed in relation to RQ2 (i.e., about transport's impact on climate), RQ3 (i.e., about food waste), and RQ4 (i.e., about combining two types of environmental impact). Third and lastly, other types of environmental impacts that are addressed in the combination of food logistics and green logistics are addressed, specifically to assess whether the thesis has overlooked any important environmental impacts.

Regarding their focus in terms of sustainability, of the 25 papers, 13 focus on sustainability in all three aspects (i.e., environmental, economic, and social), five on two aspects, and seven solely on environmental aspects. The papers addressing environmental aspects often include several types of environmental impact, yet not in any great depth. In effect, the results contradict the findings of literature reviews regarding sustainable SCM, since they demonstrate a focus on environmental issues (Carter and Easton, 2011; Seuring and Müller, 2008; Winter and Knemeyer, 2013). That most papers focus on multiple aspects of sustainability implies that they do not explore the various aspects in detail.

In relation to RQ2, which concerns transport's impact on climate, nine papers address emissions or the impact on climate; seven of those papers include the topics among several environmental impacts, while two focus solely on the impact on climate. When studying several types of environmental impacts, it is difficult for those studies to go into any depth regarding the impact on climate, unlike this thesis. Seven of the papers are related to SCM and take a wider perspective than this thesis on the impact on climate; two papers address the impact on climate in distribution (Bottani et al., 2015; Oglethorpe and Heron, 2010), yet have focuses unlike the one in this thesis. Oglethorpe and Heron (2010) use LCA analyses and address production, whereas Bottani et al. (2015) focus on coordinating logistics activities among producers in a regional cluster (i.e., pooled management).

In relation to RQ3, six papers address food waste, five of which were published in the last 3 years, thereby suggesting that food waste is gaining attention in logistics research. Four papers list food waste among several environmental impacts, and two focus solely on the topic exclusively. As for impact on climate, however, it seems difficult for papers focused on several environmental aspects to examine any aspect in depth. The papers focused solely on food waste—namely, Kaipia et al. (2013) and Rijpkema et al. (2014)—are referred to in answering RQ3.

Regarding RQ4, which addresses combining two types of environmental impact, Bloemhof et al. (2015) include both impact on climate and food waste, albeit with more variables. As such, the paper does not go into the kind of depth that this thesis seeks.

The review of papers in relation to the research questions indicates that few studies have addressed environmental impacts in terms of transport's impact on climate and food waste. The papers that have addressed those aspects exhibit differences in scope in relation to this thesis, which implies that they can be used to answer the research questions, but will not overlap with this thesis.

Lastly, other environmental impacts discussed by previous literature are also analysed in this thesis. For example, eleven papers address environmental impacts related to primary production (e.g., land and soil quality, water use, organic farming, and biodiversity). Since this thesis focuses on the environmental impacts of actors further downstream in FSCs, however, those kinds of environmental impact are less relevant to this thesis. In a different vein, four papers conduct LCAs, which benefit from a broad perspective and include all food-related environmental impacts from farm to fork. In their calculations, several types of environmental impact are considered other than the two types addressed in this thesis. Among other differences, four papers address energy usage, which could have been included in this thesis in order to study environmental impacts in logistics systems. In doing that, for example energy usage in warehouses could have also been included. However, the focuses of transport's impact on climate and food waste was considered suitable to focus on the flow in logistics systems.

Altogether, the structured review of food logistics and green logistics combined indicate that many studies have taken a broad perspective involving several types of environmental impacts and other aspects of sustainability. This was a suitable starting point for gaining an overview of the field. This thesis continues on these studies, by focusing on two types of environmental impact in logistics systems.

2.4 Concluding remarks

This chapter had three aims: to define and describe food logistics and green logistics, to position the thesis within those fields, and to further justify the purpose and research questions of the thesis. Those three aims are summarised in the remaining paragraphs of this chapter.

Definitions and descriptions of the fields: Both food logistics and green logistics are expanding fields of research, as recent literature reviews addressing the two fields confirm (e.g., Fahimnia et al., 2015; Fredriksson and Liljestrand, 2015; Shukla and Jharkharia, 2013; Touboulic et al., 2015). However, literature reviews also argue that more research is needed for addressing environmental impact in food logistics systems (Fredriksson and Liljestrand, 2015; Shukla and Jharkharia, 2013), an idea that also takes support from the structured review's finding that few papers address both fields (Table 2.3).

To achieve the first aim, definitions of *green logistics* and *food logistics* were identified that best explain the content of this thesis:

- *Green logistics* as 'The study of the environmental effects of all the activities involved in the transport, storage and handling of physical products as they move through the supply chains in both forward and reverse directions. It assesses the nature and scale of these effects and examines the various ways in which they can be reduced' (McKinnon et al., 2015, p.4); and
- *Food logistics* as the analysis of 'logistics activities within a food supply chain context by problematising food product characteristics and by examining the constellation of food supply chain actors' (Fredriksson and Liljestrand, 2015, p.13).

Position of the thesis: The above definitions of *food logistics* and *green logistics* imply the importance of positioning research in the fields in relation to its treatment of logistics and actors involved. The definition of *food logistics* moreover stresses the role of products, whereas the definition of *green logistics* stresses the need to focus on environmental impacts. To lay a foundation that accommodates those critical points, this thesis was positioned according to all four perspectives in both fields and their combination.

Concerning the focus on logistics and environmental impact, this thesis will contribute primarily to work on logistics systems and on the two types of environmental impacts addressed: food waste and impact on climate.

By contrast, since product type and actors addressed vary from study to study according to which can best illuminate challenges underlying each research question, it is impossible to precisely position the thesis in terms of those components in this chapter. Nevertheless, regarding actors involved in the FSCs, this thesis generally focuses on single actors, as is common in both food logistics and green logistics, yet addresses a supply chain to study food waste, which is common in food logistics but not in green logistics.

In relation to those four components, the literature reviews for each of the two fields have different focuses. Regarding food logistics, the reviews address the field in relation to actors and logistics, although those components are not commonly addressed in reviews of literature on green logistics. Instead, those reviews provide insight into the application of theories in the paper they include, whereas reviews concerning food logistics do not. In both fields, however, the literature reviews provide little insight in what types of environmental impact have been studied. This suggests that reviews in green logistics further could address the papers they study in terms of logistics focus, actors involved, and environmental impact(s) studied. Meanwhile, for reviews in food logistics, it would be interesting to study what theories have been applied and which types of environmental impact are considered. On a side note, because this research is phenomenon driven (see Chapter 4), it is less relevant to position it in relation to grand theories.

Justification of the purpose and research questions: To strengthen the justification of the thesis's purpose and research questions, structured literature reviews by both the author and other researchers were analysed to ensure that the topics addressed have not previously been discussed at length and that there is a need to study the research questions.

As its coverage in previous papers shows, the combined studies of food logistics and green logistics are rather new, meaning that it is difficult to identify well-studied areas whose research requires no additional replication. The exception to that trend is that studies have generally taken a broad perspective, one encompassing several types of environmental impact and other aspects of sustainability, which suggests that such studies do not require extensive replication. However, because this thesis does not take such a perspective, it therefore addresses a topic that has received less attention in earlier research.

For the justification for the thesis's research questions, Fredriksson and Liljestrand (2015) stress a general need for research on environmental impacts in food logistics, which provides support for both the purpose and RQ2–4. At the same time, two literature reviews on food logistics (Fredriksson and Liljestrand, 2015; Shukla and Jharkharia, 2013) further justify RQ1 (i.e., FSC characteristics), which seeks to identify FSC characteristics that can be used to analyse the logistics systems of food products. Lastly, Rajurkar and Jain (2011) and Shukla and Jharkharia (2013) highlight a need to further address food waste and thus provide support for RQ3, which concerns that very topic. That the need for research on food waste receives more attention than the need for research on transport's impact on climate can be attributed to that transport's impact on climate has been a common perspective in green logistics. This thesis is novel in its contribution of a perspective on food products in relation to that impact.

3 Conceptual framework

Based on key concepts identified in the research framework (Figure 1.1), a conceptual framework is developed and presented in this section (Figure 3.1), one that in turn influences the methods used and lays the groundwork for this thesis's analysis. After seven key areas are described (Sections 3.1–3.7), those areas are linked according to different logics used in addressing the research questions (Section 3.8). Literature concerning the seven key areas that inform the conceptual framework are used in two ways:

First, two overarching theories—contingency theory (Section 3.1) and a systems approach (Section 3.2)—are used to formulate the fundamental assumptions of this thesis, yet do not contribute any specific building blocks to any of the logics used in answering the research questions. Briefly, whereas contingency theory is used to describe the context of logistics systems of food products, a systems approach is used to gain a holistic view of those systems.

Second, five areas are drawn upon to create building blocks in the logics used to answer the research questions. In order to illustrate the food logistics systems and their environments, logistics performance variables (Section 3.3) and food supply chain (FSC) characteristics (Section 3.4) are described; the former are used to illustrate the objectives of the logistics systems (Section 1.5), whereas the latter are used to describe characteristics of the products and their flows, both in logistics systems and their environments, in terms of actors up- and downstream in FSCs. Furthermore, since environmental impacts are addressed in terms of transport's impact on climate and food waste, a foundation is established for how both impacts can be studied in logistics systems in Sections 3.5 and 3.6. Lastly, improvement actions examined in order to identify ways to reduce both types of environmental impact in logistics systems are described in detail (Section 3.7).

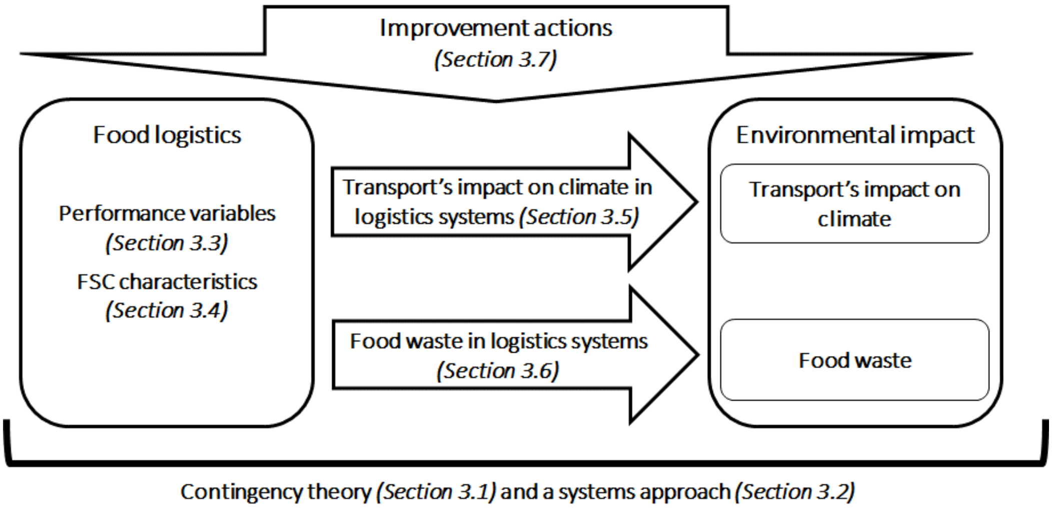

Figure *3.1* Conceptual framework

3.1 Contingency theory

In studies of logistics and supply chain management (SCM), having to adapt research to a context complicates any one-size-fits-all philosophy given the difficulties of applying the same solutions in diverse situations. On that topic, Gattorna (2009) argues that the 'one-size-fits-all philosophy is dead forever, and with it goes all the general approaches to performance measurement and management' (p. 59), and Godsell et al. (2011) add that the 'context-specific nature of supply chains means that it is not possible to develop normative solutions that can be "copy pasted" from one situation to another' (p. 310). In effect, those authors' ideas support the fundamental assumptions of contingency as an alternative to the one-size-fits-all strategy. Briefly, contingency theory holds that there is no best way to organise a company, but that any company's organisation needs to consider both internal and external factors. Three fundamental assumptions of that theory influence this thesis: that organisations are open systems, that there is no one-size-fits-all approach, and that alignment is necessary:

- *Open systems:* For Morgan (2006), 'Organizations are open systems that need careful management to satisfy and balance internal needs and to adapt to environmental circumstances' (p. 42). Accordingly, logistics systems are always open (Jonsson, 2008), which is an important assumption that informs this thesis. By extension, internal needs can be equated to sustaining an efficient material flow, studied by logistics performance variables. Meanwhile, environmental circumstances relates to FSC characteristics for actors up- and downstream in FSCs.
- *Lack of a one-size-fits-all approach:* Consistent with the ideas of Gattorna (2009) and Godsell et al. (2011), Morgan (2006) writes, 'There is no one best way of organizing. The appropriate form depends on the kind of task or environment with which one is dealing' (p. 42). In the context of this thesis, the failure of the one-size-fits-all approach indicates that any proposed framework needs to accommodate the different contexts of logistics systems, which are characterised by FSC characteristics. As such, the structures of frameworks that consider context—for example, Christopher and Towill (2002), Fisher (1997), and Persson (1991)—inspire frameworks developed in this thesis.
- *Need for alignment:* Morgan (2006) also argues that 'management must be concerned, above all else, with achieving alignments and "good fits"' (p. 42). For this thesis, that idea implies the need to balance logistics performance variables in a process known as *alignment*, which entails identifying 'good fits' among variables. The same process is also applied to answer RQ4 regarding the two types of environmental impact, which, in requiring balance, also require FSC actors to ensure good fits (RQ4).

3.2 A systems approach

Applied in logistics research since the 1950s, the systems approach is often conceived to partly form the core of the field (Lindskog, 2012). Among its major assumptions, the systems approach holds that 'decomposing reality into parts is meaningless' and that 'theory . . . is contextual rather than universal' (Gammelgaard, 2004, p. 481). Three points summarise how a systems approach permeates the research design and analysis of this thesis:

- *Food logistics operates in open systems:* Since logistics systems are always open (Jonsson, 2008), they should be studied like all open systems: in the contexts of their environments (Arbnor and Bjerke, 2008). Furthermore, since the environment creates conditions for the components of logistics systems, RQ1 (i.e., about FSC characteristics) focuses on understanding the environments of studied systems in terms of FSC characteristics.
- *Environmental performance needs to align with other logistics performance variables:* It is necessary to strike a balance among logistics performance variables, including customer service, costs, tied-up capital, flexibility, time, and the environment, all of which should align with the company's overall goals (Jonsson, 2008).

- *Any systems approach-based research should capture the holistic view of the phenomenon studied:* Gammelgaard (2004) states that a systems approach is 'often termed "holistic" as opposed to the "atomistic"' (p. 481). To gain a holistic view of environmental impacts in food logistics systems, the thesis's research design involves research questions that address several components and their relationships, in order to first understand the 'atomistic' about each component as a means to later construct a more holistic view of how they interact. Among methods that allow capturing interactions among components, Arbnor and Bjerke (2008) recommend using quantitative and qualitative case studies for any systems approach, a suggestion that the empirical studies in this thesis follow (Chapter 4). Second, to gain a holistic understanding of both types of environmental impact in the logistics systems, RQ4 builds upon results gained from the previous research question (RQ1-RQ3), thereby allowing the environmental impacts to be studied jointly.

Since both contingency theory and a systems approach are used to articulate the fundamental assumptions of this thesis, it is pivotal that the two ways of thinking align, particularly in their emphasis on context and on systems analysis. As Morgan (2006) points out, similar to organisms, organisations are sets of interacting subsystems, and Gammelgaard (2004) adds that any systems approach is contextual. Those ideas indicate the commonality of contingency theory and systems approaches: the importance of systems and context.

3.3 Logistics performance variables

Jonsson (2008) writes that 'by setting up goals defined by performance variables, measuring them and following them up, it is possible to formulate a business approach that supports competitiveness and which accords with the company's assets and the environment' (p. 9). Logistics performance variables—customer service, costs, tied-up capital, flexibility, time, and environment (Jonsson, 2008)—can be used to evaluate how well logistics systems achieve the objective of sustaining an efficient material flow. In the following paragraphs, those logistics performance variables are described:

- *Customer service* refers not only to activities that have to be managed (e.g., invoicing or handling complaints), but also to a performance measure and corporate philosophy (Stock and Lambert, 2001). Elements of customer service can be divided into pre-transactional, transactional, and post-transactional elements (Stock and Lambert, 2001). For Emerson and Grimm (1996), the three logistics dimensions of customer service are availability, delivery quality, and communication.
- Logistics *costs* can be divided into five categories: transport costs, warehousing costs, order processing and information costs, lot quantity costs, and inventory carrying costs (Stock and Lambert, 2001). For many companies, transport costs are the largest (Lambert et al., 1998).
- *Tied-up capital* affects a company's cash flow and, in logistics systems, typically refers to capital involved in the flow of materials, including raw material, production material, and products in distribution systems (Jonsson, 2008). Stock and Lambert (2001) rank inventory carrying costs among logistics costs.
- *Flexibility* in logistics systems emerges in three types: delivery flexibility, product mix flexibility, and volume flexibility (Jonsson, 2008).
- *Time*, as a central variable in logistics systems, is conceived in two ways: in terms of time to customer, which describes the delivery time, and time to market, which measures the innovation capacity according to the period from product conceptualisation to

product launch (Jonsson, 2008). The term *lead time* refers to the time between when an order is received and the receipt of goods (Jonsson, 2008).

- *Environment* represents how well companies reduce the environmental impact of their logistics systems (Jonsson, 2008).

When deciding how to implement improvement actions in order to reduce environmental impacts, actors in logistics systems need to prioritise certain performance variables, which they can do in different ways. For example, to pair SCM and sustainability, Halldórsson et al. (2009) present three approaches. First, the integrated strategy suggests that sustainability should be entirely consistent with SCM, meaning that improvement actions for reducing environmental impacts should be implemented only if they benefit other logistics performance variables as well. Second, the alignment strategy proposes that sustainability should complement SCM's traditional focus on costs and service, meaning that actors can implement improvement actions to reduce environmental impacts even if they compromise other performance variables. Third and lastly, the replacement strategy recommends that actors replace the traditional conceptualisation of SCM with an alternative focused on environmental and social aspects. For this thesis, that strategy implies an emphasis on environmental impact and less consideration of traditional logistics performance variables.

3.4 Food supply chain characteristics

Since RQ1 investigates which FSC characteristics can be used to describe the logistics systems of food products, a brief introduction to those characteristics is provided here.

Given the wide spectrum of food products, it is critical to identify specific food characteristics that create conditions for logistics systems, including product shelf life (e.g. Romsdal et al., 2011) and temperature regime (e.g. Theodoras, 2006). However, not only do characteristics linked to food products have to be considered; among other important aspects to take into account is the stage of the FSC at which actors are positioned. Generally, key actors in FSCs range from primary producers upstream to industrial producers and wholesalers downstream, ultimately ending with retailers. By extension, the distinct roles of those actors, which require facing different challenges and engaging in specific interactions, are salient features of FSCs. For instance, as Taylor (2005) observes, depending on the stage in the supply chain, an actor needs to apply different operational improvements in order to cultivate a lean value chain. Other characteristics that are important to consider include lead time (e.g. den Ouden et al., 1996; van der Vorst et al., 2001) and demand variation (e.g. Taylor and Fearne, 2006). Characteristics not directly linked to products are referred to as *flow characteristics*. In this thesis, the term *food supply chain characteristics* (FSC characteristics) includes both product and flow characteristics.

Addressing FSC characteristics aligns with how contingency theory and the systems approach are applied in this thesis, primarily by stressing the importance of understanding the context, within both the logistics system and its broader environment. Accordingly, the contexts of the logistics systems are described in terms of FSC characteristics, both within the systems and up- and downstream in the supply chain.

3.5 Transport's impact on climate in logistics systems

In this thesis, *transport's impact on climate* refers to the degree to which transport activities affect the climate as measured in CO_2 equivalents. For a better understanding of transport's impact on climate in logistics systems, four frameworks in green logistics are used in this thesis in order to describe how logistics systems influence transport's impact on climate.

First, in analysing an environmentally responsible logistics system (Figure 3.2), Wu and Dunn (1995) describe a framework that follows the flow of products within a company and identifies the logistics decisions within each value-adding logistics activity that contributes to the environmental impact. Those six activities are raw material acquisition, inbound logistics, transformation, outbound logistics, marketing, and after-sales service.

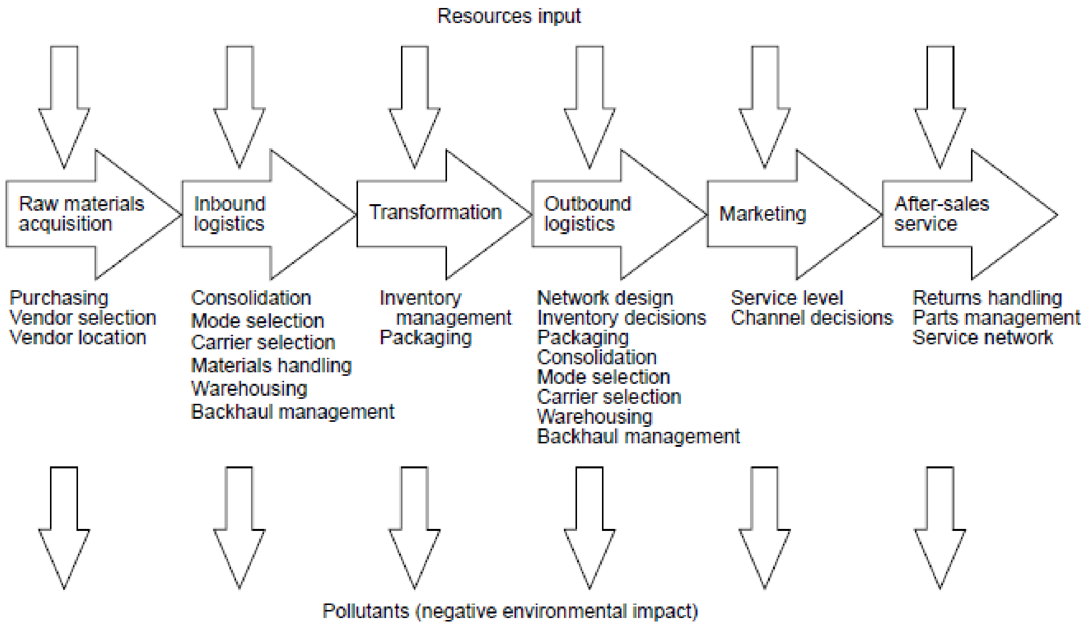

Figure 3.2 Logistics decisions that affect the environment (Wu and Dunn, 1995)

Second, in applying McKinnon and Woodburn's (1996) structure, Nielsen et al. (2003) add the dimension of environmental impact to show that interdependencies exist among logistics decision-making levels and environmental impact (Figure 3.3). CO_2 is included as a variable of environmental impact that relates to transport's impact on climate. Logistics indictors in the third step are similar to the logistics performance variables presented in Section 3.3, explaining how logistics performance variables influence transport's impact on climate.

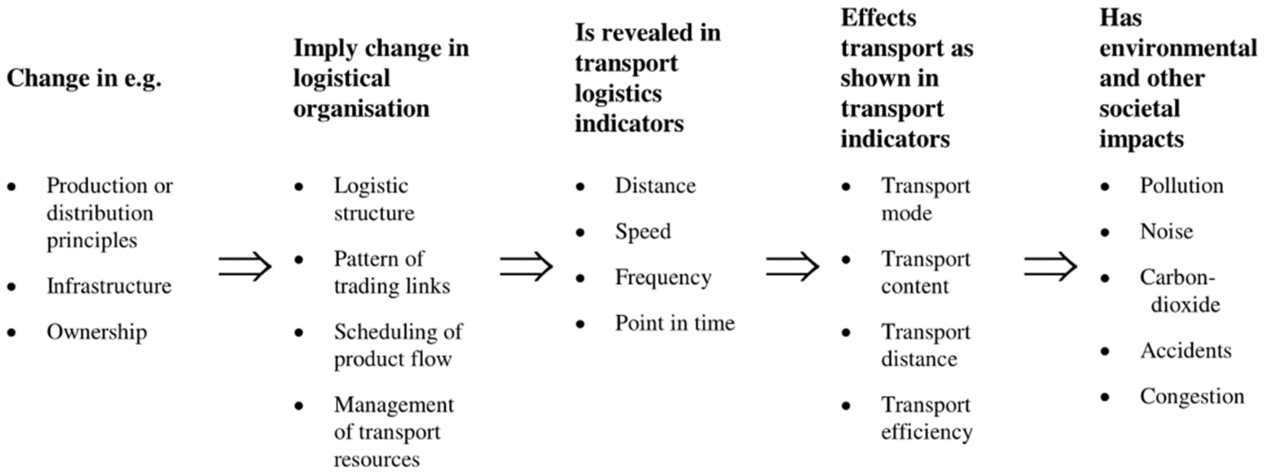

Figure 3.3 Relationships among logistics, transport, and environmental impact (Nielsen et al., 2003)

Third, Aronsson and Huge Brodin (2006) present a framework for different logistics decisions illustrated as a funnel to highlight that, with each step—for example, product designs set a product's weight and volume—possibilities are reduced, which both creates opportunities for and sets limitations on reducing the environmental impact (Figure 3.4). Their framework is also influenced by the four decision-making levels of McKinnon and Woodburn (1996).

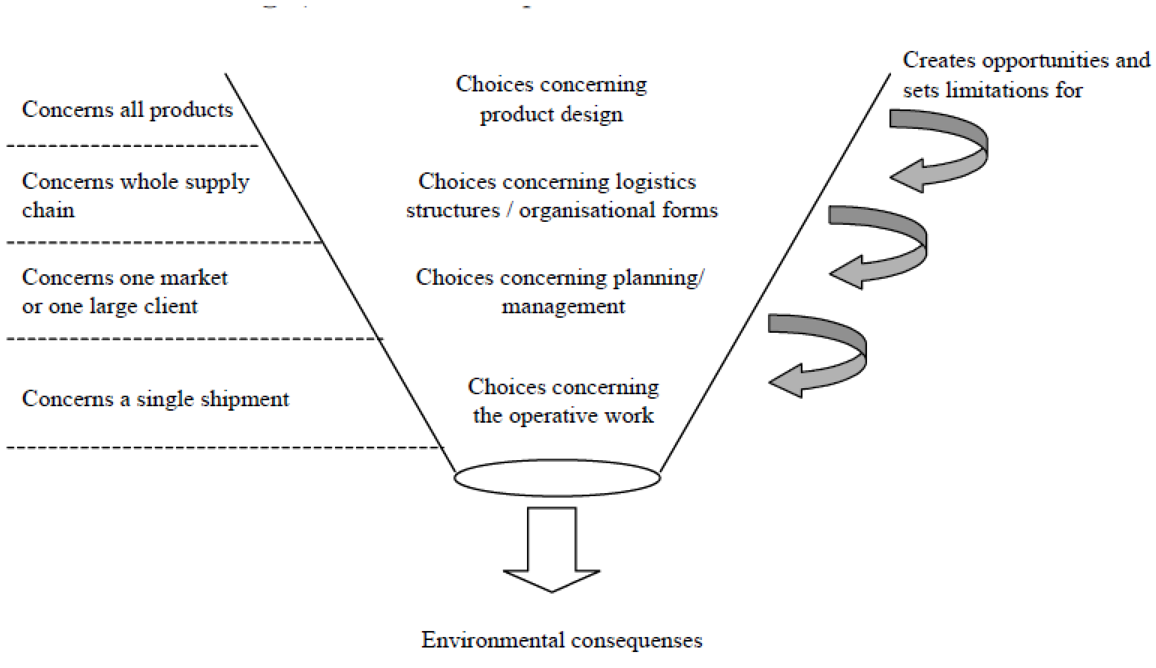

Figure 3.4 Different logistics decision-making levels and their funnel-like relationships (Aronsson and Huge Brodin, 2006)

Fourth and lastly, McKinnon (1995) describes a model of six key variables that affect the environmental output of transportation: the handling factor, average length of haul, modal split, average load on laden trips, average percentage of empty running, and fuel efficiency. Piecyk and McKinnon (2010) further develop that framework by adding a key variable—the carbon intensity of fuel—and by showing how different determinants, also based on McKinnon and Woodburn (1996) framework, affect key variables (Figure 3.5). The ultimate output of the framework is CO_2 emissions, which indicates the framework's focus on impact on climate.

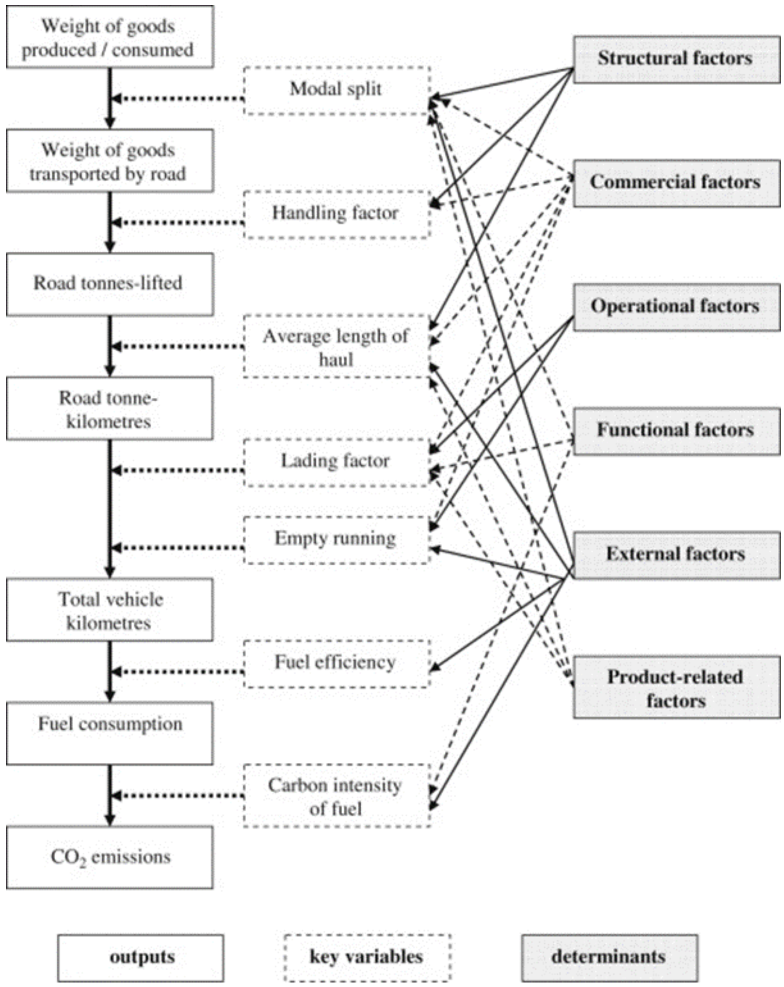

Figure 3.5 Relationships among logistical variables, determinants, and environmental impact (Piecyk and McKinnon, 2010)

Together, the four frameworks demonstrate that the linkage between logistics systems and environmental impacts is complex and that actors can alter several variables at different levels of their systems to reduce those impacts. Wu and Dunn (1995) framework follows the flow of products through a company and, as a result, considers transport to be an issue that cuts across functional lines. In fact, those cuts are the focus of the other three frameworks (Aronsson and Huge Brodin, 2006; Nielsen et al., 2003; Piecyk and McKinnon, 2010), in terms of the relation among logistics, transportation, and environmental impact. Those three frameworks are founded upon the four logistics decision-making levels presented by McKinnon and Woodburn (1996), yet add the perspective of environmental impact.

