# Accommodating Cold Logistics Chains in Seaport Clusters

Bob Castelein

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The development of the reefer container market and its implications for logistics and policy

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**Accommodating Cold Logistics Chains in Seaport Clusters**

The development of the reefer container market and its implications for logistics and policy

**Het onderbrengen van ketenactiviteiten in de koel- en vrieslogistiek in havenclusters**

De opkomst van de reefer container en implicaties voor logistiek en beleid

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# 1 Introduction

This dissertation deals with the question how maritime refrigerated container chains can be effectively accommodated in seaport clusters. The chapters are made up of research papers written (and in the majority of the cases published) by the author and others. The chapters address the theme of this dissertation from different, complementary perspectives, or highlight specific aspects of this theme where specific attention is warranted. This introduction first sketches the background of the study, building up to an outline of its relevance for research and practice. Secondly, the research question and research approach are introduced. The third section contains an overview of the chapters of this dissertation, and outlines how they are connected to each other and to the overall narrative. Lastly, this introduction includes a section detailing the author's and others' contributions to the separate chapters.

## 1.1 Background

**History**

The first application of refrigeration in shipping predates the introduction of the refrigerated intermodal container (the modern 'reefer' container) by approximately a century. After numerous experiments with insulated ships, ice and salt/ice mixtures – including an entire shipload of meat spoiling on a voyage between Texas and New York in 1869 – the first vessel with on-board mechanical refrigeration carried a shipment of frozen meat from Buenos Aires (Argentina) to Le Havre (France) in 1877 (Perren, 2017). Even after being held up in the Caribbean for months for emergency repairs, the shipment of frozen mutton arrived in France in fine condition. Soon similar technology (mechanical refrigeration with ammonia as the refrigerant) was put into use for transportation of refrigerated beef and mutton from Australia and New Zealand to the United Kingdom, interestingly using steam-powered mechanical refrigeration on sailing vessels. Despite this trade within the British Empire being the first 'mass' market for refrigerated shipping, in the late 1800s and early 1900s the United Fruit Company started applying improved refrigeration technology for shipments of fresh fruit from Latin America to the United States.

**Figure 1.1. Unloading banana ships in New York (left, approx. 1890-1910) and New Orleans (right, ca. 1903). Note the modal split *avant la lettre* between bananas being transported further on foot, by horse cart, or by railcar.**

Source: Library of Congress, call numbers LC-D4-34447 [P&P] and LC-D4-16345 [P&P]. Available at https://lccn.loc.gov/2016795480 and https://lccn.loc.gov/2016803156, respectively.

Compared to other goods and commodities, intercontinental perishables trade is a relatively complex affair due to the temperature sensitivity of the goods involved: if they are not preserved correctly they will not arrive at their destination in a condition that is suitable for sale or consumption. Most perishable goods can be preserved for longer periods under refrigeration, but this first required the introduction of dependable refrigeration systems in the mid-1800s (Gantz, 2015). The ideal temperature at which food and other perishable goods should be preserved to maximize quality and shelf-life differs between goods, as does a products' toleration of temperature fluctuations around this ideal preservation temperature (see for example the guide by container line Hamburg Sud (2010) for the temperature requirements of different types of products). Keeping the product at the appropriate 'setpoint' temperature (or at least within the tolerable bandwidth around it) is essential in retraining the product's value at the point of sale, and is commonly referred to as maintaining the integrity of the 'cold chain' (Behdani, Fan, & Bloemhof, 2019). Refrigerated cargo holds in a ship are one way of ensuring cold chain integrity during maritime transport, as is the modern refrigerated (or 'reefer') container: an insulated intermodal container with an integrated refrigeration unit.

Despite the rise of containerization of reefer cargoes (as will be discussed below), refrigerated ships are still in use today, in particular for bulk shipments and to provide transport capacity for seasonal supply peaks (Dynamar, 2017). Logistically speaking, the use of refrigerated vessels (or reeferships) has not changed much since the introduction of this type of ship in the late 1800s. In the port of loading, the cargo is collected at the quay and loaded onto the moored vessel, either from (quayside) cold storage or directly upon delivery. Subsequently, the vessel sails directly to its destination, where the cargo is unloaded and transported further, sometimes with a period of storage in a (quayside) cold store.