By extension, the logics of those three frameworks (Aronsson and Huge Brodin, 2006; Nielsen et al., 2003; Piecyk and McKinnon, 2010) are applied in studying linkages among logistics systems, transport activities, and environmental impact, as well as to create a logic for answering RQ2 (i.e., transport's impact on climate). In those frameworks, the term *environmental impact* focuses on transport's impact on climate, but not the impact caused by products (e.g., food waste), thereby making their application feasible for answering RQ2, but not RQ3. The relationship between transport activities and impact on climate is examined with the help of two key variables in Piecyk and McKinnon (2010) framework—modal split and load factor (i.e., average load on laden trips)—both of which can be implemented by actors seeking to adapt their logistics systems in order to reduce transport's impact on climate. On the one hand, *modal split* refers to the distribution between single-mode and intermodal solutions that has been identified as an important means of affecting CO_2 emissions (Behrends, 2011; McKinnon, 2008), as recently confirmed in a European Commission White Paper (2011). On the other, *load factors* improve vehicle utilisation, as McKinnon et al. (2015) attest: 'Raising vehicle load factor is one of the most attractive sustainable distribution measures to companies because it yields substantial economic as well as environmental benefits' (p. 243). Indeed, having created a decision-making tool for the cost-based pricing of transportation services between wholesalers and carriers, Bø and Hammervoll (2010) conclude that 'one of the most important factors in minimizing transport costs is to maintain high "fill rates" on the trucks' (p. 205).

3.6 Food waste in logistics systems

Food waste refers to any food that is discarded despite being appropriate for human consumption, whether it is kept beyond its expiration date or left to spoil (Food and Agriculture Organization of the United Nations, 2013). Food waste affects the environment by exacerbating energy consumption and resource usage, which makes it not only an important societal and environmental concern, but also a concern for companies in FSCs, in which waste affects costs. Food waste in logistics systems studied here refers to waste that occurs at the stages of production, wholesaling, and retail.

In order to study food waste in logistics system, it is important to understand its causes, which previous research has identified in the links between logistics and SCM. Having studied a multitier network, Mena et al. (2014) present a set of propositions to identify management practices that can trigger food waste, all of which are linked to logistics areas, including supply and demand management, availability and inventory management, quality and process control, shelf-life management, and packaging and labelling. Among other recent papers offering insights into how logistics relates to food waste, Amani and Gadde (2015) contribute a platform for pinpointing links between food waste and supply chains, Romsdal et al. (2015) identify how different product types contribute to waste at different supply chain stages, and Batista et al. (2015) present an analytical framework for mapping food waste in supply chains.

In this thesis, Mena et al. (2011) framework is applied to analyse causes of food waste. By studying food waste created between producers and wholesalers, those authors identified three primary root causes for food waste. First, there are *mega trends*, defined as 'industry trends that affect the problem of waste, such as increasing demand for fresh products, and products out of season, as well as a move away from products with preservatives' (Mena et al., 2011, p. 654). Second are *natural constraints*, or 'factors that influence waste, but that are associated with the nature of the products or process. Issues like short shelf-life of fresh products, seasonality of supply and demand, weather fluctuations and longer lead times for imported products are among these factors' (Mena et al., 2011, p. 654). Lastly, *management root causes* are defined as 'factors affecting waste on which management practices have a direct impact' (Mena et al., 2011, p. 654). In effect, those primary root causes form this thesis's foundation for analysing causes of food waste in logistics systems.

3.7 Improvement actions

To analyse how actors in FSCs can reduce the environmental impacts of their logistics systems, improvement actions require sustained attention. To begin, a definition of *improvement actions* is presented that is applicable for both types of environmental impact (Section 3.7.1). However, the two types are described differently, in light of previous research on improvement actions. For transport's impact on climate, on the one hand, research has provided frameworks for identifying improvement actions, and two improvement actions are addressed in this thesis (Section 3.7.2). For food waste in logistics systems, on the other, the literature demonstrates an understanding of causes of food waste, but provides no frameworks for improvement actions that can address those causes. In response, this section focuses on describing improvement actions (Section 3.7.3) and leaves the identification of such actions for empirical data analysis. In that sense, the two different types of environmental impact and how improvement actions are addressed in previous research pose consequences for the research approach (Chapter 4).

3.7.1 Definition of improvement action

Improvement actions are changes to the core of logistics, in other words the 'flow of materials, information, and services' (Arlbjørn and Halldórsson, 2002, p. 25) in order to reduce environmental impact. Improvement actions focus on altering logistics activities (cf. Lambert et al., 1998) that handle the flow of materials and can therefore be defined somewhat more appropriately as a combination of logistics activities that are put in place to adjust or alter the flow or the parameters used to manage the flow, if not both. That definition is intentionally broad in order to avoid the risk of excluding improvement actions; nevertheless, there are two limitations to the definition. First, improvement actions addressed in this thesis occur at the decision-making level of material and information flows, while all decisions made at higher levels—for example, regarding the structure of supply chains and supplier selection—are not addressed (cf. McKinnon and Woodburn, 1996 for the levels of decision making). Second, improvement actions linked to management areas beyond logistics (e.g., category management) are also not addressed.

3.7.2 Improvement actions to reduce transport's impact on climate

The improvement actions examined in this thesis relate to two key variables in transport's impact on climate—namely, modal split and load factor (Section 3.5)—and can reduce transport's impact on climate when actors implement them by adapting their logistics systems. The first action concerns implementing intermodal transport, which increases the use of rail and sea transport, while the second concerns ways to improve load factors. In what follows, both actions are described in terms of possible reductions in transport costs and impact on climate, and barriers for implementation.

Intermodal transport: First, intermodal transport refers to 'the movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes' (UNECE, 2001, p. 17). In general, intermodal transport is thought to decrease both transport costs and transport's impact on climate; since a large part of all transport, dubbed 'the long leg', is carried out at high capacity, it is cost-effective and environmentally beneficial to reduce each loading unit's impact on climate. Janic (2007) shows that intermodal transport involving longer distances and greater load quantities lowers both transport costs and impact on the environment, thereby underscoring the benefits of economies of distance and economies of scale. In a different vein, Roso (2007) determines that implementing a dry port solution (i.e., an intermodal solution) could reduce CO_2 emissions by 25% on average. By extension, having calculated the overall CO_2 intensity of intermodal transport, Craig et al. (2013) ultimately revealed an average intensity of 67 g CO_2/ton-mile, or a 46% decrease from using road transport only.

Among barriers to implementing intermodal transport, one set of challenges stems from current rail infrastructure, rail transport has to, for example, cope with the rigidity of government-owned railways and inadequate long-term access to rail capacity at strategic times (Woxenius and Bärthel, 2008). Rail transport is further characterised by poor punctuality (Sommar and Woxenius, 2007), insufficient availability (Bontekoning et al., 2004), and long transport times (Woxenius and Bärthel, 2008).

Load factor: Second, used to measure a transport mode’s efficiency, *load factor* refers to the ratio of the actual load carried to the maximum possible load for the vehicle (McKinnon and Ge, 2004). There are different measures for load factor, among which weight (e.g. Ülkü, 2011), tonne-kilometres (e.g. Piecyk and McKinnon, 2010), and volume (e.g. Potter and Lalwani, 2008) are common.

Increasing load factors is thought to mitigate impacts on climate and offer more economic benefits by affecting a transport system’s total vehicle-kilometres. For one, transport costs drop with the higher-capacity use of loading units, due to less fuel consumption per load weight, not per vehicle, which means reduced emissions. Furthermore, as Piecyk and McKinnon (2010) indicate, improved vehicle utilisation can offset anticipated growth in road tonne-kilometres.

McKinnon et al. (2015) identify 10 primary barriers to increasing load factors and improving vehicle utilisation: fluctuations in demand, insufficient knowledge of loading opportunities, health and safety regulations, vehicle size and weight restrictions, unreliable delivery schedules, just-in-time delivery, requirements for handling goods, limited capacity at facilities, the incompatibility of vehicles and products, and the poor coordination of purchasing, sales, and logistics. Several studies address similar and other barriers individually, including time windows (Browne and Gomez, 2011; Piecyk and McKinnon, 2010), the use of just-in-time delivery (Piecyk and McKinnon, 2010), frequency, and fluctuations in demand throughout the week (Bø and Hammervoll, 2010).

3.7.3 Improvement actions to reduce food waste

Literature on food waste does not provide the same kind of frameworks as those for transport’s impact on climate. In turn, that difference poses difficulties for pinpointing which improvement actions for reducing food waste should be studied. To avoid the risk of overlooking crucial improvement actions, an alternative approach is presented here for identifying improvement actions that can reduce food waste. The approach consists of strategies for describing improvement actions, but does not specify which actions should be studied.

In what follows, improvement actions are described in terms of three components: logistics activities, actors involved, and coordination mechanisms. First, logistics activities, as a primary term in logistics improvement actions, can be altered to reduce food waste. Second, those activities need to be executed by actors, and in order to study not only separate actors, but the entire supply chain as well, the actors need to be analysed in terms of their stages in the supply chain. Third, since logistics improvement actions can consist of a combination of logistics activities, each executed in the interface between actors at different stages, coordination mechanisms constitute the final component of improvement actions. At this stage of the thesis, however, it is difficult to determine which activities and coordination mechanisms can be identified in empirical studies. As such, this chapter briefly introduces the components, yet refrains from identifying exactly which activities and coordination mechanisms are analysed.

Logistics activities: The Council of Supply Chain Management Professionals (2013) define an *activity* as 'work performed by people, equipment, technologies or facilities' (p. 4). To identify logistics activities in particular, two frameworks have been proposed and used: Lambert et al. (1998) and Jonsson (2008). On the one hand, Lambert et al. (1998) identify logistics activities such as customer service, demand forecasting, distribution communications, inventory control, materials handling, order processing, parts and service support, plant and warehouse site selection, procurement, packaging, return goods handling, salvage and scrap disposal, traffic and transport, and warehousing and storage. On the other, Jonsson (2008) highlights functions of logistics systems thought to be conceptually similar to activities. The functions identified by Jonsson (2008) are forecasting, customer order management, production and materials management, transport planning, procurement, materials handling and internal transport, production, storage, and freight transport.

Actors and their stages in supply chains: Since actors in supply chains execute logistics activities, in this thesis they are analysed from the perspective of their stages in FSCs. In FSCs, food waste is caused both within companies and, as Mena et al. (2011) point out, in intercompany interface; however, research 'has focused on waste generated at specific stages in the chain . . . but not on the interface between stages" (p. 648). Mena et al. (2011) furthermore stress that food waste created in intercompany interface merits additional investigation, as do Lindbom et al. (2013), who estimate that food waste caused by Swedish food producers can be reduced by 50–75%, provided that certain factors (e.g., future research on SCM in FSCs) are put into play. Here, actors able to implement improvement actions are analysed in terms of their stages in FSCs.

Coordination mechanisms: To analyse the link between logistics activities, this thesis pays attention to *coordination mechanisms*, defined as 'tools to address particular coordination problems' (Fugate et al., 2006, pp. 132). In supply chains, coordination can be analysed in terms of interfaces between actors or between activities—for instance, forecasting and transport (Arshinder et al., 2008). In implementing both perspectives, this thesis examines how actors in FSCs coordinate logistics activities. To that end, several frameworks are available for studying coordination mechanisms, including van De Ven et al. (1976), which categorises those mechanisms as forms of impersonal coordination (e.g., rules and procedures), personal coordination (e.g., vertical channels), and group coordination (e.g., scheduled meetings). Among other frameworks, in focusing on price and quantities in contracts, Sahin and Robinson (2002) identify five coordination mechanisms: price coordination using quantity discounts, non-price coordination, buyback and returns policy, quantity flexibility, and allocation rules. Added to that, based on a compilation of several coordination mechanisms, Arshinder et al. (2008) describe four categories of coordination mechanisms in supply chains: contracts, information technology, information sharing, and joint decision making.

3.8 Logics for addressing research questions

The previous sections describe areas in the conceptual framework that will contribute to answering the research questions. Here, those questions are presented in relation to the parts of the conceptual framework that they involve. For RQ2–RQ4, covering several areas in the framework, logics are also presented that are applied in analysis.

RQ1 (i.e., about FSC characteristics): RQ1 seeks to pinpoint which FSC characteristics can be used to describe logistics systems involving food products (Figure 3.6) and, in turn, provide a foundation for answering RQ2–RQ4 in relation to food logistics. Logistics performance variables also serve as a starting point for answering RQ2 and RQ3 in relation to food logistics. However, those variables are not addressed in a separate research question, for they have been elaborated in previous literature, and frameworks that can be applied to answer the research questions are already available.

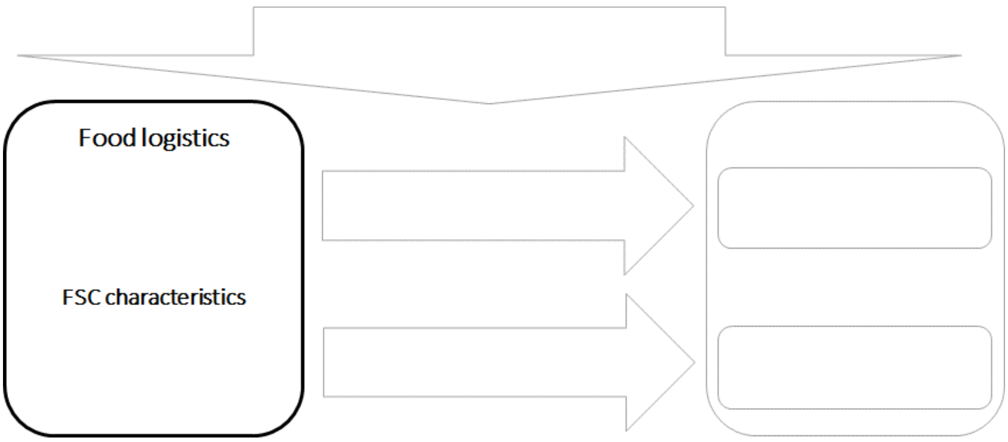

Figure 3.6 RQ1's (i.e., about food supply chain characteristics) relation to the conceptual framework

RQ2 (i.e., about transport's impact on climate): As a two-part question, RQ2 seeks to determine not only how FSC characteristics influence transport's impact on climate, but also how improvement actions in food logistics systems can reduce transport's impact on climate. In relation to the conceptual framework (Figure 3.1), RQ2 focuses exclusively on transport's impact on climate (Figure 3.7).

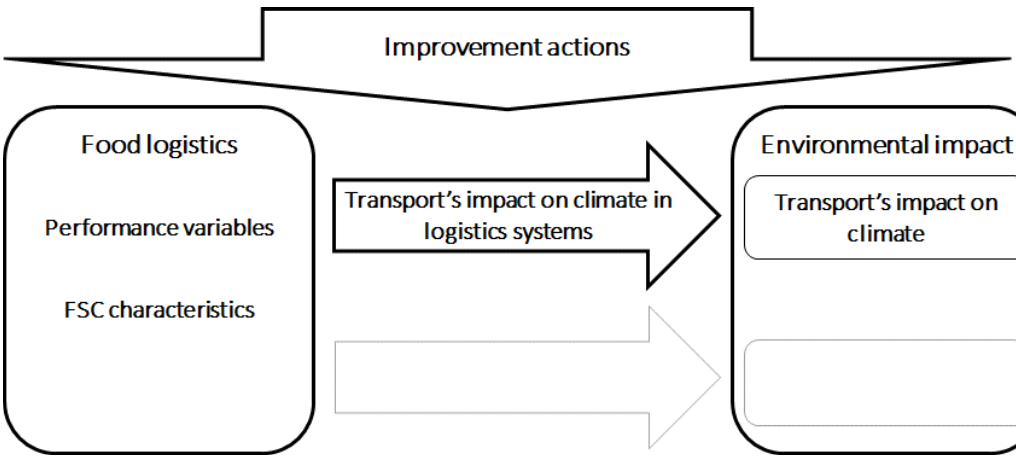

Figure 3.7 RQ2's (i.e., transport's impact on climate) relation to the conceptual framework

To answer RQ2, a logic, divided for each part of the question and more detailed than the overarching conceptual framework, is described and later applied (Figure 3.8).

Part A, or the first part of the logic, focuses on how FSC characteristics and logistics performance influence transport's impact on climate in actors' logistics systems by stressing four components and their interrelationships. The logic of the three frameworks for studying the link among logistics, transport, and the impact on climate (Aronsson and Huge Brodin, 2006; Nielsen et al., 2003; Piecyk and McKinnon, 2010), as well as the four decision-making levels in the framework of McKinnon and Woodburn (1996), are used and their different terms combined to answer the research question. The interrelationships of the components are the focus of analysis.

The first component consists of logistics performance variables and FSC characteristics that are used to illustrate the logistics system. On the one hand, logistics performance variables, described by Jonsson (2008) and reiterated in Section 3.3, demonstrate that other logistics activities influence transport activities; their importance can be observed in the framework of Nielsen et al. (2003), who show that logistics indicators, which are similar to logistics performance variables, influence transport indicators such as transport mode and transport efficiency. On the other hand, FSC characteristics address how products and flow characteristics influence transport's impact on climate. These characteristics are identified as a result of answering RQ1 about FSC characteristics, which, as described previously, can be linked to the first three levels of McKinnon and Woodburn (1996) framework.

Logistics performance variables and FSC characteristics influence the second component—namely, product flow characteristics (PFCs)—which describe the unit of analysis of the logistics system (i.e., shipments). PFCs are linked to the third level of logistics decision making in McKinnon and Woodburn (1996) framework, thereby implying that they are influenced by FSC characteristics linked to the first three levels. PFCs are identified as a result of answering RQ2.

In turn, PFCs influence the third component, which consists of the variables of modal split and load factor (Piecyk and McKinnon, 2010). This link is addressed by Nielsen et al. (2003), for example, who incorporate transport indicators such as transport mode and transport efficiency, even if they are linked directly to logistics performance variables, while the logic applied in this thesis adds the mediating component of PFCs to describe the flow of products. Ultimately, the key variables influence the fourth component—transport's impact on climate (Piecyk and McKinnon, 2010)—which is measured in terms of greenhouse gas emissions.

Part B of the logic for answering RQ2 focuses on how to reduce transport's impact on climate in logistics systems with the help of improvement actions—namely, using intermodal transport and increasing load factors (Section 3.7.2). In the analysis, frameworks are created to understand how actors with several performance variables and a variety of FSC characteristics can reduce transport's impact on climate by applying both actions, as consistent with contingency theory and systems approaches. To create the frameworks, the analysis uses the first part of the logic as a foundation.

Altogether, the components of the logic for answering RQ2 are:

- Logistics performance variables, as per Jonsson (2008) framework (Section 3.3);

- FSC characteristics, taken from the results of RQ1;
- PFCs, developed in RQ2;
- The key variables of modal split and load factor, both from Piecyk and McKinnon (2010) framework (Section 3.5);
- Transport's impact on climate, measured in greenhouse gas emissions; and
- The improvement actions of using intermodal transport and increasing load factors (Section 3.7.2).

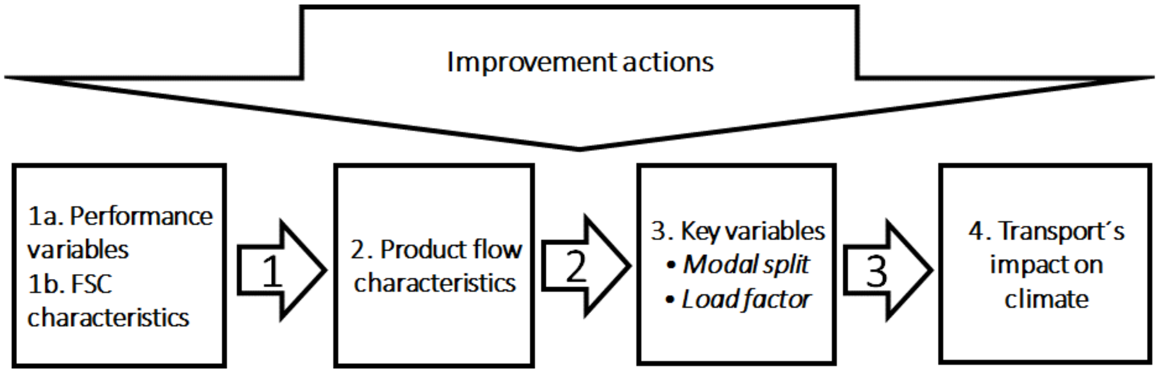

Figure 3.8 Logic for RQ2 (i.e., transport's impact on climate)

RQ3 (i.e., about food waste): As a two-part question, RQ3 seeks to answer how FSC characteristics influence food waste and how improvement actions in food logistics systems reduce food waste. In relation to the conceptual framework (Figure 3.1), RQ3 focuses exclusively on food waste (Figure 3.9).

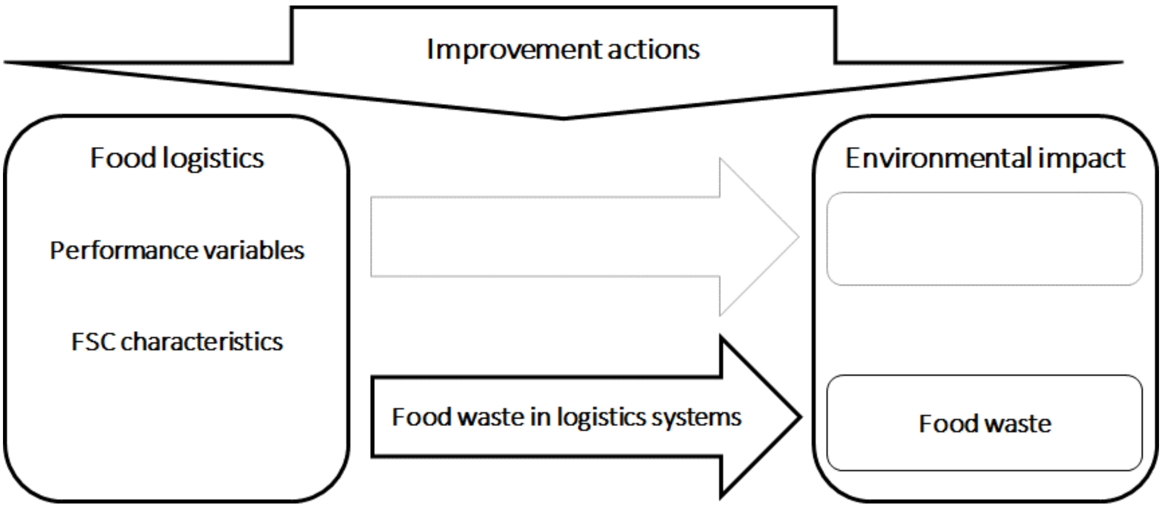

Figure 3.9 RQ3's (i.e., about food waste) relation to the conceptual framework

As with RQ2, to answer RQ3, a logic, divided for each part of the question and more detailed than the overarching conceptual framework, is described (Figure 3.10).

Part A of the logic for answering RQ3 focuses on how FSC characteristics and logistics performance variables influence food waste in actors' logistics systems in terms of three components and their interrelationships, the latter being the focus of analysis. The first component of RQ3 is the same as that of RQ2: logistics performance variables and FSC characteristics. Logistics performance variables and FSC characteristics create the causes of food waste, which is the second component. Causes are analysed in terms of mega trends, natural constraints, and management root causes (Mena et al., 2011), as described in Section 3.6; their relationships are stressed to show how logistics performance variables and FSC characteristics generate causes of food waste, which in turn create the third component: actual food waste.

Part B of the logic focuses on how actors in FSCs can reduce food waste in their logistics systems by improvement actions. Since the literature provides no frameworks for improvement actions, this thesis focuses on identifying and describing improvement actions with the help of three components: logistics activities, actors and their stages in supply chains, and coordination mechanisms (Section 3.7.3). The conceptual framework provides a structure for describing the improvement actions, which are identified in empirical data collection.

In sum, the components of the logic for answering RQ3 are:

- Logistics performance variables, as per Jonsson (2008) framework of performance variables (Section 3.3);
- FSC characteristics, taken from the results of RQ1;
- Causes of food waste, analysed in terms of mega trends, natural constraints, and management root causes (Mena et al., 2011), as described in Section 3.6;
- Food waste, measured by weight, in monetary terms, or in greenhouse gas equivalents; and
- Improvement actions, identified and described in terms of logistics activities, actors and their stages in supply chains, and coordination mechanisms (Section 3.7.3).

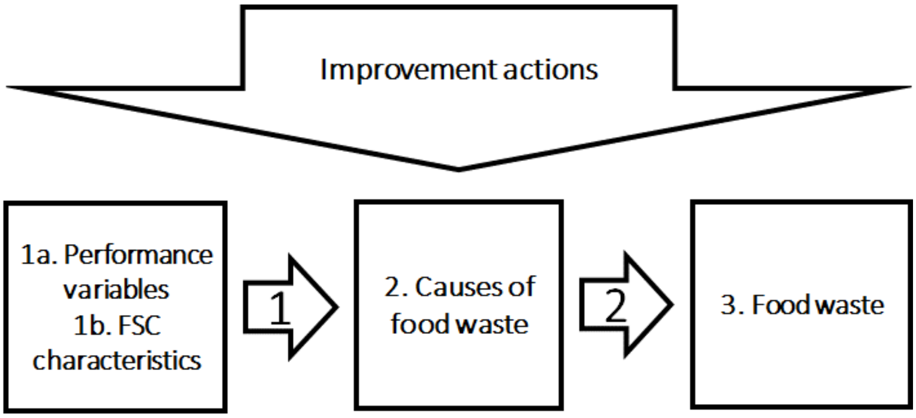

Figure 3.10 Logic for RQ3 (i.e., about food waste)

RQ4 (i.e., about combining two types of environmental impact): RQ4 seeks to study how addressing transport's impact on climate and food waste jointly can contribute to reducing the environmental impact of food logistics systems. In relation to the conceptual framework (Figure 3.1), RQ4 represents a synthesis of the other research questions and therefore encompasses the entire conceptual framework (Figure 3.11).

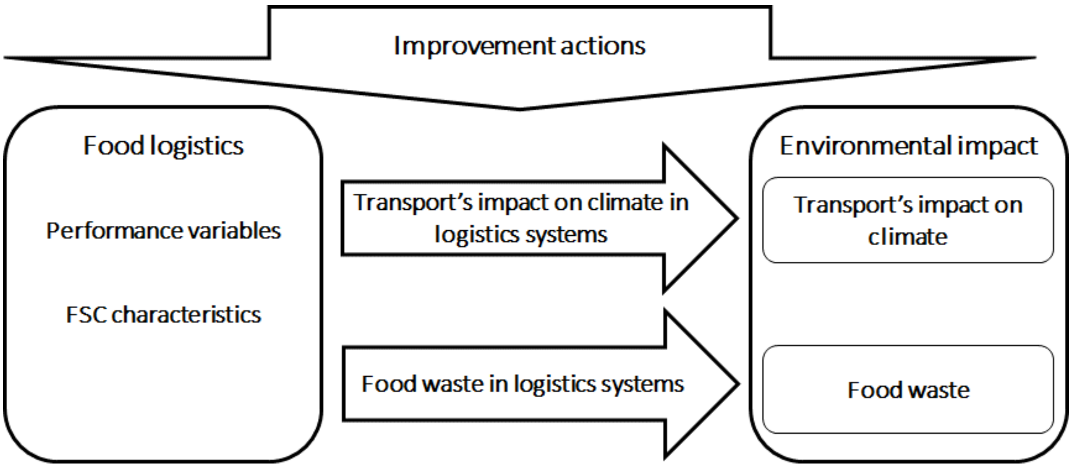

Figure 3.11 RQ4's (i.e., about combining two types of environmental impact) relation to the conceptual framework

As with RQ2 and RQ3, the logic for answering RQ4 is divided according to two parts; the first part focuses on comparing the results of Part A of both RQ2 and RQ3, whereas the second part focuses on comparing the results of Part B of both of those earlier questions (Figure 3.12).

Part A of the logic for answering RQ4 concentrates on how FSC characteristics influence the two types of environmental impact, by comparing the results from the first parts of the logics of RQ2 (i.e., about how FSC characteristics influence transport's impact on climate) and RQ3 (i.e., about how FSC characteristics influence food waste). Those conditions are compared in terms of whether they create trade-offs, converge, or moderate the two types of environmental impact.

Part B focuses on improvement actions. Ultimately, analysis compares the results of Part B of both RQ2 and RQ3.

In sum, the components of the logic are:

- FSC characteristics, taken from the results of RQ1;
- Transport's impact on climate, taken from the results of Part A of RQ2;
- Causes of food waste, taken from the results of Part A of RQ3; and
- Improvement actions, taken from the results of Part B of both RQ2 and RQ3.

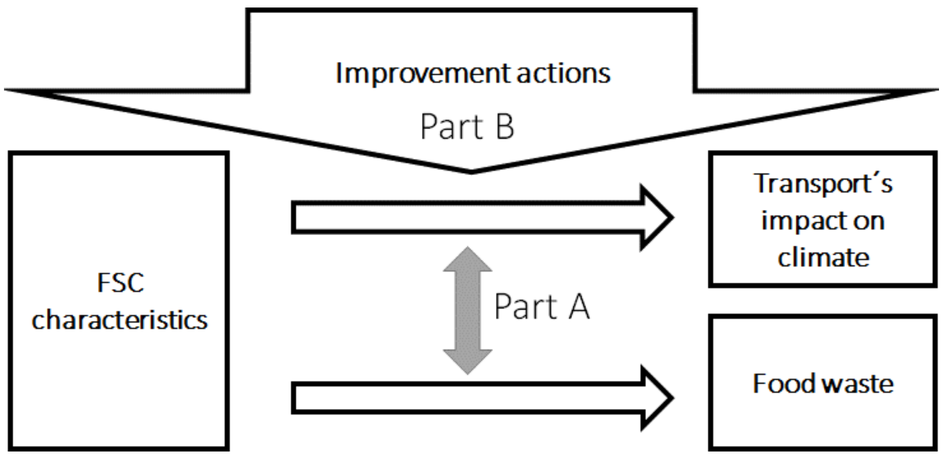

Figure 3.12 Logic for RQ4 (i.e., about combining two types of environmental impact)

4 Research design

A research design integrates the purpose, research questions, methods, and theory of a study. How those four components interrelate, however, can differ. Yin (2009) regards research design as 'linear but iterative' (p. 1), whereas Maxwell (2005) conceives it to be interactive, with an aim to 'form an integrated and interacting whole, with each component closely tied to several others' (p. 4). The development of the research design of this thesis has been interactive, insofar that the components have been developed throughout the process and adapted to each other. Therefore, the research design is here presented according to the framework of Maxwell (2005), which consists of five components: goals, a conceptual framework, research questions, methods, and validity. Each component is briefly described in this section, though more detailed descriptions can be found in other parts of the thesis, as indicated by chapter or section numbers in Figure 4.1.

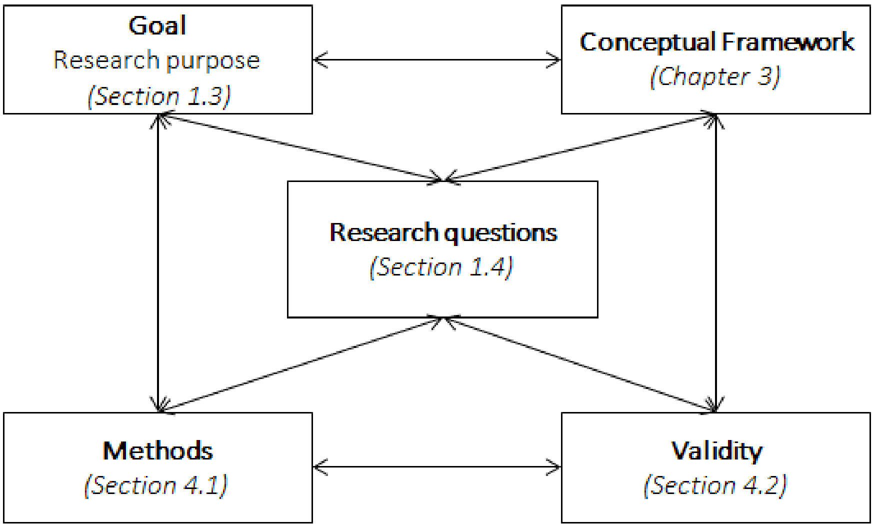

Figure 4.1 Research design, adapted from Maxwell (2005, p. 5)

As the first component, goals concern the relevance of the study, what it seeks to clarify, and what practices it seeks to influence (Maxwell, 2005). In this thesis, the goal is expressed in the purpose of the thesis (Section 1.3), based on the practical problem that actors in food supply chains (FSCs) have to reduce the environmental impacts of their logistics systems. More formally, as stated earlier, the purpose of the proposed research is to explore how actors in FSCs can lower the environmental impacts of their logistics systems in terms of both transport's impact on climate and food waste.

Regarding the second component, Maxwell (2005) defines a *conceptual framework* as the 'system of concepts, assumptions, expectations, beliefs, and theories that supports and informs research' (p .33). In this thesis, the conceptual framework (Chapter 3) influences the research design in two ways. First, the fundamental assumptions of two overarching theories—namely, contingency theory and a systems approach (Section 3.1 and 3.2)—influence the study design; Section 4.1.1 describes the coherence between those theories and the research design. Second, the conceptual framework develops logics for answering the research questions in the analysis (Section 3.8). The literature from which the logics derive mostly addresses the fields of green logistics and food logistics, though also the field of 'general' logistics. How the logics and the literature that inform those logics influence the research design is described in Section 4.1.1.

In relation to the conceptual framework, it is important to discuss how this thesis conceives it contributions. Since the research is phenomenon driven, not theory driven (cf. Schwarz and Stensaker, 2014), the starting point emerged in the phenomenon of environmental impacts in food logistics systems, particularly in terms of the practical problem that actors in FSCs have to reduce the environmental impacts of their logistics systems. In order to investigate the phenomenon, the thesis is, as described above, mostly based on literature from two fields: food logistics and green logistics.

Maxwell (2005) states that research questions are the heart of any research design. In this thesis, four research questions are formulated (Section 1.4), which together aim to fulfil the purpose. The questions are linked in two ways, insofar that answering the latter questions involves applying findings from the previous questions. First, FSC characteristics identified in answering RQ1 (i.e., about FSC characteristics) are used to answer the other three research questions. Second, RQ4 (i.e., about combining two types of environmental impact) combines the results of RQ2 (i.e., about transport's impact on climate) and RQ3 (i.e., about food waste). Figure 4.2 illustrates the links between the research questions, as well as how the conceptual framework, which is based on the logics for the research questions, and the empirical data are used to answer those questions.

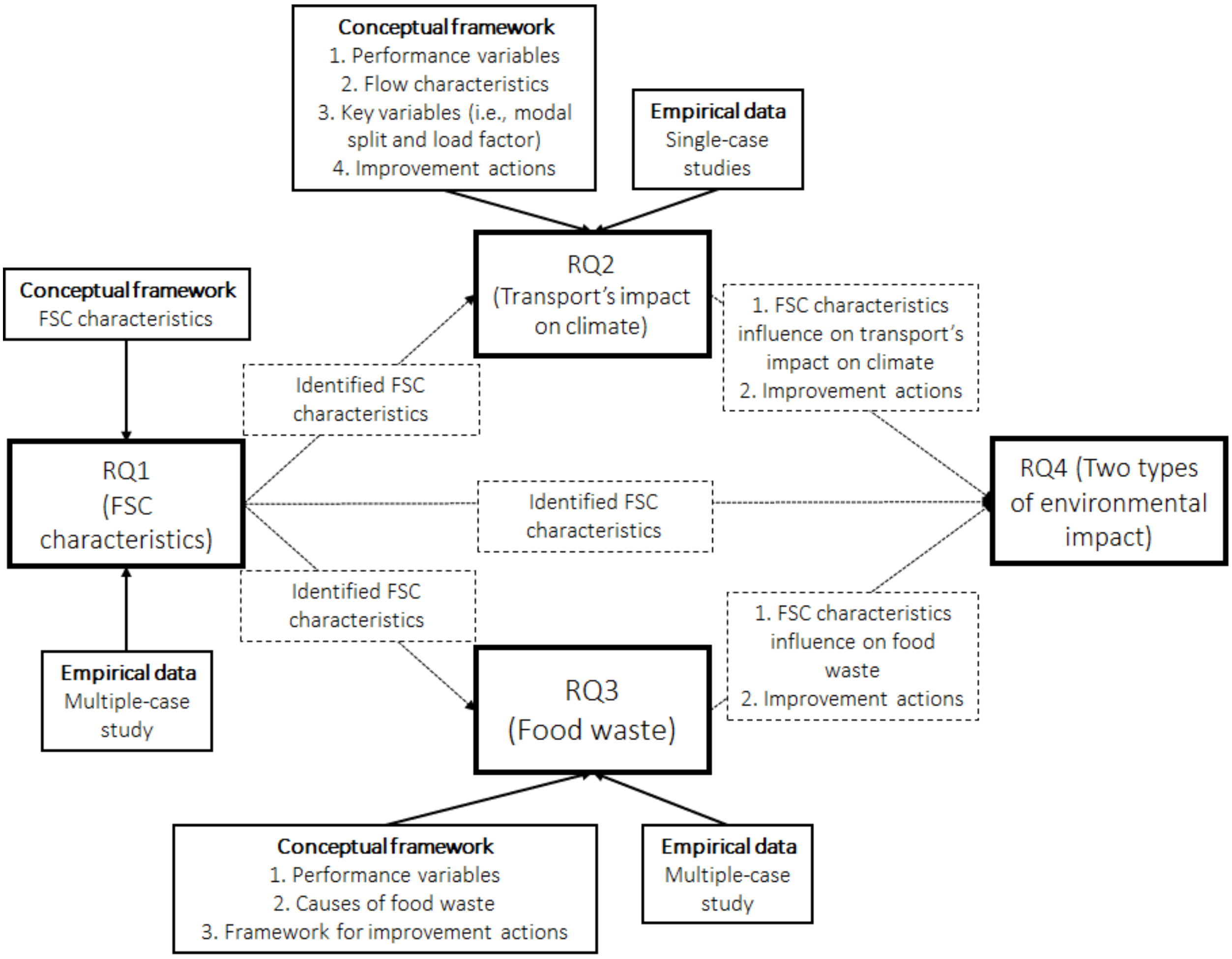

Figure 4.2 Links among the research questions and how the conceptual framework and empirical data are used to answer them

Maxwell (2005) explains that well-constructed research questions are often the result of an ongoing, interactive research process. As Figure 4.2 illustrates, the process in this thesis has been progressive. However, it should be noted that Figure 4.2 represents that process in retrospect only; in reality, the research questions have changed several times throughout the research process.

As the fourth component, methods concern how a study is conducted in terms of approaches and techniques used. Methods can be described in relation to four aspects: their relationship with study participants, sampling (i.e., the selection of settings and participants, as well as of times and places for data collection), data collection, and data analysis strategies and techniques (Maxwell, 2005). Together, those four points have inspired the structure for describing methods used in this study (Section 4.1).

As the fifth and final component, *validity* refers to the 'correctness or credibility of a description, conclusion, explanation, or other sorts of account' (Maxwell, 2005, p. 106). In this thesis (Section 4.2), validity is discussed in terms of research quality (Bryman and Bell, 2011; Halldórsson and Aastrup, 2003).

4.1 Methods

This section describes how RQ1–4 are answered over the course of five studies, whose results are presented in five corresponding papers (Figure 4.3).

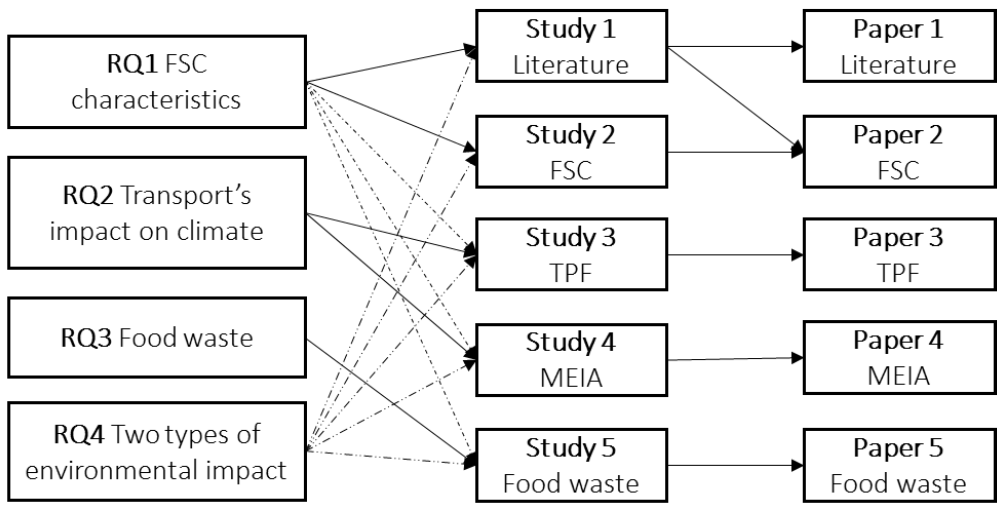

Figure 4.3 Relationships among research questions, studies, and papers (solid lines indicate primary contributions, whereas dashed lines represent secondary contributions; FSC = Food supply chain, TPF = Transport portfolio framework, MEIA = Matrix for evaluating improvement actions)

The methods section is divided into subsections that address the study approach, sampling, data collection, and data analysis (Table 4.1). The approach describes the methods used to answer the research questions, whereas sampling concerns decisions about where to conduct the research and whom to include among the participants (Maxwell, 2005). Data collection describes how data are collected (e.g., interviews), and lastly, data analysis explains how those data are analysed (e.g., via pattern matching).

Table 4.1 Summary of methods

RQ	Study	Approach	Sampling	Data collection	Data analysis
1–4	1	Literature review	Nine logistics and supply chain management journals	Search for the keywords *food* and *perishable*	Axial coding Selective coding of FSC characteristics
1 and 4	2	Explorative multiple-case study	Extreme sampling of four Norwegian food producers	Four semistructured interviews	*Within-case analysis*: Pattern matching of interviews with FSC characteristics from Study 1; *Cross-case analysis:* Comparing cases by how FSC characteristics create conditions for logistics systems
2 and 4	3	Explanatory single-case study	A Swedish wholesaler	*Qualitative and quantitative:* Shipment data and close contact with the wholesaler	Pattern matching with theoretical framework Discriminate analysis and descriptive data
2 and 4	4	Explanatory single-case study	A Swedish industrial producer	*Qualitative and quantitative:* Shipment data and close contact with the producer	Pattern matching with theoretical framework Cost and emissions calculations
3 and 4	5	Explorative multiple-case study	Two producers, two wholesalers, and a retailer, all Swedish	*Primary*: 19 semistructured interviews *Secondary*: Four tours, internal documents, and industry guidelines	*Within-case analysis*: Axial coding and pattern matching of interviews with theoretical framework *Cross-case analysis*: Comparing cases by logistics improvement actions

4.1.1 Approach

The approach describes the methods used to answer the research questions. To that end, the starting point involved identifying whether the four research questions were explorative or explanatory (Marshall and Rossman, 2006; Yin, 2009). In general, explorative research aims to identify or discover important categories, whereas explanatory research seeks to explain patterns or identify relationships that shape phenomena (Marshall and Rossman, 2006). In this thesis, identification was essential to the explorative questions, while understanding was essential to the explanatory ones; method selection was thereby influenced by whether the research questions were explorative or explanatory. An additional category of research questions includes descriptive questions (Marshall and Rossman, 2006; Yin, 2009), which were not the starting point for any of the thesis's research questions, but were nevertheless used to provide depth to the studied phenomenon. For example, when categories were identified through explorative research, describing those categories complemented the explorative step of the process.

Five studies have been conducted in order to answer the research questions. Study 1 is a literature review, whereas Studies 2–5 are empirical studies in form of case studies. A case study is ‘an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident’ (Yin, 2009, p. 18). This definition is used to explain why case studies have been conducted in this thesis; since the phenomenon studied is environmental impact in the context of food logistics systems, it would be difficult to determine the boundaries of the phenomenon and its context. Case studies are also thought to adhere to the fundamental assumptions of contingency theory and the systems approach used. For one, case studies call for a certain degree of openness, which allows an analysis of the context—that is, they adhere to contingency theory. Moreover, they allow the study of how components are interlinked within the phenomenon, which adheres to systems approaches and is in line with Arbnor and Bjerke (2008), who recommend quantitative and qualitative case studies for the systems approach. Below, with a starting point in the research questions, the motivations of the approaches are described for the five studies. For the empirical studies, the motivation includes what kind of case study is applied, as well as what the phenomenon and context are in the case studies (Table 4.2).

Table 4.2. Research approach (RQ = Research question, FSC = Food supply chain, TPF = Transport portfolio framework; MEIA = Matrix for evaluating improvement actions)

RQ	**Type of RQ**	**Study**	**Type of study**	**Case**	
				Phenomenon	*Context*
1	Explorative	Study 1: Literature review	Literature review	N/A	N/A
1	Explorative	Study 2: FSC characteristics	Multiple-case study	FSC characteristics	Two FSCs: salmon (Case 1) and crabs (Case 2)
2	Explanatory	Study 3: The TPF	Single-case study	Transport’s impact on climate	A wholesaler’s logistics system
2	Explanatory	Study 4: The MEIA	Single-case study	Transport’s impact on climate	An industrial producer’s logistics system
3	Explorative	Study 5: Food waste	Multiple-case study	Food waste	Three FSCs: meat (Case 1), fruit and vegetables (Case 2), and ambient food products (Case 3)

RQ1 asks: What FSC characteristics can be used to describe logistics systems of food products? With a starting point of identifying FSC characteristics, the question is explorative; however, those characteristics should also be described, meaning that the question is also descriptive. As such, the approaches chosen were a literature review (Study 1) and a case study (Study 2), the latter of which can be useful for explorative questions (Yin, 2009). First, the literature review identified topics addressed within food logistics literature and FSC characteristics investigated in previous research. Second, to gain better insight into FSC characteristics in logistics systems in order to describe them, a case study with food producers was conducted in Study 2. To be able to identify FSC characteristics in several contexts of those systems, a multiple-case study was chosen. The contemporary phenomenon in the study was FSC characteristics, which were studied in the context of FSCs. Though perhaps a tautological description, since the phenomenon is intimately close to the context, separating the phenomenon from the context would be difficult, which strengthens the arguments for conducting a case study. The two contexts were FSCs with different products: salmon FSCs (Case 1) and a crab FSC (Case 2).

Two papers present the results of Studies 1 and 2, respectively. Whereas Paper 1 provides an overview of food logistics literature and proposes areas for further research, Paper 2 describes characteristics identified from the literature review in combination with the case study. By extension, RQ2 (i.e., about the impact on climate), RQ3 (i.e., about food waste), and RQ4 (i.e., about combining two types of environmental impact) all draw upon FSC characteristics identified, and the studies guided by those questions also involved investigating the characteristics in logistics systems.

Next, RQ2 asks: How do FSC characteristics influence transport's impact on climate (RQ2a), and how can improvement actions in food logistics systems reduce transport's impact on climate (RQ2b)? Since the literature proposes frameworks for identifying components in the logic for answering RQ2 (Figure 3.8), it was unnecessary to conduct explorative studies to identify those components. Instead, the thesis focused on understanding the relationships between components already identified. Yin (2009) argues that questions asking *how* can be explanatory and recommend methods involving case studies, hence the use of a case study to answer RQ2. Two single-case studies were chosen in order to study links in RQ2's logic in greater depth. In both studies, since the phenomenon was transport's impact on climate and the context was food logistics systems, the case is defined as 'transport's impact on climate in food logistics systems', which were studied in two contexts defined by stage in the FSC: an industrial food producer's logistics system and a wholesaler's logistics system. In both studies, quantitative and qualitative data are combined in what is known as mixed-methods research, which has gained popularity in recent years (Bryman and Bell, 2011). Bryman and Bell (2011) argue that a particular benefit of combining qualitative and quantitative methods is that the former can facilitate the interpretation of relationships between variables. That benefit also works to the advantage of the single-case studies conducted for RQ2, which seeks to analyse logistics systems with quantitative data and, along with qualitative data, situate the results within the broader logistics system.

In Study 3, a framework, referred to as a transport portfolio framework (TPF), was created for actors to evaluate their current transport activities in terms of their potential to improve two key variables for reducing transport's impact on climate, by considering the characteristics of shipments. The framework was further developed by applying it on a wholesaler's logistics system, by conducting a single-case study. Later, in Study 4, an additional framework was developed—the matrix for evaluating improvement actions (MEIA)—in order to evaluate the effects of improvement actions for different flows in a logistics system in terms of transport costs, impact on climate, and barriers to implementation. This framework was also further developed by conducting a single-case study of an industrial food producer's logistics system. In sum, to relate Studies 3 and 4 to the logic used to answer RQ2, Study 3 provides narrow focus on understanding how product flow characteristics influence key variables, whereas Study 4 encompasses the question's whole logic in terms of both how logistics performance variables and FSC characteristics influence the transport's impact on climate and improvement actions (Figure 3.8). The studies therefore complement each other in answering RQ2; their results are presented in Papers 3 and 4, respectively.

An explorative question, RQ3 asks: How do FSC characteristics influence food waste (RQ3a), and how can improvement actions in food logistics systems reduce food waste (RQ3b)? Compared to literature on transport's impact on climate, literature on food waste remains sparse; though it provides insights into the causes of food waste, it does not provide frameworks for identifying improvement actions for reducing such waste. In response, an explorative approach was chosen to identify logistics improvement actions to reduce food waste. When research is explorative, a case study can be preferable (Yin, 2009); to answer RQ3, a multiple-case study was therefore conducted in order to identify improvement actions for food waste in food logistics systems in several contexts. The phenomenon of food waste was studied in the context of FSCs and the case was defined as 'food waste in FSCs and studied in three product-based contexts: meat (Case 1), fruit and vegetables (Case 2), and ambient food products (Case 3). To relate Study 5 to the logic for answering RQ3 (Figure 3.10), the study focused on how both logistics performance variables and FSC characteristics generate causes of food waste, as well as possible improvement actions. The results of Study 5 are presented in Paper 5.

Next, RQ4 asks: How can addressing transport's impact on climate and food waste jointly contribute to reducing the environmental impact of food logistics systems? The answer to RQ4 is a synthesis of the findings of RQ1–3 and required no additional studies to be conducted. However, an additional data analysis was undertaken, as described in Section 4.1.4.

Two of the empirical studies were multiple-case studies, while two others were single-case studies, with the difference deriving from whether their starting points were explorative or explanatory. Briefly, when the purpose was explorative and the case studies needed to identify FSC characteristics or logistics improvement actions to reduce food waste, breadth was prioritised by studying several cases. By contrast, when the studies were explanatory, they were undertaken with the help of the logic used to answer RQ2, which was based on a well-covered field of literature. Accordingly, depth was prioritised, for which single-case studies provided an opportunity to study the components identified in logics for answering RQ2 in greater depth. The approach in this thesis can thus be summarised as exploration in range and explanation in depth.

Considering research design, it is important to explain how findings in the literature and empirical material were used in the studies conducted. For instance, Study 1 was based solely upon literature. On the contrary, the four empirical studies, independent of being explorative or explanatory, required moving between the literature and empirical material in a dialogical process. The four studies commenced with searches of the literature in order to gain an understanding of previous literature and to create research frameworks. As data collection proceeded, however, it was necessary to update the searches of the literature and adjust the research frameworks—a process that recurred several times during the studies (Figure 4.4).

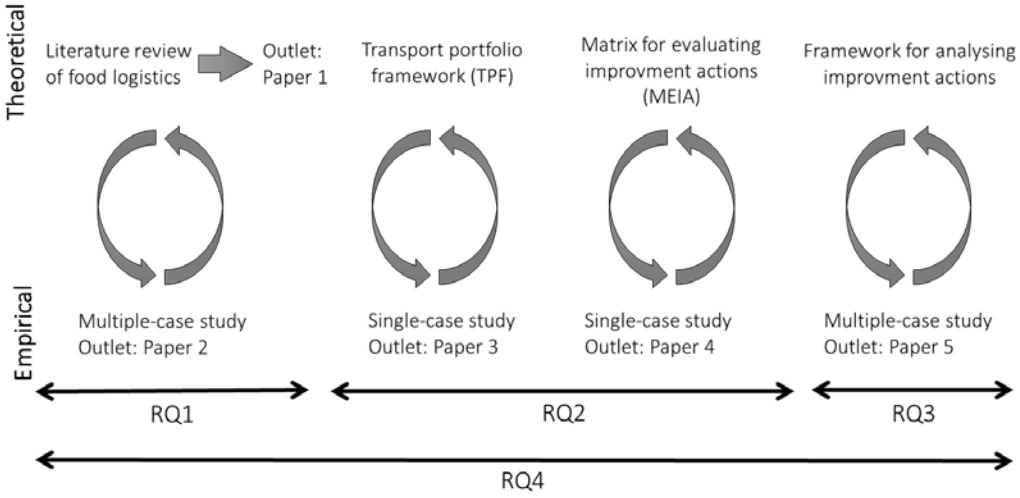

Figure 4.4 Dialogical process of integrating findings in the literature and in the empirical material

4.1.2 Sampling

Sampling involves decisions about where to conduct research and whom to include (Maxwell, 2005). In relation to the empirical studies, the system description (Section 1.5) and literature review (Chapter 2) identified important aspects of sampling: stage of the supply chain (i.e., those of primary production, industrial production, wholesaling, and retailing) and companies responsible for suitable logistics activities and with products in their logistics system that will illuminate challenges addressed in the research questions. By linking those perspectives to the aspects of where and whom (Maxwell, 2005), the question of *where* sought to identify stages in supply chains to be studied. By contrast, the question of *whom* focused on which companies would be interviewed in order to consider which food products could be included and which logistics activities brought into focus. In what follows, those decisions are described for the empirical studies (Studies 2–5). For the literature review (Study 1), the focus was where, which involved decisions about identifying relevant previous research.

Sampling decisions are linked to the findings of Chapter 2 in order to describe whether the choices are in line with previous research or take new perspectives. This description is mostly based on the literature reviews of food logistics, since reviews in green logistics do not elaborate on specific stages of the supply chain or specific logistics activities. At the same time, in terms of products, results from the reviews of green logistics showed a call for more research on specific industries, which all studies in this thesis answer by focusing on food products. Table 4.3 summarises choices in terms of stages in supply chains and types of product for the four empirical studies.

Table 4.3 Sampling

Sampling	Where (i.e., stage in the supply chain)	Whom (i.e., product type)
Study 1 (i.e., the literature review)	Nine highly ranked, peer-reviewed logistics and SCM journals	N/A
Study 2 (i.e., about FSC characteristics)	Four primary and industrial producers	Salmon and crab
Study 3 (i.e., about the transport portfolio framework)	A wholesaler	Mix of several product categories
Study 4 (i.e., about the matrix for evaluating improvement actions)	An industrial producer	Five frozen products
Study 5 (i.e., about food waste)	Two industrial producers, two wholesalers, and a retailer	Meat, fruit and vegetables, and ambient products

In Study 1, two avenues for sampling were conceived: in specific journals or in literature databases. Both avenues posed the risk that important papers would be overlooked. For the literature review of research in food logistics, searching specific journals allowed a search of the highest-ranked supply chain management and logistics journals in a single study and ensured that most important papers would be included. Those papers were also used to identify FSC characteristics, though for that, sampling was extended to databases and snowballing as well.

For Study 2, which sought to identify links among FSC characteristics, the focus is producers in FSCs. Briefly, product characteristics are deemed an important part of FSC characteristics, and producers have in-depth knowledge about products. Regarding whom to interview, the focus was on food products, and producers were chosen with extreme sampling (Flick, 2009; Yin, 2009), which implied that case companies had to have food products with salient characteristics that could help to identify and describe FSC characteristics. If food products with less salient characteristics were chosen, then the risk of not identifying the uniqueness of food products could have increased. In effect, four producers of salmon and crab products in a geographical seafood cluster participated, all of whom were selected with two key product-related attributes in mind: short shelf life and temperature regime (i.e., chilled and frozen). In relation to stages in the supply chain, the salmon producers had responsibility for both primary and industrial production; although primary production was always included, the extent of industrial production differed, ranging from selling whole salmon to portioned products. For the crab producer, the focus was on industrial production; however, the producer collaborated closely with primary production, which consisted of fisheries. Those choices adhere well with the findings of literature reviews on food logistics. First, few previous studies included primary production (Fredriksson and Liljestrand, 2015). Second, both Shukla and Jharkharia (2013) and Fredriksson and Liljestrand (2015) identify a need for more in-depth studies on specific products and the study focuses on specific food products, in which salient food characteristics influenced the sampling choices. Lastly, both Cunningham (2001) and Fredriksson and

Liljestrand (2015) have identified that few studies have been conducted within the fisheries and seafood industry.

The arguments for sampling in Studies 3 and 4 (i.e., about transport's impact on climate) are similar. In terms of where to collect data, being at a specific stage in a supply chain was not deemed important; instead, the focus fell upon which companies could illustrate and develop the proposed frameworks. A necessity was that the companies were responsible for transport activities. In Study 3, a wholesaler's logistics system with a high degree of complexity in terms of range of food products and shipments, as well as with numerous suppliers and fluctuations in demand and supply, was chosen. Those factors of complexity made the wholesaler's system a suitable case for illustrating and developing the TPF, and the choice of studying a wholesaler adheres well with the literature review of Fredriksson and Liljestrand (2015), who identify a lack of focus on wholesalers in previous literature. The choice of including a mix of different product categories was deemed suitable since the underlying challenge of the study was accommodating the complexity of having a wide range of shipments with different kinds of products. In Study 4, by contrast, an industrial food producer was chosen, whose logistics system showed suitable prerequisites for analysing selected improvement actions; prerequisites included a large responsibility for the transport activities and, with that, improvement actions, as well as international flows that could illustrate the improvement actions. Five flows with different kinds of frozen products were included. Although choices about stages in the supply chain (e.g., industrial production) and a focus on several products are common in previous research (Fredriksson and Liljestrand, 2015), the study still takes a distinct position, given its focus on environmental impact, which few previous studies have addressed.

Regarding Study 5, which aimed to identify logistics improvement actions for reducing food waste, the literature indicates a need for research that addresses interfaces among actors in supply chains. It was therefore chosen to include three stages in FSCs in Sweden: industrial producers, wholesalers, and retailers. Wholesalers are the main actor in focus for two reasons. First, wholesalers operate in the middle of supply chains, where they coordinate logistics activities both up- and downstream in the chain. Second, wholesalers are often large and thus privy to a better overview of FSCs than other actors. Sweden and other Nordic countries have the highest market concentration of food wholesalers (Lindow, 2012) among EU member states; in fact, in Sweden, 87% of the market share is split among the three largest wholesalers (DLF, 2016). That circumstance also informed decisions about which companies to include. The author had contact with two of the three largest wholesalers in Sweden, both of which agreed to participate. By focusing on those two companies, Study 5 encompassed a vast portion of the market and offered clear opportunities to identify logistics improvement actions. Two industrial producers were also included: a meat producer and an ambient food producer. The retailer included was in the same company as one of the wholesalers and was thus a major actor. Again, those choices adhere well with the literature reviews. In relation to green logistics, it is uncommon to apply a supply chain perspective involving two or more stages in the supply chain within research on sustainable supply chain management (Carter and Easton, 2011). Therefore, this thesis applies an unusual perspective by involving three stages of the supply chain. In relation to food logistics, having a primary focus on wholesalers is also uncommon (Fredriksson and Liljestrand, 2015) and therefore a novel aspect of this thesis. In relation to food products, three cases with different products were studied: meat, fruit and vegetables (FaV), and ambient products. The cases were chosen to illustrate two chief types of waste identified during a preliminary study: waste due to passed expiration dates and waste due to damaged packaging. Arguably, that decision adheres well with the need to study specific products; however, the product groups chosen involve several products. Nevertheless, focusing on specific products within those groups would limiting the scope too much and increase the risk of overlooking possible improvement actions.

Sampling for the empirical studies differed. For the phenomenon of FSC characteristics and food waste (Studies 2 and 5), an important decision in sampling addressed which stage of the supply chain would be able to identify FSC characteristics or logistics improvement actions for reducing food waste, as well as which companies had suitable products. By contrast, for studies linked to the phenomenon of transport's impact on climate (Studies 3 and 4), sampling focused on which companies assumed a large responsibility for transport activities and for which the frameworks could developed by studying their logistics systems. For the whole thesis, these decisions meant that sampling occurred at three different stages of the FSC and for different food products.

4.1.3 Data collection

For the studies in this thesis, the most common source for qualitative data collection was interviews, although documentation and direct observation were also used. Quantitative data were additionally collected for shipment datasets, whereas data for the literature review were collected by focusing on search terms to locate pertinent research. Table 4.4 summarises the methods of data collection, divided into primary (i.e., designed and planned for) and additional data collection (i.e., performed ad hoc during or following primary data collection).