The introduction of the modern intermodal shipping container in the 1950s and 1960s was a game changer for the shipping industry and the world (see Levinson (2006) for a comprehensive history of the shipping container). Using the container as a standardized load unit for cargo that was previously transported as break-bulk (i.e. items that have to be loaded and unloaded individually or in miscellaneous units such as crates, pallets, boxes etc. (Stopford, 2009)) allowed for more efficient handling with standardized equipment, economies of scale in shipping, and more efficient compatibility with land-based transportation modes such as trucks, barges, and railcars. Looking broader, the shipping container accelerated world trade growth and functioned as a major driver of globalization of production (Bernhofen, El-sahli, & Kneller, 2016). Efficient, accessible and cheaper transportation of finished and semi-finished products resulted in dispersed production networks and truly global supply chains we know nowadays.

The potential of the modern shipping container for perishables transport was recognized not long after the first successful container ship voyages. To benefit from the associated handling efficiencies, economies of scale, and intermodal compatibility, a solution had to be found to keep the cargo at the required temperature. An early solution was the 'porthole' reefer container: an insulated, standard intermodal container with porthole-shaped in- and outlets, to which a central refrigeration unit (for example of a reefership) could be connected to cool multiple containers at the same time (Behdani et al., 2019). Although an efficient, standardized load unit, the cooling of the cargo still depends on the availability of highly specific equipment (ConAir system). The modern 'integrated' reefer container is an insulated, standard intermodal container with an integrated refrigeration unit and airflow distribution system that can provide cargo cooling as long as the container is supplied with electrical power. As shown in Figure 1.2 below, the refrigeration unit is integrated in the container. Evaporator fans located at the top of the refrigeration unit draw in warmer (return) air from the cargo space, which then passes the unit's evaporator, is cooled down, and supplied back into the container at the bottom of the cargo space. The floor of the container is fitted with a T-bar floor to facilitate circulation of cold air underneath and through the cargo, all the way to the container door. By removing heat from the cargo (usually packed in boxes or crates on pallets), the cool air warms up and is drawn into the refrigeration unit again at the top of the container. The temperature (as well as humidity) of the return airflow is measured by sensors in the reefer unit, and based on the deviation from the desired internal temperature, the cooling by the refrigeration unit can be adjusted. Reefer containers are recognizably painted white in order to minimize the effect of solar radiation on the internal conditions.

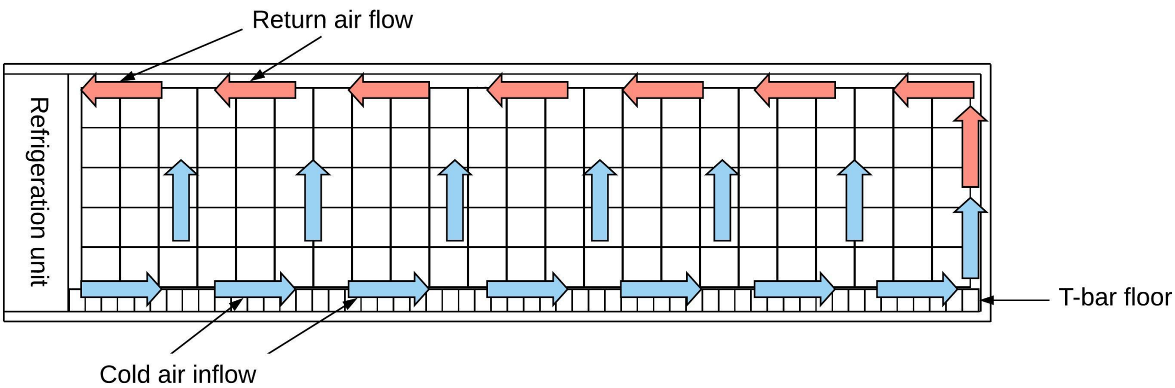


**Figure 1.2. Schematic overview of an integrated reefer container.**

Source: Author.