Table 4.4 Data collection

Study	Primary data collection	Additional data collection
Study 1 (i.e., the literature review)	159 papers	N/A
Study 2 (i.e., about FSC characteristics)	Four semistructured interviews	N/A
Study 3 (i.e., about the transport portfolio framework)	Shipment statistics and regular contact with the wholesaler	Five structured telephone interviews with transport providers
Study 4 (i.e., about the matrix for evaluating improvement actions)	Shipment statistics and regular contact with the industrial producer	Three structured mail interviews with transport providers
Study 5 (i.e., about food waste)	19 semistructured interviews: 15 at two wholesalers, two at producers, and two at retailers.	Site visits and documents

In Study 1 (i.e., the literature review), the terms *food* and *perishable* or *perishability* were sought in the title, abstract, or keywords of papers in selected journals available online. In all, 178 papers were identified, of which 169 included *food*, whereas 24 included *perishable*; most papers including *perishable* also included *food*. A reading the abstracts of the papers revealed that 19 papers addressed non-food perishable items (e.g., blood, hotel beds, and airline seats) and were thus excluded. As a result, 159 papers were ultimately included in the analysis.

Studies 2 and 5—the multiple-case studies—involved similar approaches for data collection, insofar as the primary data collection method was semistructured interviews (Flick, 2009). Semistructured interviews can help to collect data from interviewees in terms of both explicit assumptions captured with open questions and implicit assumptions captured with theory-driven or hypothesis-directed questions (Flick, 2009). For both studies, interviews were recorded and transcribed (an exception were two pre interviews in study 5, were notes were taken instead). In Study 2, four interviews were conducted—that is, one for each producer—with interviewees in management positions: three within logistics and one for the whole company. The interview guide consisted of questions relating to company background, logistics and transportation activities, trends and top challenges, performance measures, role in new structures, services at a food logistics centre (FLC), and the importance of food in a FLC (Appendix A). The focus of the guide was open questions, after which the author asked follow-up questions; however, regarding categories of services in FLCs and performance measures, the interview guide also included theory-driven questions. Although the interview guide did not include specific questions about FSC characteristics, such questions were, however, included in the answers to questions in the guide, particularly regarding logistics and transportation activities as well as trends and top challenges. In order to strengthen the data collection for RQ1, Study 5 included structured questions about the eight FSC characteristics.

In Study 5, 19 interviews were conducted: 15 at the two wholesalers, two at the producers, and two at the retailers. The interviewees ranged from logistics managers to persons responsible for the operations of logistics activities involved in logistics improvement actions. Two of interviews were pre interviews, one at each of the two wholesalers, where the issues of types of waste and case selection were discussed. These pre interviews, except for providing data for the study also helped to develop the interview protocol used in later interviews. The interview guide was divided into specific areas and combined open-ended and theory-driven questions, which allowed empirical data to be analysed with the help of previous literature, as well as data to be collected that were not predicted by the conceptual framework. The areas in the interview guide were job description, company and product characteristics, measurements of waste, causes of waste, and logistics improvement actions in terms of logistics activities and coordination mechanisms (Appendix B). All categories combined open-ended and theory-driven questions, with the exception of measurements of waste, for which only open-ended questions were asked. Prior to the interviews, a set number of questions was identified for all interviewees to answer, although during interviews, time remained for thorough questioning about areas linked to each interviewee's field of expertise. Additional data were collected during four site visits (i.e., direct observation) and document collection; site visits occurred in warehouses and complemented data collected during interviews, chiefly by highlighting examples of issues described during interviews. During site visits, notes were taken and related documents collected, all of which consisted of internal guidelines, industry guidelines, and data sheets.

Studies 3 and 4—the single-case studies—were similar in terms of data collection. For one, the author had regular contact with a representative of each case's company, namely the person most responsible for the logistics system studied: in Study 3, the in Study 4, the external logistics manager. Contact with such actors created possibilities for clarifying ambiguities in the quantitative data and for analysing and discussing the results of quantitative data analysis. In both studies, quantitative data were collected from datasets with information about shipments with the help of Microsoft Excel spreadsheets. In Study 3, data described the retailer's 7,500 import shipments from 263 suppliers in 23 European countries, and for each shipment, data were collected regarding date, supplier, origin (i.e., city and country), destination (i.e., city and country), shipment size (i.e., in pallets), temperature regime (i.e., frozen, chilled, or ambient), and transport mode (i.e., road, rail, or sea). Before data collection began for Study 4, since it was known that data analysis would include calculations performed with the Microsoft Excel tool TrExTool (Fridell et al., 2013), quantitative data collection was designed to gather data necessary for executing data analysis in that program—that is, shipment statistics including distance (km), weight (kg), volume (m^3), number of pallets, transport price (€), and transport time (h). In both Studies 3 and 4, data from the case companies' transport providers were necessary to complement data already possessed by the actors studied. In Study 3, such data were obtained by the author during brief, structured telephone interviews with five transport providers. In Study 4, the representative of the case company conducted similar data collection via email so that the author could observe data collection. Lastly, qualitative data were used to analyse results in the quantitative studies. In both Studies 3 and 4, data collection was performed when the author needed to discuss and validate quantitative results with case study representatives. In Study 4 in particular, the author conducted follow-up interviews with the external logistics manager to identify barriers.

Data collection for the empirical studies differed according to whether the research questions were explorative or explanatory. For studies linked to explorative research questions (Studies 2 and 5), the focus fell upon identifying links among FSC characteristics (Study 2) and logistics improvement actions for reducing food waste (Study 5). To that end, semistructured interviews were deemed the most suitable data collection method, since the format makes it possible to discern both explicit and implicit assumptions (Flick, 2009) about the phenomenon being studied. For studies linked to explanatory research questions (Studies 3 and 4), the target was an in-depth understanding of the logistics systems, for which the unit of analysis was shipments in those systems. In those four studies, it was considered suitable to combine quantitative and qualitative data collection methods, which together elucidated shipments in the logistics systems.

4.1.4 Data analysis

In the studies of this thesis, two primary methods of data analysis were employed: axial and selective coding (Flick, 2009) and pattern matching (Yin, 2009). For quantitative data analysis, discriminant analysis (Hair et al., 1998), descriptive statistics, and the excel tool TrExTool were also used. Table 4.5 summarises the methods used for data analysis.

Table 4.5 Data analysis

Study	Data analysis
Study 1 (i.e., the literature review)	Axial coding of findings by logistics area, types of products, and actor constellation, and selective coding of food supply chain (FSC) characteristics
Study 2 (i.e., about FSC characteristics)	*Within-case analysis*: Pattern matching of interviews with FSC characteristics from Study 1; *Cross-case analysis:* Comparing cases by how FSC characteristics create conditions for logistics systems
Study 3 (i.e., about the transport portfolio framework)	Pattern matching with theoretical framework, including discriminate analysis and descriptive data
Study 4 (i.e., about the matrix for evaluating improvement actions)	Pattern matching with theoretical framework, including cost and emissions calculations executed with TrExTool
Study 5 (i.e., about food waste)	*Within-case analysis*: Axial coding to identify logistics improvement actions and pattern matching of improvement actions with theoretical framework *Cross-case analysis*: Comparing cases by logistics improvement actions

In Study 1, data analysis entailed both axial coding (Flick, 2009), a method that involves shifting between inductive and deductive thinking (Flick, 2009), and selective coding, which focuses on core concepts or variables. On the one hand, axial coding was used to gain an overview of the field of food logistics (Paper 1). In a deductive step, categories for analysis were defined with the help of theory, and in an inductive step, adjusted throughout analysis to create a structure that better represented the content of the material. On the other, selective coding was used to identify FSC characteristics (Paper 2) that could be used to describe or analyse the systems studied.

Studies 2 and 5—the multiple-case studies—relied upon similar approaches for data analysis insofar as their approaches involved two steps: within-case analysis and cross-case analysis. In Study 2, within-case analyses consisted of pattern matching, which ‘compares an empirical based pattern with a predicted one’ (Yin, 2009, p. 136), executed by matching empirical data to FSC characteristics identified in Study 1. Since the pattern was adjusted over the course of data analysis, the framework of FSC characteristics was also adjusted when characteristics identified had not been identified in Study 1, meaning that selective coding in Study 1 had to recommence. In Study 5, the first step of within-case analysis was coding, which involved coding the transcripts in NVivo with axial coding (Flick, 2009) based on predefined categories derived from the framework (i.e., cause of waste, actors, activities, coordination mechanisms, and product type), as well as categories that emerged during coding. During coding, subcategories were first created for causes of waste, activities, and coordination mechanisms by matching empirical material with the research framework. Second, the coded material was studied to identify improvement actions for reducing food waste, first in answers to the question that directly asked interviewees to describe improvement actions for reducing waste, and second in answers to questions regarding work duties, which often mentioned waste because the interviewees knew that waste was the interview topic. With the help of codes made in

NVivo, tables depicting actors, activities, and coordination mechanisms were created to discover improvement actions not identified in previous steps. In all, nine improvement actions were identified and analysed by way of pattern matching (Yin, 2009) with a framework involving logistics activities, actors involved, and coordination mechanisms. In turn, cross-case analyses were used to gain further insights into differences between the cases, as in line with contingency theory, which provides insights into the influence of context and thus encourages transferability to other logistics systems of food products. In Study 2, cross-case analysis was applied to further explore the FSC characteristics and how their influence differed among the cases. In Study 5, Cases 1 (i.e., meat) and 2 (i.e., FaV) were compared in terms of applicable improvement actions and differences in the execution of improvement actions.

In Studies 3 and 4—the single-case studies—empirical material was also analysed in line with Yin's (2009) pattern-matching logic, beginning by matching empirical data with the developed frameworks and analysing the data according to steps developed in the frameworks. This method required quantitative data analysis of different types in the studies: in Study 3, discriminant analysis (Hair et al., 1998) and descriptive statistics, and in Study 4, TrExTool, which was used to calculate transport costs and transport's impact on climate (Fridell et al., 2013). Pattern matching analysis helped to not only illustrate the frameworks, but also to develop them, since they were adapted throughout data analysis.

Data analysis for the empirical studies differed according to whether the research questions were explorative or explanatory. For studies involving explorative research questions (Studies 2 and 5), the focus was to identify links among FSC characteristics or logistics improvement actions for reducing food waste, which both axial and selective coding were used. Once identified, the aspects could be matched with the research frameworks with the help of pattern matching, in order to also add descriptive elements to identified FSC characteristics and logistics improvement actions. By contrast, for studies involving explanatory research questions (Studies 3 and 4), components were already identified, and data analysis focused on pattern matching with the help of the research frameworks.

Analyses conducted to answer the research questions were based on an analysis of the five studies as described above. However, two additional analyses were performed in the analysis to answer RQ1 and RQ4. The analysis for RQ1 was based primarily on the analyses of Studies 1 and 2 as described above, but also included an additional pattern-matching analysis of the results from Study 5. In Study 5, data collected about FSC characteristics were analysed to answer RQ1 by matching the empirical material with the identified FSC characteristics. For RQ4—the synthesis of RQ2 and RQ3—an additional analysis was conducted with the data for RQ2 and RQ3, divided according to two parts. The first part, which focused on how FSC characteristics influence the two types of environmental impact, consisted of pattern matching with the results of RQ1–RQ3. The FSC characteristics (RQ1) were matched with how they influence the two types of environmental impact (RQ2 and RQ3). When no links were possible to identify with the help of the empirical material, literature was used when applicable. For the second part of the research question, which focused on improvement actions for the two types of environmental impact, analysis took its starting point in the four groups of coordination mechanisms identified in the analysis for RQ3. With the help of pattern matching, the frameworks developed in RQ2 were structured according to the four groups of coordination mechanisms from RQ3. Here, however, a weakness emerged due to the data collection methods.

In RQ2, two improvement actions were defined with the help of the conceptual framework, whereas for RQ3, an explorative approach was applied, in which data collection was used to identify improvement actions. That conflict posed a challenge in comparing the results, as well as influenced how normative the analysis could be; for example, it was not considered feasible to develop a framework based on those findings. Instead, to adhere to the speculative nature of the analysis, the results was presented in terms of suggestions for further research.

4.1.5 Reflections on methods selection

Three methodological approaches were conducted during the research process: a literature review (Study 1), multiple-case studies (Studies 2 and 5), and single-case studies (Studies 3 and 4). In this section, methods selection is reflect upon from two perspectives: first, in terms of what primary strengths and weaknesses the different methods implied, and second, in terms of what knowledge was gained by conducting the three different kinds of study. Table 4.6 summarises the main strengths and weaknesses of the methods selected for the five studies.

Table 4.6 Strengths and weaknesses of methods used

Study	Strengths	Weaknesses
Study 1 (i.e., the literature review)	Sampling, in terms of highly ranked journals	Sampling, in terms of excluding papers outside highly ranked journals
Study 2 (i.e., about food supply chain characteristics)	Sampling of companies with extreme characteristics	Sampling, which was limited in terms of stages in the supply chain; only one type of data collection method
Study 3 (i.e., about the transport portfolio framework)	Capacity to combine qualitative and quantitative data collection	Sampling limited to one company
Study 4 (i.e., about the matrix for evaluating improvement actions)	Capacity to combine qualitative and quantitative data collection; close contact with food producers during data collection	Sampling limited to one company
Study 5 (i.e., about food waste)	Sampling with three stages of the supply chain; several types of data collection methods	Data collection, which excluded quantitative data

For the literature review, both the primary strength and weakness related to sampling. Although it was considered a strength to focus on nine highly ranked journals, earlier searches of databases revealed that searches ultimately used overlooked several relevant papers in those highly ranked journals. At the same time, it posed the weakness of excluding relevant papers outside those nine journals. In the end, however, more was won than lost by focusing on a limited number of highly ranked journals. Furthermore, the sampling approach complemented previous literature reviews (Cunningham, 2001; Rajurkar and Jain, 2011; Shukla and Jharkharia, 2013) that had used database sampling.

The two multiple-case studies were conducted at different phases of the research process: Study 2 during the first year and Study 5 during the fourth year. The strength of the methods selected in relation to Study 2 are sampling, particularly in terms of extreme sampling of food products, which helped to illuminate salient FSC characteristics. At the same time, the sampling also posed two major weaknesses. The first was that data were collected at only one stage of the supply chain, a broader view on FSC characteristics could have been obtained had the views of wholesalers and retailers also been included. The second weakness was that only one method of data collection—namely, interviews—was applied, and those interviews were limited to four. In Study 5, two actions were taken to avoid those weaknesses. First, three stages of the supply chain were included—industrial producers, wholesalers, and retailers—to afford a better supply chain perspective. By extension, the stages were studied within the same cases, by interviewing actors at the respective stages who were involved in the same logistics improvement actions. Second, methods of data collection were extended with study visits and documents, and the number of interviews was increased, which meant that the primary weaknesses of Study 2 became the primary strengths of Study 5. A further lesson learned from conducting Study 2 concerned the dependability of the study. In that study, the difficulty of obtaining an overview and avoiding bias in data analysis when material is analysed manually became clear. Therefore, the software NVivo was used to code, and both predefined and emerging categories were applied. Given the amount of data in Study 5, using NVivo was of enormous help. A weakness of Study 5 was that it did not include quantitative data in order to quantify the improvement actions. Although doing so would have further strengthened the results, it was considered better to focus on identifying, describing, and analysing the improvement actions jointly. In that sense, quantification of the results could be a continuation for further research.

Both in-depth single-case studies were conducted during the first (Study 3) and second years (Study 4) and share similarities in terms of strengths and weaknesses. The primary strength of both studies was that they combined quantitative and qualitative data. During Study 3, the value of the strategy of combining quantitative and qualitative research to conduct in-depth case studies became quite clear. However, the benefits of mixed-methods research were not as apparent initially, and qualitative data collection was not planned in advance, but instead collected piecemeal during the analysis of quantitative data. In light of that experience, data collection for Study 4 was planned differently—namely, by assuring that close collaboration with the studied actor and both quantitative and qualitative data would be possible throughout the process. Doing so afforded a more in-depth understanding in Study 4 than in Study 3 of the quantitative results of the broader logistics system. Consequently, for Study 4, a strength was also close contact with the food producers during data collection. Both studies also have the same primary weakness: that sampling was limited to one company. This limitation is common in single-case studies and was a conscious choice for enabling more in-depth research. To reduce the effect of the weakness, considerable thought was put toward finding companies that could illustrate the challenges posed in the research question in order to increase the findings' transferability to other settings. However, even though a suitable case company was identified, the empirical material remains based on only one company.

4.2 Research quality

Quantitative research is often appraised in terms of conventional criteria of quality: internal validity, external validity, reliability, and objectivity. These criteria are also often used in qualitative research, though some arguments hold that the quality of qualitative research should not be judged according to the same criteria as quantitative research (Dubois and Araujo, 2007; Flyvbjerg, 2006). For instance, in line with contingency theory, Flyvbjerg (2006 p. 224) states that ‘concrete, context-dependent knowledge is, therefore, more valuable than the vain search for predictive theories and universals’. Consequently, generalisability is not always the goal of qualitative research, and criteria for judging qualitative research must be adapted. To that end, Halldórsson and Aastrup (2003) and Bryman and Bell (2011) propose four criteria for trustworthiness—credibility, transferability, dependability, and conformability—to guide decisions about the research design. Since Study 1 was a literature review, however, only dependability and confirmability are discussed in what follows.

4.2.1 Credibility

In the conventional sense, *credibility* is synonymous with validity, for both concern similarity in the constructed realities of respondents and the researcher’s representation (Halldórsson and Aastrup, 2003). In this thesis, two approaches were applied to ensure credibility: respondent validation and triangulation.

In Studies 2 and 5—the multiple-case studies—credibility was ensured by having interviewees read the case descriptions and results based on their interviews. In Study 2, three of the four interviewees replied to confirm that they agreed with the material; since the other respondent who did not reply had the same description as two of the other respondents, the nonresponse was not considered to influence the credibility of the research. In Study 5, all interviewees responded to either confirm the results or suggest minor changes. Furthermore, all interviews conducted in Study 5 were complemented with site visits and documents for what amounted to a triangulation of sources.

By contrast, in Studies 3 and 4—the single-case studies—respondent validation continued throughout data analysis. Credibility was strengthened by discussing results with representatives of the case companies, which enabled the triangulation of sources by combining quantitative and qualitative data.

4.2.2 Transferability

In the conventional sense, *transferability* refers to generalisability and highlights the importance of describing the context of research so that findings can be transferred if similarities emerge between sending and receiving contexts (Halldórsson and Aastrup, 2003). With a foundation in both the systems approach and contingency theory—namely, that no one-size-fits-all solutions exist—transferability is crucial in the present research, which has to be conducted and described to ensure that findings can be transferred to other settings. Emphasising context by way of case studies is a way to accomplish that end (Eisenhardt, 1989), as is providing thick descriptions with a rich account of the details (Bryman and Bell, 2011). In this thesis, which includes single- and multiple-case studies with a limited number of cases, two approaches were applied to ensure transferability to other contexts. One entailed describing the studies’ research frameworks in the papers to enable the frameworks’ transfer to other contexts; the other involved using case descriptions to help readers to understand whether the case findings could be transferred.

Regarding transferability, this thesis posed three primary challenges. First, the cases included certain products, meaning that many food products were not studied. As a result, there is a risk that the findings cannot be transferred to logistics systems for other products, and that risk increases when extreme sampling is applied, as in Study 2. In response, the risk was mitigated by presenting the results of RQ1 as a list of FSC characteristics; by describing those characteristics, actors with other types of products could compare their own products' characteristics with those studied in order to observe similarities and differences and thereby understand whether the findings are transferable. In other words, FSC characteristics can help to guide what should be included in a case description. The risk was also reduced by performing cross-case analyses, which provided an understanding about which results were transferable between product groups, as applied in both Studies 2 and 5. The second challenge stemmed from the cases' referring only to Nordic contexts (i.e., Study 2 in Norway and Studies 3–5 in Sweden). Sweden and other Nordic countries have the highest market concentration of food wholesalers (Lindow, 2012), which could have influenced the studies. When applying the findings in the contexts of other countries, that difference should be taken into consideration. Third and lastly, the food producers included were large companies. The description of Swedish FSCs reveals differences among stages of FSCs in relation to company size. Both primary and industrial producers are often rather small actors, whereas the producers examined in the thesis are large, according to statistics about company sizes in Sweden (Section 1.5.4). In fact, all except the crab producer, which had roughly 80 employees, had more than 100 employees. As such, the findings of the thesis should be transferred to small producers with caution.

4.2.3 Dependability

Conventionally, *dependability* is synonymous with reliability and indicates that the research process is documented in terms of problem formulation, participant selection, fieldwork notes, interview transcripts, and data analysis decisions, among other aspects (Bryman and Bell, 2011). In this thesis, dependability was ensured with a thorough documentation of the research process.

In all studies, method descriptions referred to sampling, data collection, and data analysis. For the multiple-case studies (Studies 2 and 5), interview guides were used, and interviews were both audio-recorded and transcribed (with the exception of the two pre interviews in study 5 for which notes were taken). For Study 5, NVivo was used, which makes it possible to follow the coding of the material. For the single-case studies (Studies 3 and 4), which focused on replicating calculations, all data files were saved: in Study 3, with Excel and the Statistical Package for the Social Sciences, and in Study 4, TrExTool.

4.2.4 Confirmability

Also conventionally, *confirmability* is synonymous with objectivity and can be achieved by having an external actor assess a study's results (Halldórsson and Aastrup, 2003). In this thesis, confirmability is discussed in terms of division of work among coauthors and how the primary author has presented and discussed results with both academic and industry representatives.

For the three coauthored papers (Papers 1–3), collaboration among the authors had to ensure confirmability. For Paper 1, data analysis was divided between the authors, and to ensure that they did not follow different processes of evaluation, several papers were read twice, and results were determined by consensus. During that process, the authors worked together closely, and if any doubt arose regarding how to classify certain papers, then the situation was discussed immediately. For Paper 2, the primary author conducted all interviews, and to ensure that the results could be analysed by both authors, all interviews were transcribed. Even though one author conducted the interviews, both authors maintained an ongoing dialogue throughout the process. For Paper 3, the primary author performed data collection and analysis in a similarly ongoing dialogue with the other authors.

To gather input from other academics, the most common method was to present papers at conferences and receive feedback from attendees, although participation in workshops and visits to other universities were other means used. For example, the results of Study 1, as part of a research project focused solely on food logistics, were presented and discussed at a seminar in 2012, in which the other author of Paper 1 participated. The results of Study 2 were presented at the 2012 ELA Doctoral Student Workshop, as well as at the EurOMA 2012 Conference, where feedback received was later applied to the present version of the paper. The results of Study 3 were presented at two academic conferences in two papers; delivered at NofOMA 2012, the first paper focused on the example case and identified product flow characteristics, whereas the other paper, presented at LRN 2012, added the dimension of the TPF. Input about Study 5 was received at two visits to research groups, both known for their expertise in food logistics: Operations Research and Logistics at Wageningen University and the Supply Chain Research Centre at Cranfield University. During both visits, seminars were organised, in which the author presented and received input on preliminary findings. Further, individual meetings were held with researchers in those groups. Lastly, a previous version of that paper was presented at LRN 2015.

To receive input from industry players, presentations were similarly delivered at conferences and workshops. The results of Study 2 were presented at a Food Port workshop in which several interviewees participated, while the results of Study 3 were presented at both the Food Port Midterm Conference 2012 in Gothenburg and the 2012 Logistics and Transportation Conference in Oslo. Later, the results of Paper 4 were presented at the Food Port Final Conference 2014, together with a representative of the case company. For Study 5, the author delivered three presentations at industry conferences during 2015: Renovas Miljödag, Recyclingdagen, and KNEG Resultatkonferens. The presentations afforded useful feedback about the results and analysis, thereby helping the primary author to avoid bias.

4.3 Research process

Pre-licentiate thesis: The research process began in 2011 as part of the Food Port, an Interreg project that aimed at ‘developing the North Sea Region as the best food cluster and hub in Europe for food products delivered via efficient and sustainable transport systems’. The Food Port involved 18 partners from six countries, including regional authorities, institutions of higher learning, the food industry, and ports, to study how transporting food products affects the climate, an aim which aligned well with the thesis’s purpose of reducing that impact. The Food Port project and, to a lesser extent, Västra Götaland County financed the research process as part of the licentiate degree.

Pre-study: Research began with planning the overall process, which was ultimately presented as part of a research proposal in August 2011. During the beginning of 2011, the author and a representative of Västra Götaland County visited producers and wholesalers in order to identify challenges in food logistics in the area, which informed the design of the overall research process. The pre-study also generated valuable relationships with industry players, whom the author contacted for data collection in later studies.

Studies on food logistics (RQ1): Data collection for answering RQ1 began in 2011. On the one hand, Study 1 was a literature review conducted until late 2013 with the purpose of providing a better overview of food logistics, as well as of identifying FSC characteristics. On the other, Study 2 was an empirical study conducted to elucidate FSC characteristics. Furthermore, as part of the Food Port project, which focused on a cluster of salmon producers and could thus illuminate the feasibility of establishing a food logistics centre and sea-based transport solution from Norway to central Europe, a case study was arranged in collaboration with a Norwegian Food Port partner that included salmon and crab producers in the cluster.

Studies on transport's impact on climate (RQ2): A few months into the research process, Study 3 began with the collection of a quantitative dataset of the shipment statistics of a large Swedish food wholesaler. Data collection continued in a series of follow-up interviews with the wholesaler's import logistics manager. In the beginning of the fall 2012, Study 4 began as another single-case study, this time involving close collaboration with the industrial producer's external logistics manager.

Parental leave: For most of 2013, the author took parental leave.

Cover of licentiate thesis: After returning from parental leave in late 2013, the author began writing the licentiate thesis, titled 'Efficient Food Logistics to Reduce Transport's Impact on Climate: A Shipper's Perspective' and presented in May 2014. The thesis focused on areas of food logistics and transport's impact on climate. The two research questions presented in the licentiate thesis bear similarities with the current versions of RQ1 and RQ2. During that period, the author also wrote a first version of paper 4.

Post-licentiate thesis: Following the completion of the licentiate thesis, the research process was financed by the Increased Transport Efficiency through Better Utilisation of Loading Capacity project, which also involved the Swedish Transport Administration, Logistik och Transport Stiftelsen, and three private companies, two of which handle food products. However, since the author needed to extend the scope of the research by addressing the environmental impact of food waste to better understand food products in logistics systems, Study 5 was designed to focus on food waste and to answer RQ3.

Study on food waste (RQ3): Commencing in early 2015, Study 5 was a multiple-case study focused on food waste in Swedish FSCs. During Spring and Fall that year, the author conducted interviews with producers, wholesalers, and retailers, after which she wrote the paper 5.

Cover of the thesis: From late 2015 through mid-2016, the author wrote the cover of the thesis. The answer to RQ4 represented a compilation of results from previous studies without any additional data, and the analysis of the question was included in the thesis writing.

Figure 4.5 illustrates the research process. The work conducted for each study is represented in terms of data collection and paper writing, although the division between stages was not as clear as the figure indicates. The author shifted between theory and empirical data, which caused paper writing to begin during data collection.

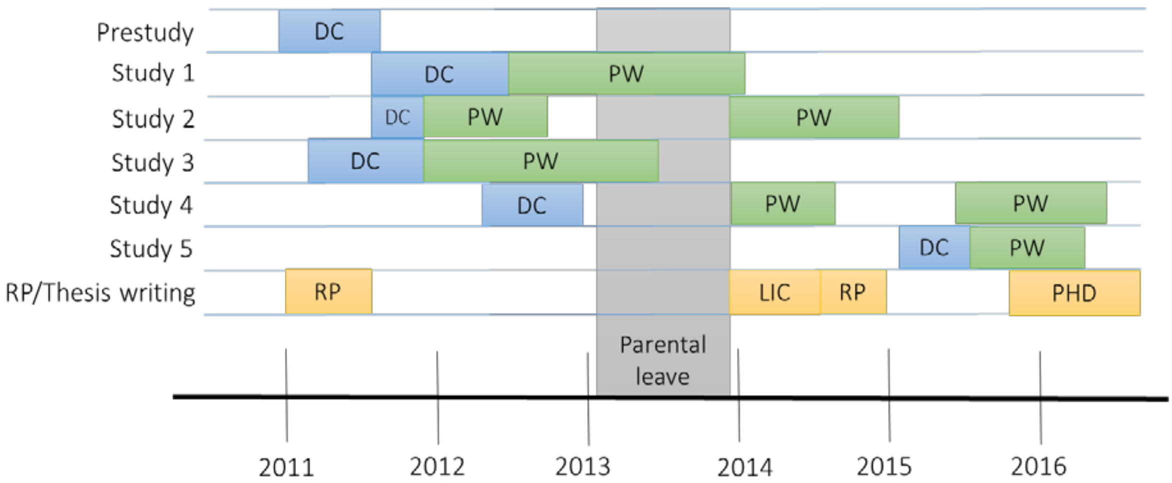

Figure 4.5. Research process (DC = Data collection, PW = Paper writing, RP = Research proposal, LIC = Licentiate degree)

5 Summary of appended papers

This chapter summarises the five appended papers in terms of their purposes and primary findings.

5.1 Paper 1: Capturing food logistics: A literature review and research agenda

Purpose: The purpose of Paper 1 was to study how food aspects have been considered in logistics literature. Its research questions sought to answer how logistics activities have been studied with a focus on food (RQ1), how food logistics can be defined (RQ2), and which aspects of food logistics require more attention in logistics research (RQ3).

Findings: Regarding aspects within food logistics (RQ1), the papers were categorised according to four perspectives: the logistics area studied, the constellation of actors in food supply chains (FSCs), types of food products, and methods applied (Table 5.1). Of the 159 papers, 104 were considered to focus on the characteristics of either products or actors in FSCs and were read more carefully in a second round of review. Regarding logistics area, the most common category was relationship management, often linked to a network perspective; by contrast, the most common category of type of actor was single actors, which indicated that food logistics are often analysed from a single actor's perspective. Regarding food products, two thirds of the papers analysed a mix of products, thereby indicating that unique food characteristics of various products remained unstudied to a large extent in the literature. Most papers considered to address frozen, chilled, or ambient products were identified as having a focus on food, given their concentration on product characteristics. In terms of methodology, there was an even balance of qualitative and quantitative methods in the first round of review; however, in papers identified as having a focus on food, qualitative methods dominated.

Table 5.1 Papers reviewed from four perspectives: logistics area, food supply chain actors, food products, and method

Logistics area	Papers (in the second round)	FSC actors	Papers (in the second round)	Food products	Papers (in the second round)	Method	Papers (in the second round)
Distribution	44 (33)	Single	72 (42)	Frozen	4 (3)	Conceptual	24 (18)
Production	14 (6)	Dyad	22 (16)	Chilled	34 (30)	Qualitative	57 (50)
Procurement	19 (11)	Network	39 (30)	Ambient	16 (7)	Quantitative	67 (30)
Relationship management	82 (54)	Industry	26 (16)	Mix of products	105 (64)	Combination	11 (6)
Total	**159 (104)**	**Total**	**159 (104)**	**Total**	**159 (104)**	**Total**	**159 (104)**

Definition of food logistics (RQ2): To distinguish the uniqueness of food characteristics, food logistics should be analysed from the perspectives of food products and FSC actors. In that sense, food logistics analyses logistics activities within an FSC context by problematizing food product characteristics and examining the constellation of FSC actors.