In the last decades, this integrated reefer container has become the standard for perishables transportation over sea, also at the expense of the market share of conventional reeferships in seaborne perishables transport and as a serious alternative for more sensitive cargoes previously transported only by airfreight (see Ch. 4 for a comprehensive discussion of this trend). These integrated reefer containers are generally (some conventional reefer operators have recently started operating dedicated reefer container vessels) transported along with conventional (or 'dry') containers on container ships. Container ships, as well as terminals, have dedicated storage bays or racks for reefer containers, equipped with power connections supply the reefers with energy. From a logistics perspective, integrated reefer containers have become a part of the conventional container system and – apart from their energy needs and required monitoring – are transported and handled much in the same way as dry containers. However, with the rapidly growing numbers of reefer containers and the challenges and more stringent requirements associated with this segment, differentiation between different types of containers and different types of cargoes may become imperative.

## The present situation

The market for seaborne perishables transport is currently split between two modes – reeferships and reefer containers – of which currently containers account for around 80% of the total volume and continue to erode the market share of conventional reeferships (Drewry Maritime Research, 2019). A third alternative mode for seaborne refrigerated shipping is the practice of loading refrigerated trucks on ferries, but due to the limited market size and global relevance, this is left outside of the scope of this analysis.

The most important reefer cargo categories are food products: fruit (most importantly bananas and citrus fruit, also including juice), vegetables, fish, meat, poultry, and dairy. Also non-food perishables are transported in reefer containers, including flowers, plants, bulbs, chemicals, and pharmaceutical products. Each individual product in these categories has its own ‘ideal’ or temperature at which it can be preserved the longest, with a tolerable range or ‘bandwidth’ of deviations around this temperature that does not severely impact product quality. Upon stuffing, the reefer unit of the container is set to maintain this desired ‘setpoint’ temperature and, if all goes well, continually keeps the cargo at or closely around this temperature. Recently however, there has been a trend of non-perishable goods that are nevertheless transported in reefer containers due to their sensitivity to extreme temperatures, including electronics and even footwear. A more detailed breakdown of the market in product categories and niche services is provided in chapter 4 of this dissertation.

The reefer container market is growing rapidly, as one of the developing niches in a overall mature container market with limited growth in dry volumes (Guerrero & Rodrigue, 2014; Rodrigue & Notteboom, 2015). The global reefer container trade comprised approximately 7.5mln TEU (Twenty-foot Equivalent Units) in 2016, comprising approximately 4.3% of total containerized trade with notable regional differences in the importance of this trade (Drewry Maritime Research, 2016b; UNCTAD, 2016). From this relatively niche status of the overall container market, the reefer market is predicted to grow at a CAGR (Compound Annual Growth Rate) of 4.5% over the next years (Drewry Maritime Research, 2019). This growth is driven partly by diversifying food tastes of consumers that develop a demand for more diverse and exotic food products as their income rises (e.g. Darmon and Drewnowski 2008), including a growing global middle class. Moreover, innovations in container technology and logistics concepts creates new niche markets within the reefer market based on the containerization of goods that were previously not transported in reefer containers (see Ch. 4 for an overview).

As examples of truly globalized container supply chains, also reefer container chains are characterized by a multitude of actors being involved in the physical handling, administrative transactions, or governance involved with the transportation of containers (Van Baalen, Zuidwijk, & Van Nunen, 2008). Figure 1.3 below summarizes actors in these functions in a layered model. In the logistics layer, products and containers (for a major part of the chain the former is packed in the latter as a standardized load unit) are physically handled. These flows are in one direction, as the supply chain functions to transport goods from an origin to a destination. Important to note is the point where the cargo is containerized (consolidated), and the point where the container is stripped, after which the cargo goes on to the end-consumer, and the container is repositioned to be used for another cargo. To make this possible various actors have to engage in transactions with one another (financial, administrative, coordination, or otherwise), sometimes including actors that do not physically handle the container or the cargo. Flows in this layer (information, resources, clearances etc.) flow between parties engaging in transactions, as opposed to the one-directional movement of the container and its cargo in the logistics layer. Moreover, all of this is subject to regulations regarding transportation, port activities, and trade, enforced by actors in the governance layer. For easier reading, actors involved with purely the financial side of the transactions (e.g. banks, insurance companies) are omitted from this adaptation of the model, as are miscellaneous port service providers and river police, who have little direct relevance for the reefer chain in particular (Van Baalen et al., 2008). Most importantly, to the original model the Reefer Service Provider has been added as an actor. These companies are involved in the cleaning, inspection, maintenance, repair, programming, and monitoring of reefer containers, and hence deal with shipping lines (owner or long-term lessors of the containers that decide on maintenance and repair activities), depots (as locations where inspections and maintenance are performed), and container terminals (that frequently outsource reefer monitoring and on-site maintenance to these specialized firms).

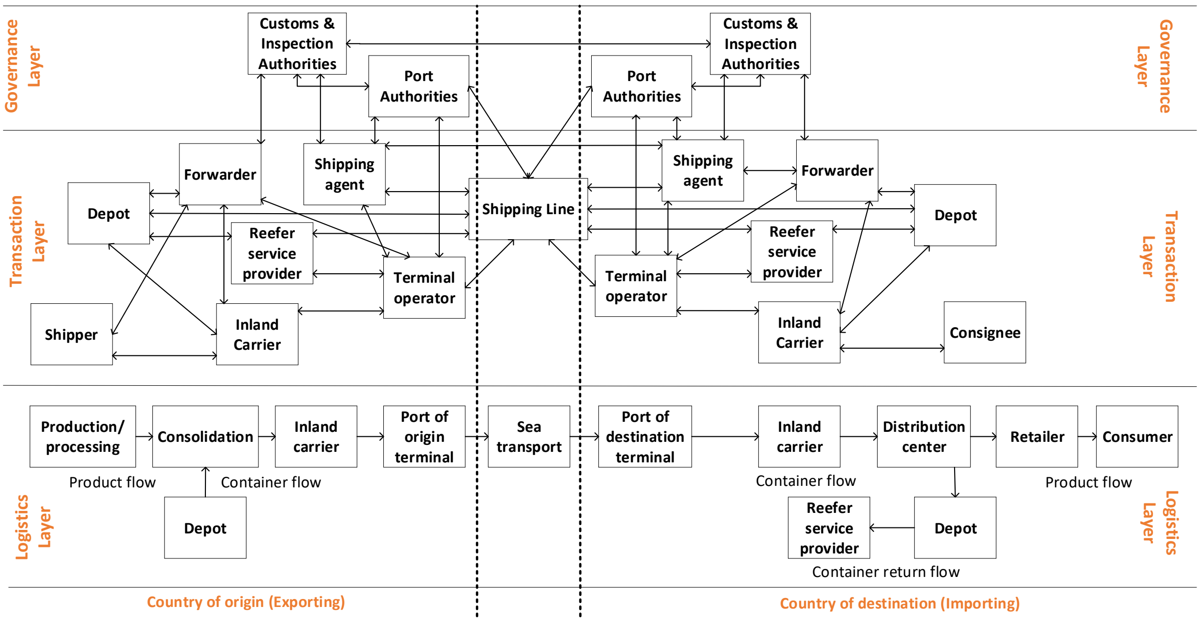


**Figure 1.3. Layered model of reefer container supply chain.**

Source: Author, adapted from Van Baalen et al. (2008).

This multitude of actors and logistics, transactional and governance relationships – along with the stringent demands for quality control and energy security – make it a highly complex system (see below), where locked-in routines and patterns are hard to change, due to the far-reaching implications change has for the other interdependent actors in the system. However, change may be necessary to address challenges and opportunities the sector is facing.

For four reasons the reefer market has become a particularly relevant focus area for supply chain actors and policymakers. These reasons form the core of this dissertation's relevance for practice, but are also related to wider societal and economic problems related to food loss and waste, and energy use and emissions of transportation and refrigeration.

First, it is a market with relatively high-value cargoes that still shows strong growth in an overall mature container market. Therefore it is highly attractive for supply chain actors active in the container market in general (carriers, container ports, terminal operators, intermodal transport service providers etc.) to share in this growth. On the policy side, port managing bodies (commonly referred to as port authorities) striving for throughput growth, value added, and increased competitiveness of their port cluster are interested in the reefer market for the same reasons.

Secondly, it is a particularly demanding type of supply chains that requires specific attention in handling of containers and cargoes. For container flows in general, it has been established that coordination between actors in seaports and associated hinterland chains is essential to mitigate the container hold-up risks that compound around the container transfer points in port clusters that often face congestion issues around terminals and on road networks (Van der Horst, 2016). While these risks have a negative impact on the efficiency and profitability of dry container chains, for refrigerated container chains they can also result in a total loss of the cargo if not appropriately addressed. With reefer containers not only the transfer and movement of the containers have to be coordinated, but also cargo quality (through adequate energy provision to the container, regular monitoring of the container, and climate control) has to be ensured along every part of the chain: preserving the integrity of the 'cold chain.'