Areas requiring further attention in food logistics (RQ3): Areas needing further research were identified according to the perspectives of logistics area, FSC actors, food products, method, and environment. The following list summarises the needs of research in the five areas in terms of those perspectives:

- *Logistics area*: Procurement including multiple actors
- *FSC actors*: The roles of wholesalers and primary producers in FSCs
- *Method*: Quantitative methods (e.g., surveys, modelling, and simulation)
- *Food products*: The influence of food product characteristics on logistics activities
- *Environment*: Environmental issues in food logistics

5.2 Paper 2: Characteristics of food supply chains: The case of seafood producers

Purpose: To provide an understanding of FSCs and the implications of improvement efforts for food producers, Paper 2 had two objectives: first, to identify by what dimensions an FSC can be characterised, largely to offer an understanding of *what* can be aligned, and second, to analyse dynamics between characteristics, largely to illustrate *how* characteristics can be aligned with the logistics flow.

Findings: The findings of Paper 2 are presented in terms of eight FSC characteristics, description of the empirical material with the characteristics and analysis of links among the characteristics. The theoretical framework involved eight FSC characteristics, divided as either product or flow characteristics (Table 5.2).

Table 5.2 Food supply chain characteristics

Product characteristics	**Flow characteristics**
Supply variation	Stage in the FSC
Product value	Demand variation
Shelf life	Relative size of the actor
Temperature regime	Lead time

Table 5.3 describes the FSC characteristics of salmon and crab producers in the empirical material.

Table 5.3 Food supply chain characteristics of the salmon and crab producers

FSC characteristics		**Salmon**	**Crabs**
Flow	Stage in the FSC	Primary and industrial production	Industrial production
	Demand variation	Medium	Medium
	Relative size of the actor	Larger	Smaller
	Lead time	Varying depending on markets	Varying depending on markets
Product	Supply variation	Low	High
	Product value	High but varying	High but varying
	Shelf life	Fresh for 14–16 d	Fresh for 5–7 d
	Temperature regime	Mostly chilled	Mostly frozen

Those FSC characteristics were interlinked in two ways, as the case study revealed:

- *Link 1:* Variation (e.g., in supply and demand) and temperature regime
- *Link 2:* Time and temperature regime

To situate FSC characteristics within logistics systems, the characteristics were linked to logistics services that the producers desired of food logistics centres. Services required of crab and salmon producers differed in terms of three FSC characteristics: relative size of the company (i.e., actor characteristic), supply variation (i.e., product characteristic), and shelf life (i.e., product characteristic).

5.3 Paper 3: Using a transport portfolio framework to reduce carbon footprint

Purpose: The purpose of Paper 3 was to explore how a transport portfolio framework (TPF) can support decision making for shippers who seek to improve their current logistics networks by reducing those networks' carbon footprints.[5] The TPF was created to enable shippers to make effective decisions toward reducing the impact on climate in their transport systems.[6]

Findings: The findings are presented as a description of the TPF and of the results of the empirical case study.

The TPF consists of three steps. The first step of the TPF involves deciding which key variables the shipper wants to improve and, with the help of shipment statistics, analysing which product flow characteristics (PFCs) bear the greatest influence on key variables. The second step entails describing each category and its performance with the help of a portfolio, whereas the third step involves creating an action plan, in which the shipper can focus on either repositioning shipments within the portfolio by changing PFCs or improving each category by changing current links among PFCs and key variables. By extension, those different improvements affect different interdependencies in the theoretical framework. The decision-making process underlying the transport portfolio framework appear in Figure 5.1.

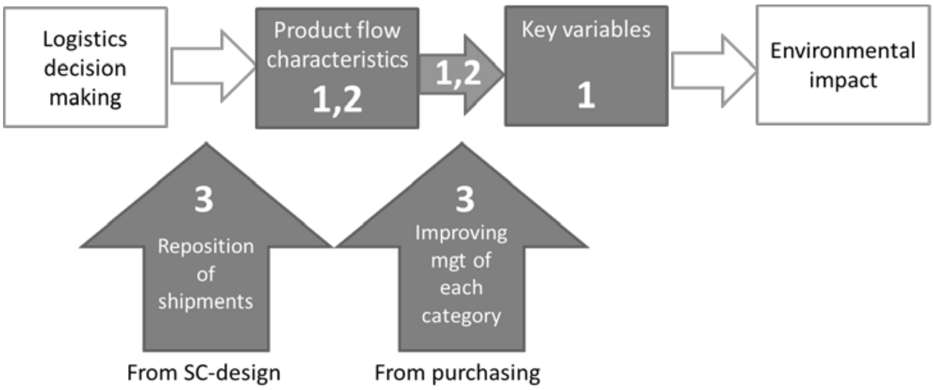

Figure 5.1 The decision-making process underlying the transport portfolio framework (TPF); numbers refer to steps of the TPF

In the example case, two transport portfolios were created: one for modal split and one for load factor. The first step revealed that PFCs with the greatest influence on modal split were

[5] The term *shipper* used in Papers 3 and 4 is synonymous with 'FSC actor' in the cover of the thesis, since *shipper* is a common term for the product owner in regard to transport activities in logistics systems.
[6] The term *transport system* in Papers 3 and 4 describes a logistics system in terms of its transport activities.

temperature regime (i.e., ambient, chilled, and frozen) and distance; for load factor, the PFCs temperature regime and shipment size exerted the greatest influence. Each PFC was conceived as both a barrier and an enabler; for example for modal split, long distances were an enabler and short distances a barrier. The second step defined the current performance and potential of each category in the portfolios; potential was estimated according to how key variables can be improved—for instance, how many shipments in total could be shifted from road transport to intermodal transport if performance increased to 100%. In the third step, nicknamed the ‘move or improve’ step, the retailer can choose whether shipment PFCs should be adjusted, in which shipments would be shifted between categories, or whether certain categories should be improved. For example, shifting between categories occurs when shippers change the PFC shipment size from small to large, thereby increasing the load factor. Improving a category can involve, for instance, applying horizontal collaboration in order to increase load factors without changing shipment sizes. Since the transport portfolios revealed a potential for improvement, the retailer can visualise which category of shipment is suitable for making effective improvements. In that case, a good starting point for increasing modal split might be the transport of ambient products over shorter distances. By contrast, to increase load factor, the potential is greatest with chilled and frozen products. The two TPFs appear in Figure 5.2.

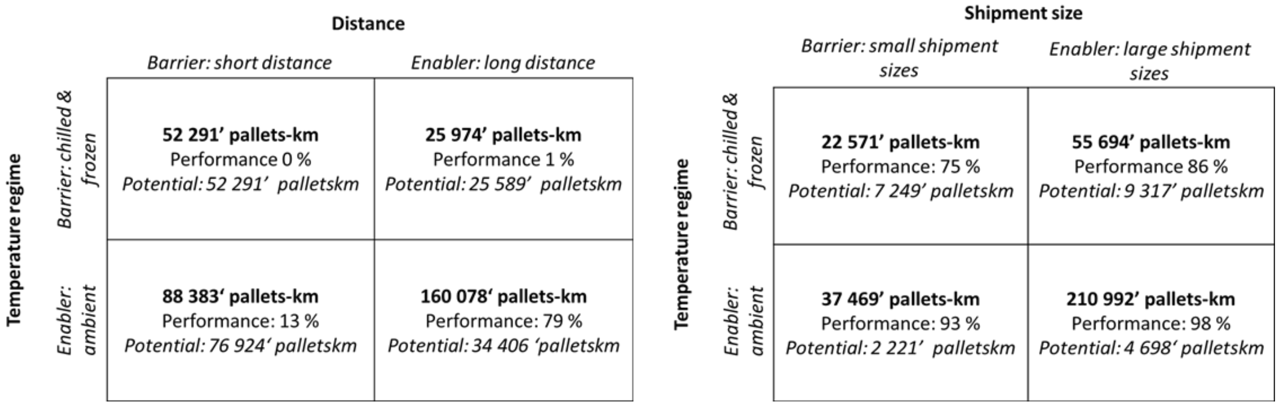

Figure 5.2 Transport portfolios for modal split and load factor (modal split in the left portfolio and load factor in the right portfolio)

5.4 Paper 4: Improvement actions for reducing transport’s impact on climate: A shipper’s perspective

Purpose: To analyse improvement actions in transport systems, shippers need structured approaches. The purpose of Paper 4 was to compare improvement actions for reducing transport’s impact on climate from the shipper’s perspective. To that end, the paper introduces an evaluative tool for comparing improvement actions in transport systems in terms of transport costs, impact on climate, and barriers to implementation. The three improvement actions analysed were engaging intermodal transport, increasing load factors by double-stacking pallets, and using high-capacity vehicles.

Findings: Findings are presented as a description of the evaluative tool and of the results of the empirical case study.

The evaluative tool for shippers is presented in form of a matrix for evaluating improvement actions (MEIA), which is structured according to three steps. The first identifies the potential benefits in terms of reduced transport costs and impact on climate, represented by the first axis in the matrix; the second identifies and classifies the barriers, represented by the second axis; and the third combines both benefits and barriers toward suggesting how the matrix can be filled.

The results of the empirical case study are structured according to the MEIA. Results showed that reductions in impact on climate and transport costs differed for the improvement actions. Engaging intermodal transport reduced the system's impact on climate by 27–53%, double-stacking pallets by 0–23%, and using high-capacity vehicles by 7–15%, with differences primarily due to different freight densities. The same figures for reductions in transport costs showed that engaging intermodal transport reduced the system's reduced transport costs by 0–42% and double-stacking pallets by 0–28%. The comparison also revealed that the most efficient improvement action can differ from flow to flow and that shippers need to conduct careful analyses when evaluating different improvement actions. Five barriers were identified: frequency of train lines, requirements imposed on balanced intermodal flows, different load weights for the road–rail system, maximum truck length allowed, and warehousing costs for lower pallets. By combining the results of the potential and barriers, a matrix emerged that can support shippers in making efficient decisions toward reducing their systems' transport's impact on climate (Figure 5.3).

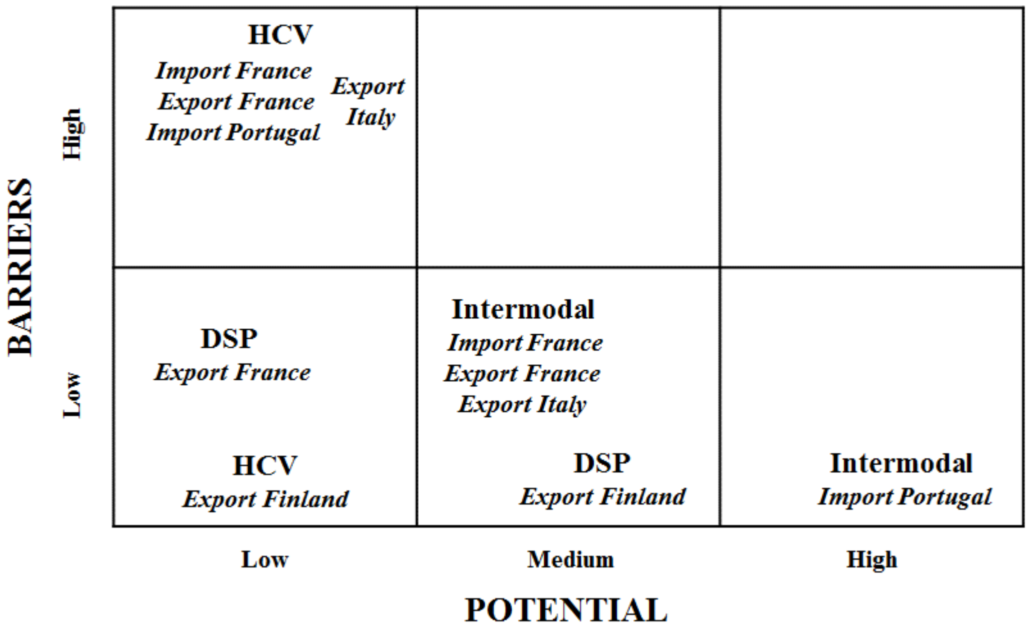

Figure 5.3 Matrix illustrating combinations of improvement actions and transport flows (DSP = Double-stacking pallets, HCV = High-capacity vehicles)

5.5 Paper 5: Logistics solutions for reducing food waste

Purpose: The purpose of Paper 5 was to expand understandings of how logistics can reduce food waste in FSCs. It first presents a research framework developed to address causes of food waste and to structure an analysis of logistics solutions[7] that can overcome those causes. Second, based on a case study, the paper provides a holistic view of logistics solutions by identifying, describing, and analysing the solutions together. Third, since FSCs are context

[7] This paper uses the term *solution*, while the cover uses the term *improvement action*, though both terms are synonymous.

dependent, especially in terms to product type and supply chain stage, the paper also analyses how logistics solutions can be adapted to various FSC contexts. Given results from all three parts, it lastly offers suggestions concerning how future research can contribute to further reducing food waste.

Findings: The research framework develops a structure for identifying and presenting logistics solutions for reducing food waste, illustrated in two parts: causes of waste and logistics solutions (Figure 5.4).

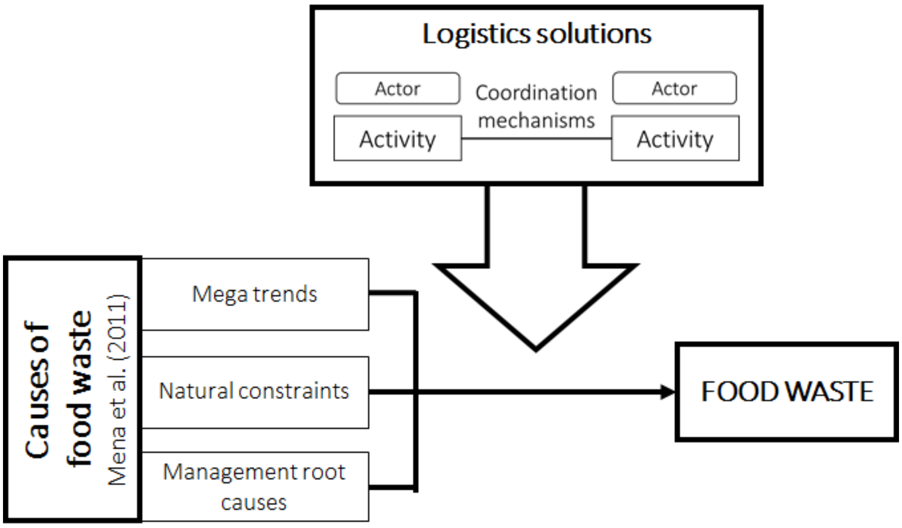

Figure 5.4 Research framework for studying logistics solutions to reduce food waste

Based on the research framework developed, nine logistics solutions were identified (Table 5.4), each in terms of four coordination mechanisms: joint decision making, information sharing, rules, and pricing. All solutions included two or three stages of the FSC, thereby underscoring the importance of adopting a supply chain perspective to reduce food waste. Adaptations of solutions were also analysed from perspectives of the market, product, and actors involved.

Table 5.4 Logistics solutions for reducing food waste (FaV = Fruits and vegetables, MTO = Make to order*)*

Solution	**Type of waste**	**Cause of waste**	**Cases**	**Coordination mechanisms**	**Actors and activities**							
					Producer	*Wholesaler*						*Retailer*
						Procurement	Replenishment	Transport	Warehousing	Packaging development	Order support	
Collabora-tive forecasting (1)	Passed expiration dates	Mismatch of supply (i.e., natural constraint) and demand (i.e., natural constraint)	Meat and FaV	Joint decision making	X		X					X
Division of lead time (2)		Mismatch of shelf life (i.e., natural constraint) and lead time (i.e., natural constraint and management root cause)	Meat	Rules (lead time)		X	X		X			X
Level of safety stock (3)			Meat	Joint decision making	X		X		X			
MTO flows (4)			Meat	Joint decision making	X		X					X
Measures of service level (5)		Mismatched assortment (i.e., megatrend) and shelf life (i.e., natural constraint)	Meat and FaV	Rules (service level)			X					X
Price reductions (6)		All three causes	Meat and FaV	Pricing	X		X					X
Product group revisions (7)			Meat	Informa-tion sharing			X					X
Visualising damaged packaging (8)	Damaged packaging	Mismatch of packaging and logistics system (i.e., management root cause)	Ambient products	Informa-tion sharing				X	X		X	X
Packaging develop-ment (9)			Ambient products	Joint decision making	X	X				X		

6 Analysis

This chapter provides answers to the four research questions proposed in Section 1.4 and is structured according to logics developed in Section 3.8. Analysis is based on the findings of the five papers (Chapter 5).

6.1 RQ1: Food supply chain characteristics

RQ1 is an explorative question that seeks to identify food supply chain (FSC) characteristics that can be used to describe logistics systems of food products. In its two-part answer, the first section identifies and describes eight such FSC characteristics in relation to logistics systems (Section 6.1.1). Later, the second section analyses links among the FSC characteristics and in relation to logistics systems (Section 6.1.2). The analysis is based on empirical material from Paper 2 (i.e., FSC characteristics) and Paper 5 (i.e., food waste).

6.1.1 Description of food supply chain characteristics

This section identifies and categories eight distinct FSC characteristics. Four product characteristics refer to physical attributes of food products: *shelf life*, *product value*, and *temperature regime*, which are linked to products throughout the supply chain, and *supply variation*, which occurs at the primary production stage upstream in the chain. Another four characteristics describe the supply chain flow; whereas *stage in the supply chain* and *relative size of the actor* represent actors who handle the flow, *lead time* describes the flow to and from actors, and *demand variation* reflects consumers' behaviour, which pose consequences throughout FSCs. Whereas the category of flow characteristics is also common in literature on non-perishable products, the category of product characteristics is more common in literature on FSCs. Figure 6.1 depicts the eight characteristics.

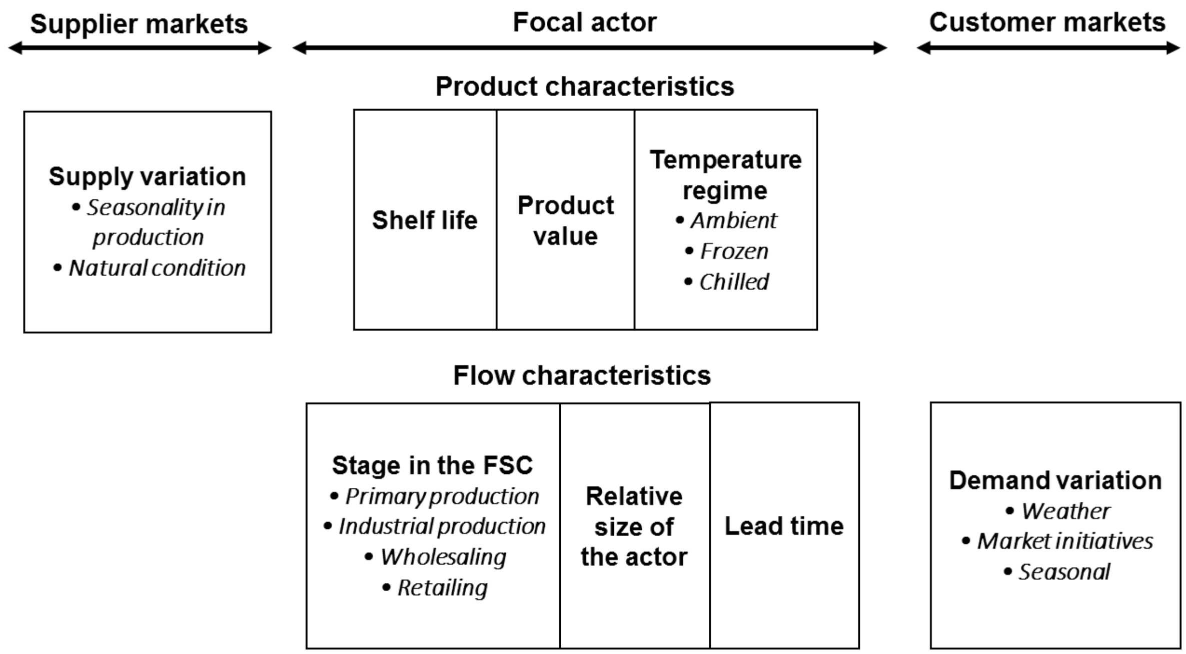

Figure 6.1 Two categories of food supply chain characteristics at three levels in the supply chain

The following section provides a brief description of each FSC characteristic and its links to logistics systems.

Stage in the FSC is divided into stages of primary production, industrial production, wholesaling, and retailing. All four stages are salient in FSCs, and how actors at different stages interact is important. In Paper 5, three of the stages were studied (i.e., industrial production, wholesaling, and retailing), and results showed that all nine improvement actions identified covered at least two stages in FSCs, thereby stressing the importance of taking a supply chain perspective to reduce food waste.

Demand variation refers to fluctuation in food product demand from consumers and three types of demand variation were identified in Papers 2 and 5:

- Weather changes, or even forecast changes, can increase or reduce demand. For example, rainy weather during the barbecue season reduced demand for barbecue products. Changes in demands posed consequences for logistics systems, particularly when products are already in production or in transport: 'If it starts raining, no one buys watermelons. Then we have to start planning. When a replenisher pulls out the stops, it takes 5 d before it stops due to transport time' (Wholesaler, Paper 5).
- Market initiatives (e.g., advertising campaigns) can create demand variation by increasing demand for certain products and reducing demand for similar products (i.e., product cannibalism), as Paper 5 shows.
- Seasons can create demand variation when holidays such as Christmas occur (Papers 2 and 5), and due to 'harvest seasons' (Paper 2).

Relative size of the actor refers to an actor's size in relation to actors at the same stage in the chain (e.g., small and large producers) and between stages in the supply chain (e.g., wholesalers and producers). Generally, the further downstream, the larger the actor. The empirical material provided examples of comparisons of actors at the same and different stages in the supply chain.

- The sizes of actors at the same stage in the supply chain affects which logistics activities they seek to outsource to logistics providers (Paper 2).
- Differences in actor size can also explain the necessary coordination among stages in the supply chain due to demand variations. As a wholesaler explained, most of its suppliers of fruit and vegetables had customers in several countries, and if the wholesaler changed an order due to demand variation, then the change did not exert a significant impact: 'We are a small country. Even if we are a large actor here [in Sweden], we are not large in Europe' (Paper 5). Swedish meat producers, by contrast, for whom the Swedish wholesalers were the largest customers, were far more sensitive to demand variations.

Lead time refers to the time from when the need for a product is recognised to when goods are received (Cox et al., 2008). Lead times in Swedish FSCs centre on the 1/6 rule, which dictates how shelf life is divided among the producer (1/6), wholesaler (1/6), and retailer (2/3). For example, if a product has a shelf life of 12 d, then the producer has a maximum lead time of 2 d. In short, shelf life determines lead time (Paper 5).

Supply variation concerns the availability of raw materials supplied for food production and processing. Availability is contingent on the harvesting seasons of such materials and subject to disruptive natural events (e.g., flooding). Two types of supply variation were identified:

- Supply variation relates to harvest seasons, which are often predicable, as a crab producer in Paper 2 asserted: 'It [supply variation] is seasonal, with 3 months of top season from August to October. During that time, 80% of the volume should come out of the sea'.

- Supply variation also relates to rapid changes in volume (e.g., due to weather) against projected volumes, which can significantly affect consequences downstream in the supply chain, as a wholesaler in Paper 5 explained: 'We decided to have a campaign on cherry tomatoes and ordered a million from a producer. A few weeks before the delivery, the producer contacted us and said that he could deliver only 500,000 tomatoes due to cloudy weather in Spain. As a result, the retailer had to cancel the campaign and change the already produced TV commercial'.

Product value can be analysed in terms of absolute value or profit margin. Two aspects contribute to how product value influences logistics systems:

- Changes in the value of raw materials pose consequences for FSCs, as the crab producer in Paper 2 detailed: 'Three years ago, there was almost a collapse in the market. They [actors downstream in the FSC] sat with stock there, and we sat with large stocks here. And there were no ideas about how to push the products, because the more we pushed, the more the prices dropped. No, it is the opposite; they [actors downstream] know that there are too few products, and they take in products to get as much as possible. For us, if we can get it [products] out as soon as possible and the money in, then we gladly do it'.
- Products of higher value are handled with greater care, as demonstrated by how often such products have higher-quality packaging material. That dynamic could reduce food waste if there are fewer damaged packages of products with higher value (Paper 5).

Shelf life describes a product's lifetime and two aspects indicate how shelf life creates conditions for logistics systems:

- Shelf life can influence the geographical position of industrial production. For example, chilled salmon products have a shelf life of 14–16 d, and given salmon's high fat content, it is difficult to remove the bones until 4 d after harvest. Industrial production thus often occurred in central Europe so that the first 4 d of production could be used to transport the products nearer to end consumers (Paper 2).
- Short shelf life can have implications for the service level, as a meat producer in Paper 5 illustrated: 'For products with long shelf lives, you have the trade-off between service level and tied-up capital, but since we have products with short shelf lives, the trade-off is between service level and clearance cost. . . . On pork products with a shelf life of 12–15 d, we unfortunately have to take the hit with the service level. It would be too much of a waste and too short a shelf life for us, the wholesaler, and the stores to provide better service. Even for a product with 25 d of shelf life, you can have only 0.5 to 1 d of safety stock. If a product has a very long shelf life—say, around 60 d—then we have to start considering tied-up capital'.

Temperature regime affects the requirements of logistics systems for food products, which in that aspect are divided into three groups: chilled, frozen, and ambient (used by e.g. Mena and Whitehead, 2008). Chilled products require shorter lead times (Paper 2), although demand for such products is increasing, as a crab producer in Paper 2 attested: 'In Europe, there is a clear trend that fresh [chilled] is increasing'. That trend will continue to affect conditions in logistics systems, since chilled products pose requirements unlike those of frozen and ambient products.

Although the quality of food products is critical to end consumers, it is not included as a FSC characteristic, because actors in FSCs ensure that aspect of food products by way of the eight FSC characteristics identified in those products' logistics systems. In that sense, in analyses of logistics systems, quality is captured by the other FSC characteristics.

6.1.2 Links among food supply chain characteristics

The previous section has described how separate FSC characteristics create conditions for the logistics systems studied. The empirical material, however, shows that such conditions are not always so simply identified as direct relationships between single FSC characteristics and logistics systems. For combinations of multiple FSC characteristics influence logistics systems as well. In what follows, two such links are analysed in terms of how they interconnect and can be moderated by other FSC characteristics.

Link 1: Supply and demand variation: Analysing the combination of supply and demand variation, as Papers 2 and 5 do, is pivotal. In Paper 2, results showed that the magnitude of variation is not as great an issue as the extent to which supply and demand can be aligned. For the crab producer, larger variations in supply were challenging to match with a demand without the same variation. In Paper 5, food waste was shown to be created neither by demand nor supply variation, but by an inability to match them.

Link 2: Lead time and shelf life: The second link concerns two measurements of time: lead time and shelf life. Lead time considers the logistics system and the flow, whereas shelf life considers the attributes of food products. To match them is a fundamental challenge for actors in FSCs, and their close interdependence is exemplified in lead times set according to divisions of shelf life in Swedish FSCs (Paper 5). That link is illustrated by two examples.

First, mismatched lead times and shelf lives cause waste, and ensuring adequate lead times so that products arrive at stores with sufficient shelf lives is critical to reducing food waste. Waste can occur in stores, as well as upstream in supply chains, if shelf-lives expire before products reach stores (Paper 5). Matching lead times and shelf lives can be achieved in several ways, and a wholesaler in Paper 5 explained how make-to-order flows can be used to shorten lead times*:* 'We had challenges with fresh poultry. The stores were not satisfied with the service level or the shelf life when products arrived in stores. . . . With the make-to-order flow, we increased the service level and, in principle, eliminated waste. . . . The stores got roughly three more shelf-life days and could therefore keep a safety stock. So, it had a good effect on waste'.

Second, the link becomes more problematic when the geographical location of primary production is determined by natural constraints and far from consumers (Paper 2). As a salmon producer explained, a fourth of salmon products' shelf life is required to transport them: 'It takes 3 d to get to the factory [in Europe], then 1–2 d in production, and then roughly 7 d to sell and eat'. The distance between primary production sites and consumers requires fast, reliable logistics systems, particularly for products with short shelf lives. It can also imply commitments that transcend several actors in FSCs, as a crab producer in Paper 2 reported: 'We have 25 receiving stations along the coast, from Målö in the south to Bodö in the north. We handle live shellfish, so it [the logistics] has to go fast and smooth. At the same time, it [crab] has a shelf life of 5–6 d, which implies that our customers have already sold the products to end consumers—either a retailer or restaurant. The setup implies that if there is trouble with logistics, then there is no buffer, and it's an immediate crisis'.

Crosslinks: Both links put considerable demands on actors' logistics systems and require close collaboration among actors in FSCs. The empirical material suggests that both links were moreover interlinked, insofar as they could amplify challenges for actors in FSCs. Regarding demand and supply variation, the challenge is often greater for products with short shelf lives, particularly ones not easily matched with lead times (Paper 2). For products with longer shelf lives, more time is available to identify a solution in the case that supply exceeds demand; by the same token, it is possible to create buffers to ensure that increases in demand can be met with an appropriate supply (Paper 5).

Moderating Links 1 and 2 with temperature regime: If a logistics system cannot accommodate mismatched supply and demand variation or shelf life and lead time, if not both, without greatly increasing food waste or cost, then it is possible to change the FSC characteristic of temperature regime, as clarified by a comparison of salmon and crab FSCs (Paper 2). On the one hand, the salmon producer could match demand and supply, and with a shelf life of around 12 d it was possible to create logistics systems that could ensure that lead times could provide the market with sufficient shelf lives. As a result, FSC actors were able to operate with a chilled instead of a frozen supply chain, and products could be shipped directly from harvest to market. The crab producer, on the other hand, could not match demand and supply to the same extent, and the shelf life of 5–7 d was often incompatible with lead times to several markets. Consequently, this FSC's actors had to operate a frozen supply chain for a large proportion of the production volume. Altogether, temperature regime moderated the challenge posed by Links 1 and 2 when they created difficult conditions for the logistics systems.

Figure 6.2 summarises the proposed links among five FSC characteristics: supply variation, demand variation, shelf life, lead time, and temperature regime. As the figure shows, actors in FSCs need to consider how combinations of FSC characteristics, which are not merely one-to-one relationships, influence their logistics systems. For both Links 1 and 2, mismatched product and flow characteristics create challenges for actors in FSCs, thereby stressing that actors should analyse the role of products in their logistics systems. Furthermore, when a mismatch occurs, it might be possible to adjust the system's flow characteristics (e.g., lead time); however, at other times, products have to be adapted to accommodate logistics systems, as exemplified by FSCs that changed the temperature regime.