Thirdly – related to the second point – the energy consumption of reefer containers is a growing concern for container terminals, grid operators, and also port authorities (Acciaro, Ghiara, & Cusano, 2014). On a large European multi-user container terminal, reefers stored and plugged in in the reefer racks in the terminal yard account for approximately 35% of total energy consumption (Van Duin, Geerlings, Verbraeck, & Nafde, 2018), a percentage that grows along with the volumes that are shipped and handled. With growing reefer container flows, more cold storage capacity is needed, also in and around seaport areas with important logistics functions such as warehousing, value added logistics, and distribution. When the energy demand from a growing cold storage capacity grows, this becomes an important consideration for port authorities (as infrastructure and land concession managers in port areas) and grid operators (as the entities responsible for the adequacy and stability of the power grid supplying industry with electricity).
Furthermore, when container ships are increasing in size, the number of reefer containers unloaded and plugged in at one time increases as well, leading to energy demand peaks that are not only costly, but also particularly demanding of container terminals' grid connection (Van Duin, Geerlings, Tavasszy, & Bank, 2019). Lastly, risks posed to the integrity of reefer cargoes during handling and transportation contribute to the global issue of food loss and waste. Approximately one-third of all food produced is not consumed ultimately, but lost or wasted along the chain (FAO, 2011). Addressing risks to cold chain integrity in food transportation is an important part of the imperative to reduce food loss and waste across the board.

## 1.2 Relation with the academic literature

**The research domain**
Because of the relevance of seaports as interfaces between maritime and land-based parts of cold supply chains, their relevance as major (cold) logistics and industrial clusters (Nijdam & Van der Horst, 2017), and their relevance as physical locations where cold chain risks compound (see above), this study focuses specifically on port-oriented reefer container supply chains and the logistics processes relevant for these chains. Covering all these dimensions, ports can be defined as geographical locations within coherent administrative and policy frameworks that function as the interface between maritime and land-based transportation networks, and function as logistics and industrial clusters, and in doing so constitute elements in global value-driven chain systems (supply chain networks) (definition drawing on elements of definitions proposed by Nijdam & Van der Horst (2017) and Robinson (2002)). The focus on seaports and port-oriented supply chains place this study within the research domain dedicated to the study of port economics, policy, and management, abbreviated to 'port studies' (Notteboom, Pallis, De Langen, & Papachristou, 2013; Pallis, Vitsounis, & De Langen, 2010; Pallis, Vitsounis, De Langen, & Notteboom, 2011).
To give an overview of the structure of this research field and the main topics addressed, several authors (notably contributions by Notteboom (2013) and Pallis et al. (2011)) have identified the following seven major sub-fields:

- **Terminal studies:** Addresses terminal productivity, efficiency, strategy, and optimization of operations (Notteboom, Pallis, et al., 2013)
- **Ports in transport and supply chains:** Addresses "shipping (networks) and its implications for ports; supply chain trends and their implications for ports and PAs [Port Authorities]; logistics activities in seaports; information flows in supply chains and their impact on ports and hinterland logistics" (Pallis et al., 2011, p. 453)

- **Port governance:** Models of defining roles and responsibilities of port managing bodies, formal government, and the private sector regarding port activities, development and institutional arrangements, reform and evolution of these models, and comparative analysis (Pallis et al., 2011; Q. Zhang, Geerlings, El Makhloufi, & Chen, 2018). This sub-field also includes analysis and and evaluation of governance tools at the strategic, managerial, and institutional levels (Q. Zhang, Zheng, Geerlings, & El Makhloufi, 2019)
- **Port planning and development**: This sub-field includes studies on port planning, (economic) impact studies, forecasting, port development, and concessions of land in port areas to users (Pallis et al., 2011)
- **Port policy and regulation:** Deals with issues such as market access, pricing, financing, environmental regulation, safety, and security (Pallis et al., 2011).
- **Port competition and competitiveness:** Competition between seaports serving the same supply chains and/or hinterland (De Langen, 2007; Notteboom, 2010; Robinson, 2002). Including port choice, evaluation and modeling of port competition, competitiveness, effectiveness, and competitive strategies.
- **Spatial analysis of seaports**: Including port-city relations, spatial development of port systems, interactions between port systems and their hinterlands, position of ports in (maritime or hinterland) networks (Pallis et al., 2011)

The observant reader will notice that these are not by any means discrete, mutually exclusive categories. There is considerable overlap (and perhaps need for conceptual clarification) between the categories, such as between port governance and port policy, and in the fact that there is a significant spatial dimension to port planning and development, as well as ports in transport and supply chains.