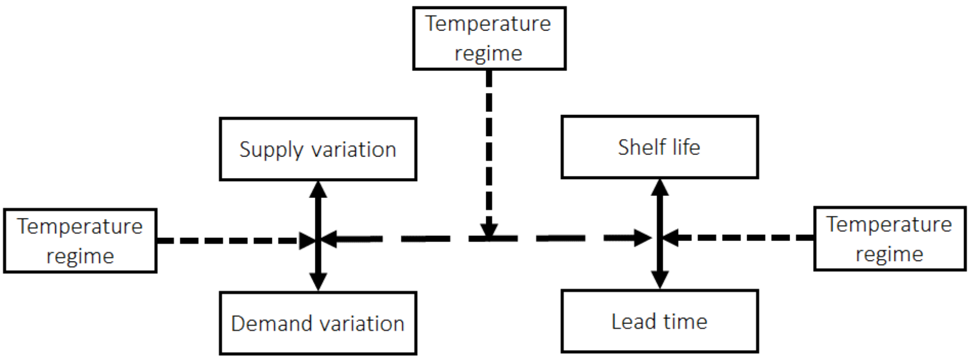

Figure 6.2 Links among five food supply chain characteristics

6.1.3 Concluding remarks

In sum, the answer to RQ1 has identified and described eight FSC characteristics, as well as identified and analysed two combinations of FSC characteristics that influence the logistics systems. Furthermore, the results align well with both contingency theory and the systems approach applied in the study. On the one hand, contingency theory stresses the importance of considering context, which the results of RQ1 do by identifying eight FSC characteristics that can be used to describe actor's own logistics systems as well as the systems of actors up- and downstream in FSCs. On the other hand, in relation to a systems approach, the results align with the tenet that it is important to take a holistic view, as opposed to an atomistic one, given the unfeasibility of analysing FSC characteristics in isolation and the need to study them in combination. The findings of RQ1—both the identified FSC characteristics and the finding that it is important to consider them jointly—are applied in analyses to answer the other research questions.

6.2 RQ2: Transport's impact on climate in logistics systems

An explanatory question in two parts, RQ2 asks: How do food supply chain characteristics influence transport's impact on climate (RQ2a), and how can improvement actions in food logistics systems reduce that impact (RQ2b)? The results and analysis in response to those questions are based primarily on the findings of Paper 3 (i.e., about the transport portfolio framework, TPF) and 4 (i.e., about the matrix for evaluating improvement actions, MEIA) and secondarily on the findings of Paper 2 (i.e., about FSC characteristics).

The answer to RQ2 is based on the logic shown in Figure 6.3. In what follows, Section 6.2.1 specifies factors included in the components: performance variables and FSC characteristics, product flow characteristics, key variables, and transport's impact on climate. As such, it identifies the categories applied in the analysis. Later, Section 6.2.2 addresses the first part of the analysis and responds to RQ2a by explaining how FSC characteristics and logistics performance variables influence transport's impact on climate in actors' logistics systems. Lastly, Section 6.2.3 responds to RQ2b by explaining how improvement actions in food logistics system can reduce transport's impact on climate; its answer is guided by two frameworks that actors can use to evaluate improvement actions and analyse what components and relationships should be changed in the logic for answering RQ2.

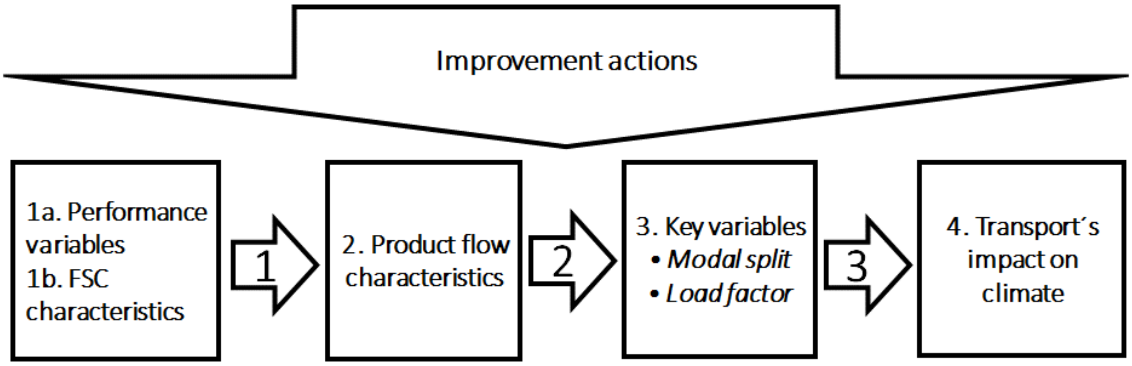

Figure 6.3 Logic for RQ2 (i.e., transport's impact on climate); FSC = Food supply chain

6.2.1 Components in the logic

The components used to answer RQ2 in Sections 6.2.2 and 6.2.3 are identified in what follows, based on logic for answering RQ2 (Section 3.8) and the findings of Papers 3 and 4.

1. FSC characteristics and logistics performance variables: To identify possible factors, candidate factors were drawn from the FSC characteristics found by answering RQ1 and from logistics performance variables in the framework of Jonsson (2008). Of those factors, five were identified in light of empirical material in Papers 3 and 4: three FSC characteristics (i.e., temperature regime, supply variation, and shelf life), one logistics performance variable (i.e., cost), and density. Density is a characteristic linked to products, but not included in the framework of FSC characteristics developed as a result of answering RQ1. Briefly, since FSC characteristics are developed for logistics systems that include all kinds of logistics activities, and since density is foremost relevant when studying transport activities, density was excluded in answering RQ1, but included in answering RQ2.

2. Product flow characteristics (PFCs): Five PFCs were included: temperature regime, shipment size, variance of shipment size, frequency, and distance (Paper 3). Temperature regime was included as both an FSC characteristic and PFC, for it sets conditions for other PFCs and directly creates conditions for key variables.

3. Key variables: The key variables addressed were modal split and load factor. Modal split refers to the distribution among modes of transport, which in this thesis were sea, rail, and road transport. Sea and rail transport were studied in combination with road transport in intermodal solutions. By contrast, load factor was analysed in terms of both deck-space utilisation and weight.

4. Transport's impact on climate: This impact was measured in terms of greenhouse gas emissions (i.e., CO_2 equivalents).

5. Improvement actions: Improvement actions were implementing intermodal transport and increasing load factors.

6.2.2 How food supply chain characteristics and logistics performance variables influence transport's impact on climate

How FSC characteristics and logistics performance variables influence transport's impact on climate is explained in two steps. First, how FSC characteristics and logistics performance variables influence the key variables load factor and modal split (i.e., Links 1 and 2 in Figure 6.3) is described, followed by a description of how the key variables influence transport's impact on climate (Link 3 in Figure 6.3).

How FSC characteristics and logistics performance variables influence the key variables load factor and modal split

Nine relations were identified for how FSC characteristics and logistics performance variables influence PFCs (i.e., Link 1 in Figure 6.3), which in turn influence the key variables (i.e., Link 2 in Figure 6.3). Whereas Relationships 1–7 originate in identified performance variables or FSC characteristics, Relationships 8–9 do not relate to those aspects, but focus solely on the links among PFCs and key variables (Figure 6.4).

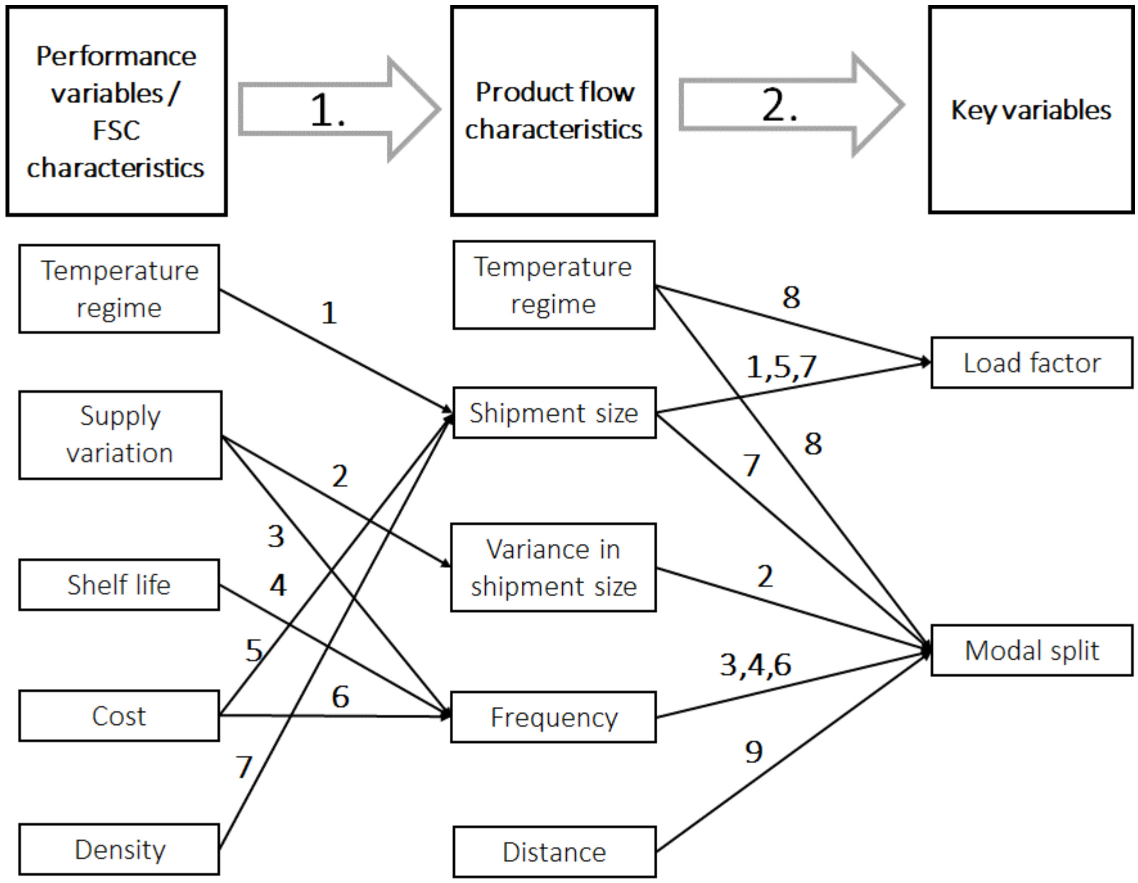

Figure 6.4 Links explaining how food supply chain characteristics and logistics performance variables influence the key variables load factor and modal split

1. Temperature regime, shipment size, and load factor (i.e., Relationship 1 in Figure 6.4)

Temperature regime created conditions for shipment sizes for the intra-European transport activities of a Swedish wholesaler (Paper 3). With 13 pallets on average, sizes were smaller for chilled shipments than for ambient and frozen shipments, which used an average of 36 and 32 pallets, respectively. Since shelf life is usually less for chilled products, shipments are more frequent but smaller, which consequently sets conditions for load factor, since it is more difficult to achieve high load factors with small shipment sizes.

2. Supply variation, variance in shipment size, and modal split (i.e., Relationship 2 in Figure 6.4)

3. Supply variation, frequency, and modal split (i.e., Relationship 3 in Figure 6.4)

Relationships 2 and 3 are analysed jointly, since they are based on the same empirical material. A major supply variation occurred during a peak in flow at the end-of-summer harvest season in Sweden that influenced the PFCs of variance in shipment size and frequency. Specifically, the industrial producer required larger, more frequent shipments then than at any other time of the year (Paper 4). That circumstance was incompatible with the intermodal solution (i.e., rail) in terms of both required frequency and volumes. In short, high frequency and large shipment size variation reduced the use of intermodal transport (i.e., modal split).

4. Shelf life, frequency, and modal split (i.e., Relationship 4 in Figure 6.4)

If products have limited shelf lives, then demand for high-frequency shipments increases, which in turn reduces the use of intermodal transport (i.e., modal split). That dynamic became clear when salmon producers considered using a sea-based solution instead of the current system using trucks as a means to ship to factories in Europe (Paper 2). Although transport time was sufficient with the sea-based solution, due to a low frequency of vessels, it would have become too long if it included the storage time spent while waiting for vessels. That relationship shows similarities with Relationship 3, insofar as both identified another relationship between frequency and modal split.

5. Cost, shipment size, and load factor (i.e., Relationship 5 in Figure 6.4)

Two relationships between cost and shipment size were identified. The first exists between transport costs and shipment size (i.e., measured in pallets), which in turn sets conditions for the load factor (i.e., measured in floor space utilisation). That relationship became clear in that the industrial producer and wholesaler in the empirical studies to a large extent purchased full truckload (FTL) shipments (Papers 3 and 4). In Paper 3, two peaks in shipment size occurred at 33 and 66 pallets, which represents a 100% load factor for an 18.75-m vehicle, whether single or double stacked. In Paper 4, to reduce transport costs, the industrial producer always purchased FTL shipments, thereby implying that the requirements for low transport costs influence shipment size, which can nevertheless occur by either reducing or increasing shipment sizes. Regardless of the direction of change in shipment size, the load factor will increase.

The second relationship emerged between logistics costs (i.e., warehousing) and shipment size measured in weight, which in turn sets conditions for load factor, also measured in weight (Paper 4). The industrial producer had considered using double-stacked pallets for a certain transport flow (i.e., FTL), which would imply a lower height of pallets but a higher total weight of shipments and, in turn, fewer trucks and thus lower transport costs. However, pallets would have to be stored at external warehouses in Europe, where the cost of storing short and tall pallets is identical. Using double-stacked pallets could therefore increase warehousing costs. Requirements for low warehousing costs would prompt smaller shipment sizes measured in weight, thereby implying a lower load factor, also measured in weight.

A comparison of both relationships shows that requirements for low costs can both increase and reduce load factors, for two reasons. One, in the first link, the scope encompasses only the transport activity, and the relationship is not tied to warehousing costs; by contrast, the second relationship encompasses two logistics activities, since a change in the transport activity increases warehousing costs. That dynamic stresses the importance of understanding the broader system in terms of logistics activities when considering improvements for transport activities. Two, shipment size and load factor are measured differently for the two links, which suggests the importance of considering which measurements to use in order to capture different empirical cases. For example, no difference would be observable in Relationship 2 if load factor had been measured in terms of floor space utilisation.

6. Cost, frequency, and modal split (i.e., Relationship 6 in Figure 6.4)

Demands for low costs of tied-up capital induced requirements for high-frequency shipments, which in turn reduced the use of intermodal transport (i.e., modal split). The industrial producer wanted low tied-up capital costs and therefore required a certain frequency of shipments. Since a proposed intermodal solution (i.e., rail) lacked the same frequency as road transport, the industrial producer would have been forced to increase the safety stock, thereby inducing tied-up capital costs, as described in Paper 4.

7. Density, shipment size, load factor, and modal split (i.e., Relationship 7 in Figure 6.4)
The density of products created conditions for shipment size, measured both in weight and pallets, which in turn created conditions for both modal split and load factor, measured in both weight and floor space utilisation, as described in Paper 4. For low-density products in FTL shipments, shipment sizes were larger in terms of pallets per shipment, yet smaller by weight per shipment, and vice versa for high-density products. That dynamic in turn created requirements for load factor; shipments of low-density products have a high load factor in terms of floor space utilisation and a low one in terms of weight, and vice versa for shipments of high-density products. In effect, that relationship also sets conditions for modal split due to the maximum loading weights of road and intermodal transport. In intermodal systems, the possible loading weight of shipments increased from 22 to 26 tonnes, yet floor space remained the same, which implied that for high-density products, it was possible to increase shipment size and reduce the total amount of shipments required. However, that possibility could not be used for low-density products, whose shipment sizes were set at a 100% load factor in terms of floor space utilisation. Ultimately, for shipments of low-density products, that relationship lowered the use of intermodal transport (i.e., modal split) and load factor measured in weight.

8. Temperature regime, load factor, and modal split (i.e., Relationship 8 in Figure 6.4)
Temperature regime imposed conditions for both load factor and modal split, insofar as the key variables were greater for ambient products than for chilled and frozen ones (Paper 3). To explain, both a wholesaler and transport providers identified a difference in the performance of transport activities depending on the temperature regime (Paper 3), for two reasons. One, from a transport provider’s perspective, there is less freight to consolidate with chilled and frozen products, which reduces opportunities to achieve high load factors by way of consolidation. Two, for those shipments, it was more difficult to implement intermodal transport.

9. Distance and modal split (i.e., Relationship 9 in Figure 6.4)
Distance stems from supplier selection (cf. McKinnon and Woodburn, 1996) and creates conditions for modal split. Distance was therefore included in analysis, even if it was not linked to a performance variable or FSC characteristic. Among its relationships, the longer the distance, the greater the use of intermodal transport (i.e., modal split). In Paper 3, average distances for the three modes studied were 1,113 km for road transport, 1,737 km for rail intermodal transport, and 2,725 km for sea intermodal transport. In Paper 4, flows considered for rail intermodal transport were 1,100–2,400 km, and the distance for sea intermodal transport was 2,900 km. Table 6.1 summarises the relationships between FSC characteristics (i.e., performance variables) and key variables.

Table 6.1 Summary of relationships between food supply chain characteristics/performance variables, product flow characteristics and key variables

Link	FSC characteristics/ performance variables	Product flow characteristics	Key variables
1	Chilled products (temperature regime)	Small shipment sizes	Low load factor
2	High supply variation	High variance of shipment size	Modal split (low usage of intermodal transportation)
3	High supply variation	High frequency	Modal split (low usage of intermodal transportation)
4	Short shelf life	High frequency	Modal split (low usage of intermodal transportation)
5(a)	Demands on low cost (transport)	Small/large shipment sizes	High load factor
5(b)	Demand on low cost (warehousing)	Small shipment sizes	Low load factor
6	Demands on low cost (tied-up capital)	High frequency	Modal split (low usage of intermodal transportation)
7	Low density	Small shipment sizes (weight), and large shipment sizes (floor space utilization)	Low load factor (weight), high load factor (floor space utilization) and modal split (low usage of intermodal transportation)
8		Chilled products (temperature regime)	Low load factor and modal split (low usage of intermodal transportation)
9		Short distance	Modal split (low usage of intermodal transportation)

How key variables influence transport's impact on climate

How key variables influence transport's impact on climate was calculated for five flows, as shown in Paper 4. For modal split, transport's impact on climate dropped between 27% and 53% when the use of intermodal transport increased from 0% to 100%; reductions were 27–31% for rail intermodal transport solutions and 53% for sea intermodal ones. When double-stacking pallets was applied, the load factor measured in weight increased for two flows. For the first, the load factor increased from 72% to 100%, which reduced transport's impact on the climate by 23%. For the second flow, the respective figures marked an increase from 92% to 100% and a reduction of 5%. Taken together, the potential to increase both the modal split and load factor is different for different flows. A salient characteristic that influenced the difference was product density; with greater density, reductions in the impact on climate increased for intermodal transport, yet lowered with the double-stacking of pallets. That result implies that PFCs can help to elucidate how key variables influence transport's impact on climate.

In relation to the content of this section, it is also of interest to consider the transferability of the findings. The analysis here takes a starting point in certain FSC characteristics and logistics performance variables. FSC characteristics sharpen the focus on the context of food products, whereas logistics performance variables are generally for logistics systems. In that sense, relationships linked to logistics performance variables are applicable to logistics systems of other products as well. However, it should be stressed that data collection encompassed flows that occurred upstream in the supply chain, either between primary production and industrial production or industrial production and wholesaling. For flows further downstream (i.e., between wholesaling and retailing) or for other types of products, it is possible that other FSC characteristics would be identified. For actors in FSCs, the challenge of having to consider their own contexts in terms of identifying FSC characteristics and link them and logistics performance variables to transport's impact on climate is addressed in the following section.

6.2.3 Frameworks for reducing the impact on climate of transport

The analysis in the previous section stressed the importance of context, since FSC characteristics and logistics performance variables influenced transport's impact on climate (i.e., Links 1–3 in in Figure 6.3). That circumstance creates a need for actors to identify relevant FSC characteristics and logistics performance variables and to understand when to implement what improvement actions as a means to efficiently reduce transport's impact on climate. In response, two frameworks are presented for that process: the TPF in Paper 3 and the MEIA in Paper 4. This part of the paper analyses how, both separately and in combination, those tools can support actors in four areas: approach (i.e., chief purpose of the frameworks), steps in the frameworks, improvements (i.e., how suggested improvements are positioned in the logic), and takeaways regarding what to consider when applying the frameworks (Table 6.2).

Table 6.2 Comparison of the transport portfolio framework and matrix for evaluating improvement actions

Area of comparison	Transport portfolio framework	Matrix for evaluating improvement actions
Approach	Evaluate all shipments in the logistics system according to potential for improving the key variables of modal split and load factor (i.e., horizontal analysis in the logic for answering RQ2)	Evaluate the effects of improvement actions for particular flows (i.e., vertical analysis in the logic for answering RQ2)
Steps	1. Classification 2. Categorisation 3. Action planning	1. Reductions in the impact on climate and transport costs 2. Barriers to implementation 3. Combining the perspectives
Improvements	1. Change product flow characteristics (PFCs) 2. Change key variables	1. Change priorities among performance variables 2. Change PFCs
Takeaways	1. Structure the complexity 2. Manage data 3. Be effective	1. Combine enablers and barriers 2. Include more logistics activities than transport in the analysis 3. PFCs, especially density, influence for the potential of various improvement actions

Approach: On the one hand, the TPF is a tool for supporting decision making that scrutinises logistics systems from the perspective that they encompass many shipments with different characteristics that impose requirements for transport's impact on climate. Actors therefore need to understand which shipments have a strong potential for improving the key variables of modal split and load factor. In relation to the logic for answering RQ2 (Figure 6.5), that potential is narrow in terms of the horizontal link between PFCs and key variables, but wide insofar as it includes all shipments in the logistics system. On the other hand, the MEIA evaluates how different improvement actions affect transport's impact on climate and transport costs. In relation to the logic for answering RQ2 (Figure 6.5), improvement actions constitute the starting point, yet are analysed in relation to other components in the logic in the vertical analysis. As such, the framework encompasses the entire logic, yet is limited to particular flows and thus a certain number of shipments. The frameworks therefore complement each other; the TPF can be applied when actors want an overview of their entire logistics system, while the MEIA can be applied when they want to compare improvement actions.

Steps: Both frameworks entail three steps. The TPF is based on portfolio models from both purchasing and supply chain design and consists of classification, categorisation, and action planning. The MEIA, by contrast, focuses on specific flows and the comparison of improvement actions. As a result, it provides support for identifying possible reductions in the impact on climate and transport costs, and barriers to implementation, as well as combines the perspectives of transport costs, the impact on climate, and barriers to implementation. As such, the frameworks therefore also complement each other in this aspect.

Improvements: Both frameworks provide guidance for reducing transport's impact on climate by suggesting improvements at different stages of the logic of RQ2 (Figure 6.3). For one, the MEIA suggests that shifting priorities among performance variables can allow actors to overcome barriers. Moreover, both the TPF and MEIA suggest that changing PFCs (e.g., shipment size) is possible. Lastly, as based on previous research, the TPF suggests that it is possible to change key variables without changing shipment characteristics; two such improvements could be horizontal collaboration or increasing load factors without increasing shipment size by collaborating with other actors. In effect, several different approaches for actors to reduce transport's impact on climate are available, ranging from changing the overall performance variables of a logistics system to more minor adjustments in the system.

Takeaways: Both frameworks additionally provide practical guidance for actors who want to reduce their transport's impact on climate. For actors with large logistics systems with many shipments, all with different PFCs, it is suggested to use the TPF in order to identify ways to structure complexity, manage data, and be effective. The takeaways of the MEIA are oriented toward comparing improvement actions at different flows, by combining the perspectives of enablers and barriers and applying a systems approach that includes the logistics systems. It also shows that PFCs, particularly density, influence not only key variables, but also the potential of various improvement actions. That effect implies that there are several aspects that actors need to consider when understanding the causes of their transport's impact on climate. In all, actors have to strike a balance between achieving exact results and not being overwhelmed with components and calculations. The frameworks should be able to contribute to their ability to strike such a balance.

6.2.4 Concluding remarks

In all, the answer to RQ2 promotes an understanding of how FSC characteristics and logistics performance variables impose requirements for key variables that, in turn, influence transport's impact on climate. It furthermore provides guidance for reducing transport's impact on climate with the help of two frameworks. The results underscore the importance of adhering to fundamental assumptions of overarching theories in the conceptual framework (Sections 3.1 and 3.2). On the one hand, contingency theory was applied in this analysis, since the context of FSC characteristics was a starting point for explaining the phenomenon of transport's impact on climate in the context of food logistics systems. Three FSC characteristics were identified that influence transport's impact on climate. Furthermore, the two frameworks of the TPF and MEIA were created in order to aid actors in considering their context when reducing transport's impact on climate in their logistics systems. On the other, the feasibility of applying a systems approach was clear in two aspects. First, the inclusion of logistics performance variables showed that when reducing transport's impact on climate, logistics activities beyond transport activities have to be considered. That necessity was shown with the inclusion of three types of costs: transport costs, warehousing costs, and costs of tied-up capital, which were linked to warehousing activities in this thesis, both in the analysis in Section 6.2.2 and in the MEIA. That result implies the importance of applying appropriate system boundaries by including relevant logistics activities when analysing how a logistics system creates conditions for transport's impact on climate. Second, the logic for answering the first part of RQ2 consisted of three links (Section 6.2.2). To explain the first and second links, it was necessary to analyse them in tandem, for analysing them separately would have led to fragmented explanations. That circumstance aligns with the view that it is important to take a holistic view, as opposed to an atomistic one (Gammelgaard, 2004). In relation to a systems approach, it was also relevant to consider what measurements were applied for load factor (i.e., weight, volume, and floor space utilisation). The choice of measurement influenced the potential for the improvement actions and should be regarded from case to case in order to choose a measurement that can best illuminate PFCs and key variables. The results of RQ2 provide input to answering RQ4.

6.3 RQ3: Food waste in logistics systems

An explorative question in two parts, RQ3 asked: How do FSC characteristics influence food waste (RQ3a), and how can improvement actions in food logistics systems reduce that waste (RQ3b)? The analysis is based on the findings of Paper 5 (i.e., food waste).

The answer to RQ3 is based on the logic used to answer RQ2 (Figure 6.5). In what follows, Section 6.3.1 specifies factors included in the components of that logic: performance variables and FSC characteristics, causes of food waste, and food waste itself. As such, it identifies categories used in the analysis. Section 6.3.2 addresses the first part of the analysis and answers RQ3a by exploring how FSC characteristics and logistics performance variables influence causes of food waste. Lastly, Section 6.3.3 answers RQ3b by exploring how actors in FSCs can reduce food waste in logistics systems, largely by identifying and describing logistics improvement actions to that end.

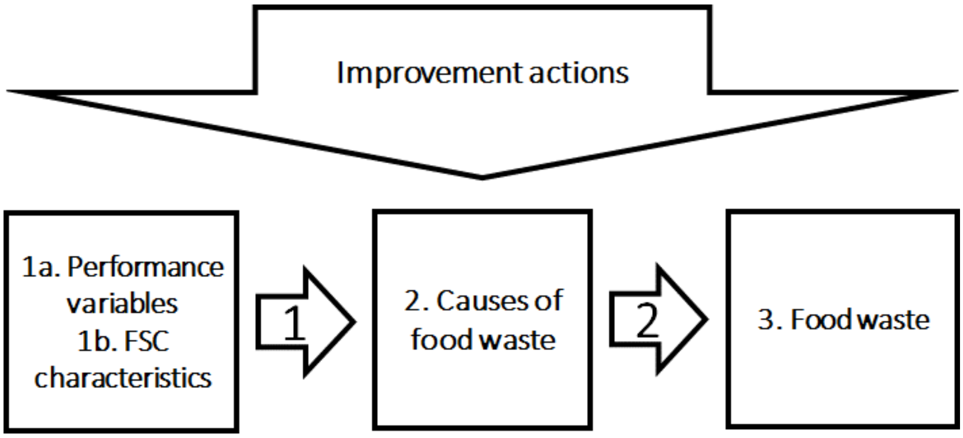

Figure 6.5 Logic for RQ3 (i.e., food waste) (FSC = Food supply chain)

6.3.1 Components in the logic

The components used to answer RQ3 in Sections 6.3.2 and 6.3.3, based on the logic for answering RQ3 (Section 3.8) and the findings of Paper 5, are identified in this section.

FSC characteristics and logistics performance variables: Possible factors were identified among FSC characteristics (i.e., RQ1) and logistics performance variables in the framework of Jonsson (2008). Empirical material from Paper 5 was used to identify five factors to include: four FSC characteristics (i.e., demand variation, supply variation, shelf life, and lead time) and two logistics performance variables (i.e., lead time and customer service in terms of assortment). Lead time is included as both a FSC characteristic and a performance variable.

Causes of food waste: These causes are analysed in light of three root causes of food waste: mega trends, natural constraints, and management root causes (Mena et al., 2011), as described in Section 3.6.

Food waste: Food waste can be measured by weight, in monetary terms, or in greenhouse gas equivalents, however this component is not studied in the thesis.

Logistics improvement actions: Logistics improvement actions are analysed according to components of logistics activities, actors and their stages in FSCs, and coordination mechanisms, as described in Section 3.7.3.

6.3.2 How food supply chain characteristics and logistics performance variables influence causes of food waste

To explore how FSC characteristics and logistics performance variables influence causes of food waste, three causes were analysed from the perspectives of mega trends, natural constraints, and management root causes. The causes consist of mismatches of two FSC characteristics or one FSC characteristics and one logistics performance variable. The analysis focuses on the first relationship in the logic for answering RQ3 (Figure 6.5) and is similar to the analysis in Paper 5.

1. Mismatched demand and supply variation

A cause of food waste was that demand (i.e., a FSC characteristic and a natural constraint) and supply (i.e., a FSC characteristic and a natural constraint) did not align. That these did not align could depend on variation in both demand and supply.

2. Mismatched shelf life and lead time

Ensuring an adequate lead time for products (i.e., a FSC characteristic, a logistics performance variable, a natural constraint, and a management root cause) so that they arrive at stores with sufficient shelf lives (i.e., a FSC characteristic and a natural constraint) is important to reducing food waste. Waste can occur in stores as well as upstream in FSCs if shelf lives end before products reach stores. A focus on shortening lead times is highlighted in the following quote describing the logistics activities at a wholesaler: 'We prioritize products with a very short shelf life…. we try to have as fast a flow as possible' (Wholesaler, Case 1).

3. Mismatched assortment and shelf life

Stores' demands for wide assortments have increased in recent years (i.e., a logistics performance variable and a mega trend), and poses a challenge for products with short shelf lives (i.e., a FSC characteristic and a natural constraint). The following quote highlight that logistics plays a role in mitigating the waste: 'The waste problem is very much about assortment . . . and we can mitigate the effects only with clever logistics solutions' (Wholesaler, involved in all cases).

The three causes reveal that food waste can be attributed to both FSC characteristics and logistics performance variables. That combinations of two characteristics prompt food waste, is consistent with the analysis for RQ1 regarding the importance of considering combinations of FSC characteristics.

6.3.3 Logistics improvement actions

The analysis of logistics improvements consists of two parts. First, the logistics improvement actions are described, structured first in terms of type of waste, and within types of waste structured by causes of waste. Second, a cross-case analysis is presented for how the improvement actions have been adapted in the cases. Table 5.4 illustrates the basis for the analysis and provides a guide for readers by summarising relationships among components that describe the logistics improvement actions. The analysis is a shorter version of the analysis in Paper 5.

Collaborative forecasting (1) reduces food waste in terms of passed expiration dates due to mismatched supply and demand by applying the coordination mechanism of joint decision making. It is executed by joint forecasts between the producer and wholesaler (the activity of procurement) or the wholesaler and retailer.

Division of lead time (2) reduces food waste in terms of passed expiration dates due to mismatched shelf life and lead time by applying the coordination mechanisms of rules. The rules for the division of lead time among producers, wholesalers, and retailers were adjusted in order to increase the priority of longer shelf lives for consumers over longer lead times for actors in FSCs. A project was initiated in order to identify products for which a longer shelf life could help customers reduce waste in households. If consumers store or use the same item for a long time—for instance, a bottle of ketchup,—then they should have more of the total lead time to finish the product. On the other hand, products that are stored for a shorter time, such as a bag of potato chips, did not have the same need for longer shelf life for consumers. The project involved a wholesaler (the activities of procurement, replenishment, and warehousing) and a retailer, and it adjusted the 1/6 rule for 180 representative groups (note: including more products than the addressed cases) according to consumer storage times.

Level of safety stock (3) reduces food waste in terms of passed expiration dates due to mismatched shelf life and lead time by applying the coordination mechanism of joint decision making. The improvement action lessens the level of safety stock in warehouses and internal production units as a way to reduce lead times until they comply with short shelf lives. Determining the level of safety stock requires integration in daily processes since it is based on a trade-off; replenishment want low levels of safety stock to reduce waste, whereas production and warehousing want higher levels to be able to operate efficiently.

Make-to-order flows (4) reduce food waste in terms of passed expiration dates due to mismatched shelf life and lead time by applying the coordination mechanism of joint decision making. They involve the producers, wholesalers (the activity of replenishment), and retailers and are executed through postponed manufacturing until stores place orders.

Measures of service level (5) reduce food waste in terms of passed expiration dates due to mismatched assortment and shelf life by applying the coordination mechanism of rules. This improvement action implies suggesting alternative measures for service level in which the cost of food waste is prioritised over the service level. It involves the wholesalers (the activity of replenishment) and retailers. Two approaches for adjusting service level were identified. The first concerns measuring it jointly for equivalent products from different countries. The other approach proposes measuring service level together with similar stock keeping units instead of single stock keeping units at the end of a season.

Price reductions (6) reduce food waste in terms of passed expiration dates for all three causes described above with the coordination mechanisms of pricing. This improvement action is executed through reducing prices for products that have exceeded or will soon exceed the agreed-upon shelf life with the next actor downstream in the supply chain. It involves the stages of production, wholesaling (the activity of replenishment), and retailing.

Product group revisions (7) reduce food waste in terms of passed expiration dates for all three causes described above with the coordination mechanisms of information sharing. Per industry guidelines, wholesalers and retailers have to host joint product group revisions, typically three times per year. At such meetings, wholesalers (the activity of replenishment) and retailers decide which products to include and exclude in certain assortments. The improvement action implied preparing waste statistics for those revisions meetings. This improvement action was executed through a report package identifying the 10 products and three producers with the most waste. At the meetings, the causes of waste were identified, and ways to reduce waste were discussed.

Visualising damaged packaging (8) reduces food waste in terms of damaged packaging caused by a mismatch of the packaging and the logistics system by applying the coordination mechanism of information sharing. It involves sharing information about waste in terms of its magnitude and causes. Information was collected concerning the three logistics activities of transport, warehousing, and order support at the wholesalers, as well as retailers, and was made accessible to the activities of procurement and packaging development at the wholesalers. Regarding the activities of transport and warehousing, personnel at warehouses reported all instances of waste into computer programmes so that people responsible for the activities of procurement and developing packaging were able to access it. Further, as a part of the activity of order support, complaints from stores (i.e., involving retailers) were collected, which were forwarded to the activity of procurement, where action could be taken.

Packaging development (9) reduces food waste in terms of damaged packaging due to a mismatch of the packaging and the logistics system by applying the coordination mechanism of joint decision making. It is an ongoing improvement action on visualising damaged packaging that was applied in order to reduce the waste identified with the help of information sharing. This improvement action involves the producers and wholesalers (the activities of procurement and packaging development). In order to motivate changing packages to reduce waste, it is of importance to take a holistic approach that considers a packaging's pros and cons at warehouses and in stores, often with total cost analyses.

Adapting logistics improvement actions: Comparing the meat FSC (Case 1) and the FaV FSC (Case 2) involved analysing how two improvement actions were adapted in response to product characteristics, market requirements, and actors, as well as why four improvement actions were applied in the meat FSC only (Case 1).

Two improvement actions were adapted depending on the product type and actors involved: collaborative forecasting (1) and measures for service level (5). Collaborative forecasting (1) was adapted in two ways. First, the improvement action was more intense between wholesalers and meat producers than between wholesalers and FaV producers. Most meat producers were Swedish and had Swedish retailers as their top customers. For FaV, most producers were larger foreign companies for which Sweden was a relatively small market. As such, a change in demand from a Swedish wholesaler would not have the same consequences for a foreign FaV producer as it would for a Swedish meat producer. Accordingly, the need for coordination in terms of joint decision making for demand forecasts was greater for meat producers. Second, collaborative forecasting due to supply variation was more intense between FaV producers and wholesalers. For FaV products, rapid drops in supply due to weather could create shortages for wholesalers, who in response frequently had to contact producers regarding expected harvests. For meat products, by contrast, the input of raw material for production was rather stable and would not cause any unexpected variations in volume. Therefore, in light of supply variation, the need for coordination in terms of joint decision making for supply forecasts was greater for FaV producers. To address measures of service level (5), the wholesaler had the option of sourcing the same kind of FaV products from various countries, which would not be applicable for meat products given market requirements that preclude the possibility of substituting Swedish meat products with foreign ones.

Four improvement actions were identified only for meat FSCs: division of lead times (2), product group revisions (7), level of safety stock (3), and MTO flows (4). The division of lead times (2) and product group revisions (7) were applied in meat FSCs only because improvement actions focused on products stored in wholesalers' internal warehouses, whereas FaV warehousing activities were outsourced. It is possible that it would also have been feasible to apply the same improvement actions for FaV products. The improvement action regarding level of safety stock (3) could also have been feasible for FaV FSCs, since the challenge of having a suitable level of safety stock is also applicable in warehouses for FaV. Conversely, MTO flows (4) were conceived to be more difficult to implement in FaV FSCs than in meat ones. For both meat and FaV products, long production times characterised primary production, which implied that the MTO process was impractical at that stage, but could be applied for industrial production instead, where the lead time was shorter. In meat FSCs, appropriate prerequisites for MTO flows were in place: stable input from primary production, a wide range of possible products from each animal, and short production and transport times. For FaV chains in this study, by contrast, supply variation was greater, transport times were longer, and the number of possible products for each crop was more limited, all of which posed barriers for implementing MTO flows in those FSCs.

6.3.4 Concluding remarks

Altogether, the answer to RQ3 promotes an understanding of how FSC characteristics and logistics performance variables create causes of food waste. It furthermore provides guidance for reducing food waste by identifying, describing, and analysing nine logistics improvement actions. The results underscore the importance of adhering to fundamental assumptions of overarching theories in the conceptual framework (Sections 3.1 and 3.2). On the one hand, it applies contingency theory by consider context in two ways; the context in terms of FSC characteristics was a starting point for describing causes of food waste, and a case comparison showed how context in terms of product characteristics, market requirements, and actors influences logistics improvement actions. Second, it applies a systems approach by including six logistics activities together in the analysis of logistics improvement actions and stresses the importance of including several logistics activities in order to reduce food waste. Moreover, the results indicate that the logistics improvement actions are interlinked and that coordination is needed not only within logistics improvement actions, but also between them. That circumstance stresses the importance of analysing logistics improvement actions within logistics systems jointly, in alignment with the importance of taking a holistic view, as opposed to an atomistic one (Gammelgaard, 2004). In terms of this thesis, the results provide input to answering RQ4.

6.4 RQ4: Combining two types of environmental impact

RQ4 sought to explore how addressing transport’s impact on climate and food waste jointly can contribute to reducing the environmental impact of food logistics systems. In this section, that challenge is analysed from two perspectives: in terms of how FSC characteristics influence both types of environmental impact (i.e., transport’s impact on climate, or RQ2a, and food waste, or RQ3a) and in terms of how actors take inspiration from improvement actions for one environmental impact to reduce the other (i.e., RQ2b and RQ3b). It addresses the entire conceptual framework (Figure 3.11) and, as such, can be viewed as a synthesis of the thesis. The results and analysis are based on the findings of Papers 2–5. Figure 6.6 presents the logic used for answering RQ4; Part A of the figure is presented in Section 6.4.1 and Part B in Section 6.4.2.

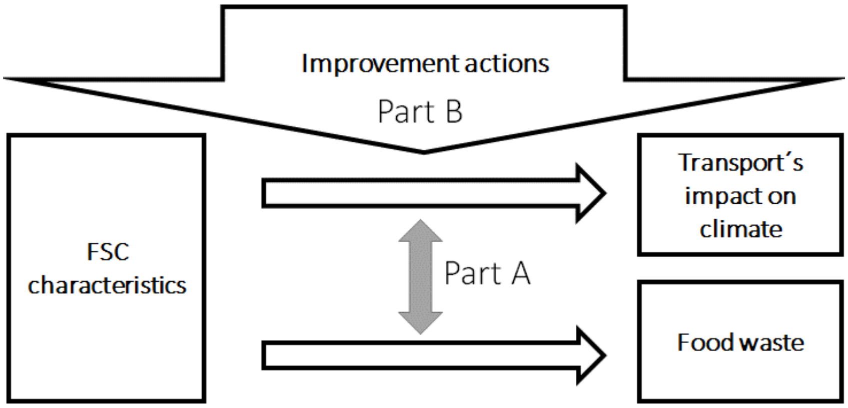

Figure 6.6 Logic for RQ4 (i.e., about combining two types of environmental impact) (FSC = Food supply chain)

6.4.1 How food supply chain characteristics influence both types of environmental impact

This section presents an analysis of how FSC characteristics (i.e., from RQ1) influence transport's impact on climate (i.e., for RQ2) and food waste (i.e., for RQ3). To that end, FSC characteristics are analysed according to their classification as trade-offs, convergences, or moderators (Table 6.3). A *trade-off* means that the direction of FSC characteristics creates conditions for both types of environmental impact differently. By contrast, a *convergence* of the FSC characteristics means that their direction creates the same conditions for transport's impact on climate and food waste. Lastly, a *moderator* refers to an FSC characteristic that can reduce a trade-off based on another characteristic. The analysis is based mostly on the results of answering RQ2 and RQ3, although literature was also used to complement the empirical material. It should be stressed that this analysis is speculative, since data were not collected primarily to answer this research question.

Table 6.3 Relationships among food supply chain characteristics and transport's impact on climate and food waste, based on results of answering RQ1–3

FSC characteristic, based on RQ1	**Transport's impact on climate, based on RQ2**	**Food waste, based on RQ3**	**Trade-off, convergence, or moderator**
Lead time	McKinnon (2016) argues that increasing lead times in supply chains can increase both load factors and the use of intermodal transport. Requirements for short lead times in supply chains can limit possibilities for changing the mode of transport, as shown in Paper 2.	Since mismatched lead times and shelf lives are a cause of waste, as shown in Paper 5, short lead times are desired to reduce food waste	Trade-off, especially for products with short shelf lives
Shelf life	Short shelf-life limits possibilities for changing the mode of transport, as shown in Paper 2, if it increases the lead time.	Since mismatched lead times and shelf lives are a cause of waste, as shown in Paper 5, products with shorter shelf lives require shorter lead times.	Trade-off for products with short shelf lives (i.e., the same trade-off as lead time)
Temperature regime	Temperature regime creates conditions for modal split and load factor. For chilled and frozen products, load factors and the use of intermodal transport are less than for ambient products, as shown in Paper 3.	Since chilled products often have shorter shelf-lives than ambient and frozen ones, as shown in Paper 3, they require shorter lead times.	Trade-offs for chilled products (i.e., the same trade-off as for shelf life and lead time)
Supply variation	High supply variation can reduce the use of intermodal transport, as shown in Paper 4.	High supply variation can increase food waste, since mismatched demand and supply cause waste, as shown in Paper 5.	Convergence; high supply variation can negatively affect both types of environmental impact
Demand variation	Supply variation reduces the use of intermodal transport, as shown in Paper 4, and it is assumed that high demand variation can cause similar challenges.	High demand variation can increase food waste, since mismatched demand and supply cause waste, as shown in Paper 5.	Convergence; high demand variation can negatively affect both types of environmental impact

Product value	For products with less value, transport costs can be a large part of the total cost (Lambert et al., 1998), which implies that lower transport costs are important. Since transport costs and transport's impact on climate are often linked, the focus on efficient transport increases with lower product value.	For products of greater value, there can be greater incentives to reduce food waste (Paper 5), which then encourage smaller shipment sizes.	Trade-off; both for products with high and low values
Stage in the supply chain	González–Benito and González–Benito (2006) show that the stage in a supply chain sets conditions for the environmental proactivity of companies; the further downstream, the more environmentally proactive the company. This dynamic implies that the further downstream in the supply chain, the greater an actor's focus on both types of environmental impact.		Moderator; stages downstream in the supply chain can be a moderator
Actor size	González–Benito and González–Benito (2006) also show that company size affects the companies' environmental proactivity; the larger the company, the more environmentally proactive it is. That characteristic therefore sets conditions for both types of environmental impact. Larger companies in FSCs often have larger volumes. With larger base volumes, trade-offs between transport's impact on climate and food waste can be reduced as the economy of scale and responsiveness align.		Moderator; large company size can be a moderator

Trade-offs, alignments, and moderators were identified with the help of the eight FSC characteristics. First, products with the FSC characteristics of low/high product value, short shelf life, requirements for short lead times, and the chilled temperature regime were identified to be part of the challenge of creating trade-offs. In light of the importance of analysing FSC characteristics jointly, as shown in answering RQ1, trade-offs related to short shelf life, requirements for short lead times, and chilled temperature regime were found to not only link to each other, but be difficult to isolate. Second, two FSC characteristics converged in terms of creating difficulties for reducing both types of environmental impact: high demand variation and high supply variation. Accordingly, for actors who confront those FSC characteristics, it is crucial to understand how they influence both types of environmental impact, as well as to identify improvement actions for reducing them. Third, some FSC characteristics were found to moderate both types of environmental impact: being downstream in the supply chain, which can support active work toward mitigating environmental impacts, and being a large company, which can moderate trade-offs (e.g., through shipment size). For example, to reduce transport's impact on climate, large shipment sizes are beneficial; however, smaller sizes can better reduce food waste. For large companies with larger shipments, that trade-off might therefore be less salient than with small companies.

Although this analysis provides insight into how FSC characteristics influence the two types of environmental impact jointly, due to the speculative nature of the analysis, further research is needed to clarify how actors in FSCs can modify FSC characteristics trade-offs, convergences, or moderators in order to reduce environmental impacts.

6.4.2 Comparison of improvement actions for the two types of environmental impact

In this section, a combined analysis of answers to RQ2 and RQ3 is presented that focuses on improvement actions. The basis of the comparison is the four groups of improvement actions, developed with help of included coordination mechanisms, which were identified in answering RQ3. The analysis consists of comparing the nine improvement actions for reducing food waste, with the two decision-making support tools developed to answer RQ2 (Table 6.4). When conducting this analysis, the four groups formed in answering RQ3 were renamed in this analysis in order to focus on their relation to not only coordination mechanisms involved—visualisation, flow (i.e., efficiency), performance priorities (i.e., effectiveness), and emergency—but also the logistics system. Lastly, the groups are compared according to the three strategies used to combine supply chain management (SCM) and sustainability presented by Halldórsson et al. (2009). As in the previous section, since this research question is speculative and synthesises the results of answering the other research questions, an inevitable outcome of its analysis is a suggestion for further research.

Table 6.4 Comparison of logistics improvement actions for the two types of environmental impact (TPF = Transport portfolio framework, MEIA = Matrix for evaluating improvement actions)

	Visualisation	**Flow (i.e., efficiency)**	**Performance priorities (i.e., effectiveness)**	**Emergency improvement actions**
Food waste (i.e., RQ3)	Two improvement actions based on the coordination mechanism of information sharing	Four improvement actions based on the coordination mechanism of joint decision making	Two improvement actions based on the coordination of mechanism rules	One improvement action based on the coordination mechanism of price
The TPF assesses the entire logistics system according to potential for improvement actions (i.e., RQ2)	Describes how to visualise the current situation in the logistics system for two key variables		Addressed as limitations of possible improvement actions	Not addressed
The MEIA evaluates the effects of improvement actions for different flows (i.e., RQ2)	Describes how to visualise the potential of three improvement actions for specific flows		Addressed as barriers possible to change	Not addressed

Visualisation: Visualisation concerns understanding where and why environmental impact occurs with the help of frameworks, tools, and processes. To answer RQ3, visualising waste was performed with the coordination mechanism of information sharing in order to identify the largest contributors of food waste and understand their causes. In retrospect, the frameworks developed to answer RQ2 clearly emphasised visualisation, particularly in visualising the current performance of the logistics system and the potential for improvement actions.

Similarities and differences in challenges in developing visualisation tools and frameworks characterise the two types of environmental impact. Among similarities, both types of environmental impact occur in large logistics systems, with many products and transport flows, and gaining an overview is therefore not always easy. For both types, it can be necessary to include different actors to collect the necessary data. To assess transport's impact on climate, it is often necessary to retrieve data from transport providers regarding for example load factor (i.e., for less-than-truckload shipments), and type of truck. In relation to food waste, it can be necessary to retrieve information from actors up- or downstream in the supply chain, if not both, about their waste, largely in order to achieve a supply chain perspective. Another difference concerns measurements and necessary calculations; food waste is often measured in weight or in monetary value, both of which values are relatively easy to access in organisations as long as food waste statistics are collected in logistics systems. To estimate the impact on climate of the transport activities, often time-consuming calculations are necessary to yield CO_2 equivalents. It should be stressed, however, that if food waste is gauged with measures related to environmental impact such as CO_2 equivalents, then more calculations are necessary.

In Paper 5, it was revealed that industrial producers were not involved in logistics improvement actions linked to visualisation, which was thus underscored as an area for further research. By situating that circumstance in terms of the TPF and MEIA, both tools emerge to be limited to focusing on only one actor at only one stage in the FSC. Since the analysis conducted to answer RQ2 showed that FSC characteristics influence transport's impact on climate and are in turn influenced by actors up- and downstream in FSCs, it could be interesting to further study visualisation involving several stages of supply chains in order to reduce transport's impact om climate.

Flow (i.e., efficiency): Changes to the flow imply long-term adjustments to the material or information flow in order to reduce the environmental impact of the logistics systems and coincidentally make the logistics systems more efficient. In answering RQ3, such changes were made with four improvement actions based on the coordination mechanism of joint decision making. As shown in answering RQ2, proposed improvement actions (i.e., double-stacking pallets and implementing intermodal transport) adapted the material flow.

To compare flow improvement actions, two aspects need to be considered: logistics activities involved and with whom improvement actions are coordinated. Improvement actions to improve the flow in order to reduce food waste involve several logistics activities at the wholesaler (i.e., procurement, replenishment, warehousing, and packaging development), all of which are coordinated both upstream with producers and downstream with retailers. Put differently, a supply chain perspective has to be applied. For improvement actions aimed at reducing transport's impact on climate, focus fall on the activity of transport, and coordination occur with the transport and logistics providers who can execute that activity. In the logic for answering RQ2, FSC characteristics and performance variables influenced transport's impact on climate, all set by either other logistics activities or actors up- and downstream in the supply chain. Therefore, it would be interesting to further investigate how joint decision making can be applied in dyads or supply chains in order to reduce transport's impact on climate.

Changing performance priorities (i.e., effectiveness): Changing performance priorities is linked to altering logistics performance variables used to describe the objectives of the logistics systems—that is, to questioning the effectiveness of logistics systems. In answering RQ3, two improvement actions were identified that involve changing the performance priorities of supply chains as based on the coordination mechanisms of rules. Although identified between wholesalers and retailers, the actions did not include industrial producers. In the logic used to answer RQ2, performance priorities were identified that relate to transport's impact on climate, and in the TPF, performance variables were considered to limit the possibility of improvement actions, though reprioritising them was not addressed. In the MEIA, the variables were barriers, and the framework showed that they could be changed. It is thus necessary to further study how altering performance priorities in actors' logistics systems can influence the impact of their transport on climate. For food waste, more studies are also necessary on the topic of changing performance priorities, particularly in order to include industrial producers. In that sense, further research, preferably quantitative studies, needs to investigate the potential for reducing both types of environmental impact by altering performance priorities in single actors' logistics systems as well as supply chains.

Emergency improvement actions: Emergency improvement actions are applied in response to an immediate risk of high environmental impact not mitigated by other identified improvement actions. In answering RQ3, this risk implied reducing the price of food products with short shelf lives by applying the coordination mechanisms of price, which was used by all stages in the FSC. Since nothing similar was identified for transport's impact on climate in answering RQ2, it would be interesting to investigate emergency improvement actions for transport's impact on climate—for example, having buffers of extra freight without time restrictions given a low load factor in transport activities.

Three approaches for combining SCM and sustainability: As presented in Section 3.2, there are three approaches for combining SCM and sustainability: the integration strategy, the alignment strategy, and the replacement strategy (Halldórsson et al., 2009). These are here linked to the four groups of logistics improvement actions. The groups of visualisation, flow, and emergency actions fit into the group of integration, since improvement actions in that case also benefit logistics performance variables. The group of modified performance priorities is linked to the alignment strategy, which considers ways to align environmental impact by changing performance variables. Lastly, the strategy of replacement was not identified for either type of environmental impact. Therefore, future studies should examine how logistics improvement actions can be developed in that last category, which implies developing logistics systems focused on reducing transport's impact on climate and food waste. To further the development of improvement actions in current logistics systems, an understanding of what alternative systems might involve would be useful, and it would therefore be valuable to analyse how improvement actions linked to replacement strategies affect logistics systems.

6.4.3 Concluding remarks

Altogether, the answer to RQ4 promotes an understanding of how FSC characteristics influence both types of environmental impact (i.e., transport's impact on climate and food waste) and how actors can take inspiration from improvement actions for one environmental impact to reduce the other. The results underscore the importance of adhering to fundamental assumptions of the overarching theories in the conceptual framework (Sections 3.1 and 3.2). First, it applies contingency theory, since FSC characteristics were used as a foundation for analysing how the logistics systems created conditions for the two types of environmental impacts jointly. Second, it relates to a systems approach in terms of analysing environmental impact from activities and products jointly, in terms of the two types of impact in the logistics systems. The analysis stressed the importance of taking a holistic perspective on environmental impact in logistics systems, both when identifying what characteristics influence the environmental impact as well as identifying and developing improvement actions for reducing that impact. That emphasis aligns with the importance of taking a holistic instead of an atomistic view (Gammelgaard, 2004).

7 Discussion

This thesis has taken as its starting point the phenomenon of environmental impact in food logistics systems and the practical problem that actors in food supply chains (FSCs) have to reduce that impact. To explore that phenomenon, the thesis was based on literature in two fields: food logistics and green logistics.

The discussion that follows is divided into four parts. Section 7.1 discusses the results of the thesis in relation to the four research questions, with a focus on describing the contributions of each question, discussing the findings in relation to previous research, and elaborating upon what implications the findings pose for further research. The discussion relates to the literature reviewed in Chapter 2 in relation to green logistics and food logistics, as well as the conceptual framework in Chapter 3. Later, Section 7.2 describes the managerial implications of the thesis, after which Section 7.3 discusses the transferability of the findings in relation to stages in FSCs and product types. Lastly, Section 7.4 offers suggestions for further research.

7.1 Discussion of results

This section discusses the results of the respective research questions.

7.1.1 RQ1: Food supply chain characteristics

The analysis for answering RQ1 aimed to identify FSC characteristics that can describe the logistics systems of food products. Since the research was primarily based on literature in food logistics, the results are discussed in relation to that field, for both the literature review and the study of FSC characteristics.

With the literature review, a first contribution of answering RQ1 is the definition of *food logistics*. Unlike *green logistics* and related concepts in terms of green supply chain management (SCM) and sustainable SCM, for which several definitions are provided, no definitions were identified for *food logistics*. This thesis therefore contributes by providing a definition of *food logistics* that emphasises the need to scrutinise aspects specific to food products and FSC actors. Second, this thesis contributed by assessing literature addressing food logistics from a logistics perspective and identifying areas requiring further attention from the food logistics research community.

For results in relation to FSC characteristics, all FSC characteristics derived from previous literature, and that they were also identified in the empirical material confirms their importance. FSC characteristics for which different categories were identified in the literature (i.e., supply variation, demand variation, and temperature regime) were also confirmed with empirical findings. The same types of supply variation—that is, seasonality in production and natural condition—emerged in both the literature (e.g. Aramyan et al., 2007) and empirical material. For demand variation, three of the four types identified in the literature—namely, market initiatives, seasonality, and weather (e.g. van der Vorst et al., 2001)—also appeared in the empirical material. Lastly, the empirical material suggests that the three types of temperature regime create different conditions for logistics systems, as previously reported (e.g., Mena and Whitehead, 2008). However, seldom has research identifying FSC characteristics addressed more than two characteristics at once. As such, this thesis expands previous research by compiling eight FSC characteristics into two categories and analysing how links among the characteristics create conditions for logistics systems. Although Romsdal (2014) identifies FSC characteristics from a production-based perspective, four of those characteristics are similar to the ones in the thesis: supply variation, demand variation, shelf life, and lead time. That both lists of FSC characteristics include those characteristics demonstrates their significance from both a logistics and production perspective. The FSC characteristics in this thesis also included stage in the supply chain and relative size of the company, which are important when considering collaboration among actors in FSCs. Other characteristics identified in the thesis were product value and temperature regime, which together afford further understandings about food products in terms of their value and requirements for logistics systems. Clearly, the frameworks share similarities (i.e., supply variation, demand variation, shelf life, and lead time), but also exhibit differences. Since Romsdal's (2014) work takes a production-based perspective while this thesis takes a logistics ones, the frameworks can complement each other and thus support researchers who study both logistics and production systems.

For food logistics researchers, the compilation of FSC characteristics can aid both research design and analysis. First, the characteristics can be used to support sampling, insofar as researchers can consider which ones create conditions for phenomena examined and, from that, make decisions about which ones the studied cases might illustrate. Second, the compilation of FSC characteristics can be used in case descriptions and, third, in analyses in research studies. In both Papers 2 and 5, along with singular FSC characteristics, combinations of characteristics were shown to create conditions for logistics systems. By extension, researchers can consider whether analysing combinations of FSC characteristics can be useful for studying the phenomena addressed in their research. The usability of the characteristics was exemplified in Paper 5, in which the framework of the eight characteristics was used in sampling and case descriptions, as well as in the foundation for analysing causes of food waste. Lastly, the eight FSC characteristics can be used to discuss the transferability of FSCs in different studies.

7.1.2 RQ2: Transport's impact on climate

An explanatory question in two parts, RQ2 asked: How do FSC characteristics influence transport's impact on climate (i.e., RQ2a), and how can improvement actions in food logistics systems reduce that impact (i.e., RQ2b)? Since the research for answering RQ2 was foremost based on literature in green logistics, the results are discussed in relation to that field.

In terms of their contributions, the results found by answering RQ2 first expand research in green logistics by considering the context of food products in relation to transport's impact on climate. The frameworks upon which the logics are built stress that products influenced transport's impact on climate in logistics systems (Aronsson and Huge Brodin, 2006; Piecyk and McKinnon, 2010; Wu and Dunn, 1995), but do not consider FSC characteristics such as temperature regime. Therefore, this thesis expands the understanding of those frameworks, chiefly by showing how three FSC characteristics (i.e., temperature regime, supply variation, and shelf life) influence transport's impact on climate in logistics systems. Considering that the field of green logistics has grown in recent years and that several frameworks can explain links between the logistics systems and transport's impact on climate, it was deemed suitable to adapt those frameworks to accommodate FSCs. Such thinking is in line with that of Carter and Easton (2011), who conclude that more research is needed on specific industries. Furthermore, the answer explained how the performance variable of cost influences transport's impact on climate. In particular, it showed that in some cases, improvement actions imply increased costs for the entire logistics system, even if the costs for the activity of transport are reduced. Considering that cost reductions are identified to constitute a motivator for reducing the environmental impact in food logistics systems in Chapter 1, it is important to identify improvement actions that entail reduced costs for the actors' logistics systems, which can be performed with the matrix for evaluating improvement actions (MEIA). Lastly, the findings also show that shipment density influenced the potential of improvement actions; considering that density is highly linked to products and not easily changed, actors have to ensure that appropriate improvement actions are put in place in order to exploit the potential of the actions in relation to the density of the products.

Second, with the help of the developed frameworks, the answer to RQ2 shows how using matrixes and portfolios in green logistics clarifies how actors can efficiently reduce their transport's impact on climate by analysing how FSC and product flow characteristics influence transport's impact on climate in logistics systems. Indeed, matrixes and portfolios have been used in several logistics and supply chain-related fields, including purchasing (e.g. Kraljic, 1983; Olsen and Ellram, 1997) and supply chain design (e.g. Christopher, 2000; Christopher and Towill, 2001; Fisher, 1997; Godsell et al., 2011; Persson, 1991), yet not in green logistics. That this thesis applies matrixes and portfolios in studying green logistics implies the possibility of considering the context of different supply chains when seeking to reduce transport's impact on climate.

The combination of the existing frameworks in green logistics with matrixes and portfolios implies possibilities to further innovate ways to address product characteristics in green logistics. The logic explaining how logistics performance variables and FSC characteristics influence transport's impact on climate can be used by researchers to analyse links among logistics systems and transport's impact on climate in FSCs. It could also be applied to other types of products, either if they have similar characteristics as FSCs or if FSC characteristics are replaced with other characteristics. At the same time, the frameworks developed based on the ideas of matrixes and portfolios can be applied by researchers to evaluate types of logistics systems other than those in the empirical cases in RQ2—for example, for other stages in supply chains (e.g., downstream between wholesalers and retailers), other types of shipments (e.g., less-than truckload shipments), and other product types.

7.1.3 RQ3: Food waste

An explorative question in two parts, RQ3 asked: How do FSC characteristics influence food waste (RQ3a), and how can improvement actions in food logistics systems reduce food waste (RQ3b)? The research undertaken to answer that question was chiefly based on literature within the field of food logistics and therefore the results are discussed in relation to that field.

First, whereas previous research has examined specific logistic improvement actions in great depth (e.g. Kaipia et al., 2013; Rijpkema et al., 2014), RQ3 has instead taken a broader perspective by identifying, describing, and analysing nine logistics improvement actions. Such an approach allowed the corresponding analysis to identify the logistics improvement actions based on four coordination mechanisms, involving six logistics activities, and covering all three stages of FSCs. Such variety poses a challenge for actors in FSCs in gaining an overview of all current logistics improvement actions for reducing food waste. Having that overview is important, because the improvement actions are interlinked in at least two ways. First, the results of actions related to information sharing can provide important insights into improvement actions linked to other coordination mechanisms; for example, for both actions for reducing waste caused by damaged packaging, joint decision making is based on information sharing. Second, if improvement actions based on rules and joint decision making are applied efficiently, then they can reduce the need for improvement actions linked to the coordination mechanism of pricing. That dynamic implies that coordination is not only needed within each improvement action, but also between improvement actions. In that sense, this research contributes by offering an overview of the nine logistic improvement actions.

Second, the results confirm the importance of taking a supply chain perspective in order to reduce food waste, as suggested by Mena et al. (2011) and Lindbom et al. (2013). Such significance stems from the fact that, in this thesis, all logistics improvement actions examined affect at least two stages of the supply chain. The findings offer insights into what coordination mechanisms are currently applied among stages of FSCs in order to reduce food waste. Although some logistics improvement actions transcend the three supply chain stages, when jointly analysing the perspectives of those stages regarding coordination mechanisms, it is clear that producers are involved in logistics improvement actions linked to pricing and joint decision making, albeit neither information sharing nor modifying the rules. Studying three stages of FSCs can also be viewed as a methodological contribution to green logistics, since, as Carter and Easton (2011) show, within sustainable SCMs, studies of dyads or more actors within supply chains account for only 4% of the literature.

In relation to how those findings can be applied in further research, the logic used to answer RQ3 can be applied to further develop existing improvement actions and identifying new ones, and the findings of RQ3 provide insight into how to achieve that end. For example, the findings suggest that when developing logistics improvement actions to reduce food waste, the type of waste addressed has to be clear (e.g., expired dates or damaged packaging), and different improvement actions have to be applied for different types of waste. Furthermore, the findings imply the significance of considering context in terms of product characteristics, market requirements, and actors when developing logistics improvement actions to reduce food waste. Lastly, the comparison of logistics improvement actions demonstrates that there is potential to further reduce food waste—for instance, by including food producers in improvement actions in terms of information sharing and altering the rules.

7.1.4 RQ4: Combining two types of environmental impact

An explorative question, RQ4 asked: how can addressing transport's impact on climate and food waste jointly contribute to reducing the environmental impact of food logistics systems?

In this thesis, RQ2, which focused on transport's impact on climate, was primarily based on research in green logistics, whereas RQ3, which focused on food waste, was primarily based on research in food logistics. By contrast, RQ4, which represents a synthesis of RQ2 and RQ3, combines both fields and studies what can be called green food logistics. In short, combining the two fields provided a foundation for studying the phenomenon of environmental impact in food logistics systems. Applying green logistics clarified how logistics activities influence transport's impact on climate, while applying food logistics provided insights into products in food logistics systems and causes of food waste. The literature review in Section 2.3 identified

25 papers published since 2005 that have combined perspectives of food logistics and green logistics, thereby indicating that even despite an increasing trend among publications to cross the two fields, much remains to investigate. In relation to the phenomena studied in this thesis (i.e., transport's impact on climate and food waste), only Bloemhof et al. (2015) has included both environmental impacts. However, by examining more variables, their paper does not go into the depth that this thesis has. Studying transport's impact on climate and food waste jointly was deemed important, since many actors in FSCs have to consider both impact from products (i.e., food waste) and logistics activities (i.e., transport's impact on climate). The findings of RQ4 confirmed that necessity, since FSCs can influence the two types of environmental impact differently, as well as that actors can further reduce either type by taking inspiration from the other. Such findings would not have been identified if answering RQ4 had not drawn from both fields. Although the author does not want to go so far as to state that a new research field of green food logistics should be formulated, in order to study the phenomenon of environmental impact in food logistics systems, further research should continue to combine food logistics and green logistics. By doing so, ample opportunities should emerge to study ways to reduce environmental impact in food logistics systems.

There are two primary ways to implement the above findings in further research. The first concerns applying the idea that FSC characteristics can be trade-offs, convergences, or moderators in relation to different types of environmental impact—for example, applicable to further study transport's impact on climate and food waste, as well as by analysing other types of environmental impacts in logistics systems. Second, the four groups of improvement actions could be used to develop the identified improvement actions for reducing the environmental impact of food logistics systems and to identify new improvement actions.

7.2 Managerial implications

In this section, managerial implications are directed toward actors in FSCs, particularly logistics mangers, and address three topics: the environment of the logistics system and where and why environmental impact occurs, a holistic view of environmental impacts, and improvement actions.

The first topic is the importance of understanding the influence of the environment of logistics system, as well as of where and why environmental impact occurs. The results of the thesis show that when seeking to reduce environmental impact in logistics systems, actors in FSCs need to first understand their environments in terms of characteristics of products and flows, both within their own logistics systems and those of actors up- and downstream in FSCs. Therefore, a framework of eight FSC characteristics is presented for analysing the environment in terms of product and flow characteristics, as well as how they create conditions for an actor's logistics system. However, identifying where and why environmental impact occurs can be difficult, for actors often have large, complex logistic systems involving many products and flows to up- and downstream actors. To support overviews of where and why environmental impact occurs, this thesis proposes a framework—the transport portfolio framework (TPF)—to help to structure complexity in relation to transport's impact on climate. In relation to food waste, the thesis identifies two improvement actions linked to information sharing that can be implemented between wholesalers and retailers in order to visualise the size of food waste for different products.

The second topic concerns the need to adopt a holistic view of environmental impacts and to reduce types of environmental impact jointly, largely because certain FSC characteristics can create trade-offs between the types. At the same time, since some FSC characteristics can align, implying that they can pose challenges for reducing both types of environmental impact. Generating an overview can be problematic, since as the results of this thesis indicate, the responsibility of reducing environmental impact usually falls to actors responsible for different logistics activities. Reducing transport's impact on climate involves scrutinising and modifying transport activities, while responsibility for reducing food waste is often linked to logistics activities such as replenishment, procurement, warehousing, and packaging development. It is thus recommended that overall responsibility for both types of environmental impact be taken in logistics systems. For example, it might be feasible to have a person or group responsible for all environmental impacts in the system in order to coordinate work involved in reducing both transport's impact on climate and food waste.

Lastly, the third topic concerns suggestions for identifying, evaluating, and creating suitable conditions for implementing improvement actions. To initially identify such conditions, as the study on food waste (i.e., Paper 5) indicates, since a range of improvement actions are available, the first recommendation is to conceive the entire logistics system in order to identify what actions are possible and to not jump to conclusions concerning what improvement actions should be implemented. The study on food waste, for example, suggests four different types of coordination mechanisms that can be applied to accommodate improvement actions to reduce food waste: information sharing, joint decision making, rules, and pricing. Those mechanisms can help supply chain actors to think outside the box and identify possibilities not previously considered. An important avenue for reducing the environmental impact in logistics systems lies in scrutinising the performance variables of the systems. One question to ask might be whether current demands for service level and lead times are necessary or whether customers would be equally satisfied, if not more satisfied, if certain demands were lowered in order to reduce environmental impact. The results of the study on food waste also describe examples of when similar reasoning successfully reduced food waste. In relation to transport's impact on climate, scrutinising performance variables can present avenues to increase the use of proposed improvement actions.

In terms of evaluating improvement actions, it is critical to consider what improvement actions are feasible and most efficient for each logistics system. Regarding transport's impact on climate, the results of the thesis generally indicate that the potential of different improvement actions differs depending on characteristics such as freight density. The thesis therefore proposes a framework—the matrix for evaluating improvement actions (MEIA)—to help to not only evaluate the potential of different improvement actions, but also to consider potential barriers to their implementation. Concerning food waste, the findings show that not all improvement actions are feasible for all kinds of products and actors; some actions are inapplicable for certain products, whereas others have to be adapted in certain cases. It is therefore impossible to make recommendations applicable to all actors in FSCs in terms of which improvement actions to implement. Instead, this thesis provides guidance for how to evaluate which actions might be most feasible.

Lastly, in terms of creating suitable conditions for implementing improvement actions, the recommendation is to analyse which logistics activities and actors should be involved. For transport's impact on climate, responsibility for improvement actions is often limited to persons responsible for transport activities in an actor's logistics system. However, the results also indicate that FSC characteristics and performance variables actively influence improvement actions, which suggests that it could be feasible to consider ways to involve other logistics activities in the company when seeking to implement improvement actions. It might also be feasible to consider the possibility of collaboration among stages in FSCs in order to reduce transport's impact on climate. Concerning food waste, coordination both among logistics activities of single actors and between stages of FSCs is generally more extensive than concerning transport's impact on climate. However, there is room for improvement, particularly considering ways to involve industrial producers in improvement actions that currently involve only wholesalers and retailers. Table 7.1 summarises the managerial implications in terms of the recommendations and how the work of this thesis can support actors in FSCs.

Table 7.1 Managerial implications

Area	Recommendations	Support from this thesis
The logistics system's environment and where and why environmental impact occurs	Analyse the environment of the logistics system	Framework of eight food supply chain (FSC) characteristics
	Identify where and why environmental impact occurs	1. The transport portfolio framework (TPF) for reducing transport's impact on climate 2. Two improvement actions for information sharing in order to reduce food waste
A holistic view of environmental impacts	Address transport's impact on climate and food waste jointly Ensure that there is shared responsibility for the two types of environmental impact in the logistics system	A structure for analysing how FSC characteristics influence the two types of environmental impact
Improvement actions	Identification: Think broadly when identifying improvement actions, particularly those linked to changing performance variables	Nine improvement actions for reducing food waste and three improvement actions for reducing transport's impact on climate, categorised and compared in four groups
	Evaluation: Choose feasible and efficient improvement actions	1. The matrix for evaluating improvement actions (MEIA) 2. An analysis of how actors and products require adaptions to accommodate improvement actions for reducing food waste
	Creating suitable conditions: Include several logistics activities in each actor and analyse how coordination among stages in FSCs can enable improvement actions	An analysis of activities and actors involved in improvement actions for reducing food waste

7.3 Transferability in relation to stages in the food supply chain and products

The literature review (Chapter 2) identified the significance of carefully considering which stages in FSCs and products should be studied. This thesis did not limit its scope to certain stages or products, but instead examined certain stages and products in specific studies in order to best address the underlying challenges of the research questions. That scope prompted the study of actors at four stages in FSCs involving the products of salmon, crab, meat, fruits and vegetables (FaV), and frozen food, as well as a mix of product categories. How those choices influenced the transferability of the findings is discussed for the various research questions.

In answering RQ1 (i.e., about FSC characteristics), FSC characteristics were identified in literature addressing several types of food products and were further developed with the help of empirical material concerning primary and industrial producers of salmon and crab. Since such producers offered a limited scope, in terms of both stage in FSCs and food products, the study on food waste reapplied the FSC characteristics to describe the cases and provide a foundation for identifying causes of food waste. Since the setting included stages of industrial producers, wholesalers, and retailers for meat and vegetable products, the FSC characteristics were transferable to both another part of supply chains and other types of products. That setup affords the possibility of transferring FSC characteristics to different stages of supply chains and to other products, albeit with the disclaimer that general FSC characteristics are transferable, not their specific contexts in the studies. It could be further discussed whether it is also possible to apply certain FSC characteristics to supply chains with other perishable products (e.g., blood and flowers). For those supply chains, product characteristics such as shelf life and temperature regime are also important, and the framework can be applicable to them as well.

By answering RQ2 (i.e., about transport's impact on climate), two frameworks were developed based on different stages and product types. The TPF was developed for a large wholesaler with a wide range of food products, primarily in order to illuminate the challenge of having large, complex logistics systems with many flows and a range of different products. The MEIA was developed for a large food producer of frozen products. The choices of actor and product were not considered to be as important as the focus on identifying a logistics system upon which an actor exerted a significant influence on transport activities. The studies regarding the frameworks built upon portfolio techniques, with underlying fundamental assumptions that the frameworks had to be able to adapt to the context of different logistics systems, in which both characteristics linked to products and actors can be considered. As such, it is possible to transfer those frameworks to other stages of supply chains and products. At the same time, two other aspects urge caution in terms of the frameworks' applicability for actors in FSCs. The first concerns that the frameworks are developed for large actors with complex logistics systems. For smaller actors with a limited amount of flows, the need for such frameworks might be less, which implies that the frameworks might not be especially relevant for small actors—often, primary and industrial producers—or for actors who are not responsible for transport activities (e.g., retailers). The second aspect concerns the actors' types of shipment. The frameworks were developed for actors who can influence transport activities executed by logistics service providers, since they consisted of FTL shipments to a large extent. If actors send smaller shipments only in terms of parcels or pallets, then their influence on transport activities is limited, and it might be unfeasible to apply the frameworks. At the same time, the frameworks are not limited to food logistics systems, for they can be adapted to suit the context of logistics systems and are thus also applicable for other product categories.

In answering RQ3 (i.e., about food waste), improvement actions for food waste were studied in three stages of supply chains: those of industrial producers, wholesalers, and retailers. The findings reveal a preference for involving several stages for improvement actions, which implies that transferability is a challenge in relation to not only which stages of supply chains are involved, but also the number of stages involved in the improvement actions. A single actor at one stage of a supply chain can have difficulty implementing improvement actions without coordinating logistics activities with actors up- or downstream in supply chains. Regarding food products, three types of products were examined that were major contributors to food waste, which they exemplified in two types of food waste. When comparing improvement actions linked to passed expiration dates, for which meat and FaV were investigated, only one improvement action was identified as applicable in the same way for the two food products. For the rest, either the action was applicable for one type of food product or the improvement actions had to be adapted. That dynamic implies that improvement actions have to be transferred to other types of food products with extreme care in evaluating how they have to be adapted, if at all, to become feasible for implementation.

In sum, by applying an approach based on contingency theory, which assumes that not all actors and products can be treated interchangeably, the frameworks developed are adjustable to increase the transferability. Accordingly, the results in terms of frameworks are applicable to different stages of FSCs and different products; however, the specific findings of the empirical cases should be transferred with extreme caution.

7.4 Further research

Although research combining green logistics and food logistics has grown in popularity, many opportunities remain to further clarify how environmental impacts in logistics systems can be reduced. In this section, three areas for further research are suggested based on the findings of the thesis.

The first area for further research responds to the findings from comparing the improvement actions studied in addressing the two types of environmental impact. To that end, six proposed focuses for possible future studies along those lines are suggested (Section 6.4.2):

1. Further analysis of how actors in FSCs can handle FSC characteristics in order to reduce environmental impact in terms of whether the characteristics pose trade-offs, convergences, or moderators;
2. The development of visualisation tools involving several stages of supply chains for both types of environmental impact;
3. The expansion of joint decision making from single actors to dyads or entire supply chains in order to reduce transport's impact on climate;
4. An investigation of the potential of reducing both types of environmental impact by changing performance priorities in a single actor's logistics systems as well as entire supply chains;
5. An investigation of possible emergency improvement actions for transport's impact on climate in food logistics systems—for example, having buffers for extra freight without time restrictions in the case of a low load factor; and

6. An analysis of how improvement actions linked to replacement strategies affect logistics systems.

The second area for further research concerns the replication of results in the context of other actors and products. The thesis has aimed to foster transferability among FSCs by describing the context of products and the flow in terms of other FSC characteristics. It would, however, be interesting to study the proposed frameworks for product types other than food. For example, what happens when the MEIA is applied to floral products, or what improvement actions might be identified in studying how to reduce waste in blood supply chains?

The third area for further research concerns the application of other methods, largely to glean a better understanding of both types of environmental impact. For transport's impact on climate, single-case studies conducted used both quantitative and qualitative data. In further research, it could be interesting to apply quantitative methods (e.g., hypothesis testing) with samples of several actors in order to quantify and compare links among components in the logics. It would also be interesting to conduct explorative studies, as in Study 5, in order to analyse whether more improvement actions are available or if the existing actions could be implemented by applying other coordination mechanisms. Regarding food waste, a multiple-case study was conducted and two primary areas for further research are identified. First, it would be valuable to have a more in-depth understanding of the nine improvement actions previously not studied in-depth in literature in relation to food waste. This could be afforded by conducting studies focused on a limited number of improvement actions. Second, it would be interesting to apply quantitative methods in order to quantify the potential of the nine improvement actions.

8 Conclusion

The purpose of this thesis was to explore how actors in food supply chains (FSCs) can lower the environmental impact of their logistics systems in terms of both transport's impact on climate and food waste. Investigations into four areas have contributed to achieving that purpose.

8.1 Food supply chain characteristics

To explore ways in which actors in FSCs can reduce the environmental impact of food logistics systems, this thesis began by identifying and describing the uniqueness of those systems in terms of eight FSC characteristics. Four of the characteristics describe products—supply variation, shelf life, value, and temperature regime—whereas the other four describe the flow of products and actors handling that flow—stage in the supply chain, relative size of the company, lead time, and demand variation. The findings show that not only individual characteristics create conditions for logistics systems, but links among those characteristics do as well. Two links in particular were identified, each consisting of a product and a flow characteristic: on the one hand, supply variation and demand variation (i.e., Link 1), and on the other, shelf life and lead time (Link 2). Temperature regime also emerged as a moderating FSC characteristic insofar as it can reduce both links' influence on logistics systems. That finding underscores the importance for actors to analyse the interaction between product and flow characteristics in their FSCs and to consider strategies for adapting them to one other.

Regarding FSC characteristics, the research makes contributions by:

- Identifying and describing eight FSC characteristics associated with food logistics systems; and
- Identifying and describing two links among FSC characteristics.

8.2 Transport's impact on climate in food logistics systems

Studying the phenomenon of transport's impact on climate in food logistics systems allowed the thesis to make two main contributions. The first contribution lies in explaining how FSC characteristics and performance variables influence transport's impact on climate. Results show that characteristics such as temperature regime and product density influence transport's impact on climate. Such a finding highlights the importance for actors in FSCs to understand how their particular context, in terms of FSC characteristics and performance variables, influences transport's impact on climate and thus improvement actions for reducing that impact. To aid actors in evaluating improvement actions toward that end, the second contribution is the development of two frameworks: the transport portfolio framework (TPF) and the matrix for evaluating improvement actions (MEIA). Both frameworks aim to encourage and assist actors to conduct analyses based on their logistics systems before implementing improvement actions.

Regarding transport's impact on climate, the research makes contributions by:

- Describing how logistics performance variables and FSC characteristics influence transport's impact on climate;
- Developing a framework (i.e., the TPF) for considering product flow characteristics in order to prioritise shipments that should receive focus for reducing transport's impact on climate in logistics systems; and
- Developing a framework (i.e., the MEIA) for comparing improvement actions in logistics systems, namely from the perspectives of transport costs, impact on climate,

and barriers to implementation, in order to prioritise improvement actions for efficiently reducing transport's impact on climate in logistics systems.

8.3 Food waste in logistics systems

Studying the phenomenon of food waste in food logistics systems led to two primary contributions. The first contribution is a description of how FSC characteristics and performance variables influence causes of food waste. As for the second contribution, to aid actors in reducing food waste, nine logistics improvement actions to that end were identified, described, and jointly analysed in light of the components of causes of waste, actors involved, logistics activities, and coordination mechanisms. The findings show that improvement actions involve two or more stages in FSCs, which stresses the importance of taking a supply chain perspective in order to reduce food waste efficiently. The findings furthermore reveal that to facilitate the stated improvement actions, actors in FSCs have applied four different coordination mechanisms: information sharing, joint decision making, rules, and pricing between six logistics activities, which suggests that the work to reduce food waste have to be integrated in many parts of the actors' logistics systems. Third and ultimately, the findings underscore that improvement actions have to be adapted to the specific FSC context in light of the market, the products, and actors.

Regarding food waste in logistics systems, the thesis makes specific contributions by:

- Describing how logistics performance variables and FSC characteristics create causes of food waste in logistics systems;
- Identifying, describing, and analysing nine logistics improvement actions to aid actors in identifying, improving, and prioritizing logistics improvement actions; and
- Analysing how logistics improvement actions have been adapted to the FSC context from the perspectives of the market, the products, and actors to underscore the idea that actors need to modify logistics improvement actions to suit their specific contexts.

8.4 Combining two types of environmental impact

Lastly, studying the phenomena of transport's impact on climate and food waste jointly in food logistics systems yielded two final contributions. First, the thesis explored how the eight FSC characteristics, classified as trade-offs, convergences, or moderators, create conditions for both types of environmental impact. Such a dynamic stresses the potential importance for actors to adopt a joint overview of both types of environmental impact before determining which improvement actions can curb the respective impacts in their FSCs. Second, a comparison of improvement actions to mitigate transport's impact on climate and food waste reveals several avenues that actors in FSCs can take to further reduce the environmental impact of their logistics systems. For example, reconsidering current performance variables of logistics systems is vital to reducing both types of environmental impact.

In terms of combining both types of environmental impact in food logistics systems, the research makes contributions by:

- Classifying FSC characteristics as trade-offs, convergences, or moderators in order to help actors analyse the context of their FSCs in relation to both types of environmental impact; and
- Comparing improvement actions for both types of environmental impact to propose avenues by which actors in FSCs can reduce them, which in turn generated suggestions for further research.

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Appendix A – Interview guide Study 2

- General introduction to the company
- The interviewees position
- Describe the supply chain the company participates in, from production to end customers. What are the activities the company is responsible for in the supply chain?
- Describe the company's logistics and transportation activities? (For example location of warehouses, mode of transportation etc.)
- What logistics activities are your company responsible for today and what is outsourced (see Table A)?
- What activities will be moved to the food logistics centre? Who will be responsible for these?

Table A Logistic outsourcing levels (Hsiao et al., 2010)

Level 1	**Level 2 (Value-added activities)**	**Level 3 (Logistics planning and control)**	**Level 4 (Distribution network design and 4PL activities – SC restructuring)**
Transportation	Labelling	Inventory management	Selection of road carriers
Warehousing	Packaging	Transportation management	Reassignment of roles and responsibilities
	(Mixing flavours)		Changes of the warehouse structure
			Redistribution of inventory between tiers
			Changes in transportation network
			Consolidation points

- What are the main challenges for your company regarding logistics?
    - For example lead time, low cost or flexibility
- What are important trends for your logistics activities?
    - For example more SKUs and smaller shipments size.
- What are the important KPIs for the SC/your company (both for logistics and general for the company)?
    - Lead time
    - Cost
    - Flexibility
    - Punctuality
- What are the expected changes in KPIs before and after food logistics centre?
- What are the main reasons for your company to take part of the food logistics centre?
- What is the producers' role in a food logistics centre?
- Why the F in food logistics centre?

Appendix B – Interview guide Study 5

Inledning

Inledande frågor för att få information om respondenten samt identifiera vilka funktioner (Jonsson, 2008) och aktiviteter hen arbetar med, integration upp och ner i kedjan samt koordinering (Arshinder et al., 2008)

1. Namn
2. Position
3. Tidigare positioner
4. Arbetsuppgifter
5. Vilka funktioner arbetar du med?
    a. Inköp
    b. Prognoser
    c. Kundorder/Försäljning
    d. Produktion
    e. Lager
    f. Transport-planering
    g. Transport
    h. Returhantering
    i. Miljöarbete
6. Kan du beskriva er försörjningskedja?
    a. Leverantörer
    b. Distributionslager, butiker
7. Hur koordinerar du arbetet med aktörer upp och ner i kedjan?
    a. Kontrakt (returer, vinstdelning, kvantitets-flexibilitet samt kvantitets-rabatter)
    b. Informationsteknologi (Email, internet, EDI, ERP and POS)
    c. Informationsdelning (Efterfrågan, lagernivåer, ledtid, produktionsplanering, kapacitet och kostnader)
    d. Gemensamma beslut (kostnadsöverväganden, påfyllning (replenishment), prognoser samt beställningar)

FSC-characteristics

Frågorna ställs för att beskriva kontexten. De olika kategorierna är baserade på studie 2 som delar upp kontexten i flödes- och produkt-karakteristika. Sist ställs en fråga för att öppna upp för att det finns andra karakteristiska än de som identifierats av studie 2.

8. Företagets position i kedjan
9. Storlek på företaget
10. Ledtider
    a. Framåt i kedjan
    b. Bakåt i kedjan
11. Produktkostnad
    a. Genomsnittligt pris
    b. Prisvariation
    c. Marginaler (Höga eller låga)
12. Efterfrågevariation (Mena 2014 kopplar denna till svinn)
    a. Hur mäts den?
    b. Hur stor är den?

13. Supply-variation
    a. Hur mäts den?
    b. Hur stor är den?
14. Hållbarhet
    a. Hur sätts den?
    b. Hur lång är den?
15. Temperaturkrav
    a. Vilka temperaturer
    b. Spann som produkten klarar av
    c. Går det att ändra temperatur, t.ex. från kylt till fryst
16. Några andra karakteristiska som borde beskrivas?

Definition av svinn

Typer av svinn

17. Vad är svinn? (t.ex. allt som kastas, reducerat försäljningspris...)
18. Hur definierar och skiljer man på oundvikligt och onödigt svinn inom organisationen?
19. Delar ni upp svinn i olika kategorier?
    a. Skadat gods
    b. Felaktiga leveranser
    c. Korta datum

Mätning

20. Var i din organisation mäts svinn?
21. Hur mäts svinn?
    a. Omsättning
    b. Vikt
    c. Antal produkter
    d. CO2-equivalenter
22. Hur samlas data in?
23. Kan du se några konkurrerande KPIer?
24. Hur kommuniceras svinnmätningarna?
25. Vilket svinnmått använder du dig av?
    a. Hur påverkar den ditt arbete?

Var i flödet

26. Var i flödet uppstår svinnet?
27. Hur stort är svinnet idag?

Anledningar till svinn

Den första frågan är öppen för att se vad respondenterna väljer ut själva. Nästa fråga som är mer detaljerad är baserad på Mena et al. (2011) och Mena et al. (2014) som har fokuserat på att identifiera orsaker till svinn, samt förstudien.

28. Vilka anledningar till svinn kan du identifiera?
29. Hur stor påverkan tror du att följande anledningar till svinn har? Koppla dem till logistik-aktiviteter.
    a. Brist på informationsdelning
        i. Vissa organisationer är inte öppna för att dela information
        ii. Industrin får begränsad information från detaljhandeln

iii. VMI-leverantörer saknar detaljerad information för att kunna fatta rätt beslut

b. **Bristfälliga prognoser och ordersystem**
   i. Saknas prognosföranden
   ii. Prognosförfaranden skiljer sig åt i industrin
   iii. Felaktiga prognoser
   iv. Bristfällig inventering leder till större order
   v. För att erhålla mängdrabatter och uppnå effektivitet i transportsystemet görs större beställningar än nödvändigt

c. **Resultatmätning och ledning**
   i. Resultatindikatorer fokuserar på kostnad, effektivitet och tillgänglighet
   ii. Krav på att minimera logistikkostnader
   iii. För att skapa effektivitet i produktionen tillverkas för stora kvantiteter som trycks genom försörjningskedjan
   iv. Kreditering gör det möjligt att förflytta kostnaden för svinn bakåt i kedjan (Förstudie)

d. **Hantering av kylkedjan**
   i. Dåliga metoder/praxis i kylkedjor påverkar produkterna
   ii. Befintlig teknologi säkerställer inte en obruten kylkedja
   iii. Lagerhåller på fel temperaturer

e. **Utbildning (specificera var i kedjan frågan besvaras)**
   i. Personal är inte tillräckligt tränad
   ii. Tillfällig personal är inte tillräckligt tränad

f. **Kvalitetsledning**
   i. Misslyckanden att bibehålla kvalitet, inklusive säkerhetsaspekter skapar återkallelser av produkter.
   ii. Industrin försöker sälja alla produkter för att undvika svinn (defekta produkter anländer till distributionslager)
   iii. Destruktiva tester av produkter (t.ex. lök och avokados)
   iv. Trycker fruktprodukter snabbare genom försörjningskedjan med hjälp av högre temperaturer

g. **Ansvar för svinn**
   i. Ansvarsfördelningen för att hantera svinn är inte tydlig i organisationen
   ii. Ansvarsfördelningen för att hantera svinn är inte tydlig mellan företag
   iii. När VMI används engagerar sig inte detaljhandeln för att minska svinn

h. **Kampanjer**
   i. Saknas ett strukturerat tillvägagångssätt för kampanjer
   ii. Tillvägagångssätt för kampanjer följs inte
   iii. Brist på flexibilitet under kampanj hos detaljhandeln
   iv. Kannibalism mellan liknande produkter (t.ex. två liknande brödsorter)
   v. Kannibalism mellan olika produktgrupper (t.ex. äpplen och päron)

i. **Paketering**
   i. Förpackningar är inte designade för att minimera svinn

j. **Annat**
   i. Kross
   ii. Felaktiga datum
   iii. För många SKUs

Arbete för att minska svinn

Frågorna 31 och 33 ska först svaras öppet och om det behövs så går jag igenom listan på aktiviteter (Jonsson, 2008) och koordinering (Arshinder et al., 2008). Fråga 32 ställer jag för att Mena et al. (2014) har flera propositioner om att samarbete leder till minskat svinn.

30. Vad ser du för lösningar till de orsaker som ansågs viktiga under fråga 29.
31. Hur arbetar du/andra i organisationen idag med att minska svinn? (Koppla till olika aktiviteter)
    a. Prognoser
    b. Kund-order
    c. Produktion
    d. Inköp
    e. Lager
    f. Transport-planering
    g. Transport
    h. Retur-transporter
    i. Miljö-arbete
32. Hur samarbetar ni med aktörer upp och ner i kedjan för att minska svinn? (Kopplad till 33)
33. Hur kan koordinering användas för att minska svinn?
    a. Kontrakt (till exempel returer, vinstdelning, kvantitets-flexibilitet samt kvantitets-rabatter)
    b. Informationsteknologi (till exempel email, internet, EDI, ERP and POS)
    c. Informationsdelning (till exempel efterfrågan, lagernivåer, ledtid, produktionsplanering, kapacitet och kostnader)
    d. Gemensamma beslut (till exempel kostnadsöverväganden, påfyllning (replenishment), prognoser samt beställningar)