In the emphasis on policy, regulation and planning in several of these research themes, the research focuses on the role of port managing bodies, commonly referred to as port authorities – private, public, or semi-public entities responsible for the management of port areas. Depending on the governance model through which traditional government responsibilities regarding ports have been devolved to these separate entities, the scope of port authority responsibilities may include infrastructure, superstructure, regulation, pricing, land concessions, operations and/or labor (Brooks & Cullinane, 2006; Van der Lugt, Dooms, & Parola, 2013; Verhoeven, 2010; World Bank, 2007). Notwithstanding national and regional differences in governance models and port authority responsibilities (Debrie, Lavaud-Letilleul, & Parola, 2013), these entities are important actors to study and include in analyses of seaport-related developments. For the scope of this study in particular, it is important to realize that port managing bodies are the only actors that can be seen as problem owners of all relevant challenges stemming from reefer market developments as outlined above. They are responsible for port policy and planning, an important actor in governance processes, and the only actor involved with port-oriented (reefer container) supply chains that has a statutory responsibility to facilitate efficient operations, stimulate economic competitiveness, as well as to mitigate negative externalities of port cluster activities (most importantly furthering environmental sustainability). Recognizing this unique and important position of port managing bodies, this study adheres to the tradition in the field of port studies to explicitly account for the position of these entities in port-oriented supply chains.

This dissertation is firmly established within the field of port studies, touching upon issues relevant across all the seven sub-fields – to varying degrees of depth. The main theoretical contribution this dissertation makes to the field lies in its focus on one type of container supply chain (i.e. reefer containers). Where commonly intermodal container flows are treated as one type of homogenous commodity without much regard for the specific content of the container (Rodrigue & Notteboom, 2015), this dissertation recognizes the heterogeneity of container contents. In doing so, the studies included consider different cargo types, their requirements, and the related stakeholder processes, needs and preferences. As the first comprehensive study in the field, this dissertation looks beyond the container as a 'black box' (or, in the case of reefers, a white box), and provides an in-depth examination of all relevant aspects of this type of supply chains in a port context.

**Theory**

The field of port economics, policy and management is defined by the topics it studies, rather than the theoretical lenses through which this is done. In their overview of the field, Pallis et al. (2011, p. 469) describe it as being in a 'pre-paradigmatic' phase, with a "consensus on definitions, concepts, problems to be investigated and methodology" yet to be reached, and the absence of a common theoretical and methodological framework to study relevant issues (see also Pallis et al. (2010) for similar conclusions). The same authors – as well as a methodology-focused review by Woo et al. (2011) – highlight the multidisciplinary nature of research in the field, drawing on theories and methods from logistics, economics, planning, public administration, and geography. This eclectic set of perspectives is warranted given the multidisciplinary nature of the topic and questions addressed, but stimulates little coherent theoretical debate within the field. In the adjacent field of intermodal transportation research, Bontekoning et al. (2004) have noted the same dynamics.

There is however a small number of well-established and often-quoted theoretical paradigms and conceptual frameworks that inform seaport research on well-defined topics. The research in this dissertation ties in in particular with two conceptual discussions.

The first is the perspective developed by Robinson (2002) in what is at the moment still one of the most-quoted paper in the field of port studies. In the 'new paradigm' he introduces, ports are no longer seen only as geographical units with certain functions (industrial, transportation, logistics), but also in a more abstract way as elements in 'value-driven chains' or 'value chain constellations.' In the latter perspective, port managing bodies are not simply landlord-like entities facilitating the functions of the seaport cluster, but strategic actors active in supply chains as service providers and competitors. This requires other capabilities than the more narrow focus previously assumed. The concept of 'value' is critical here: ports that can offer most value (or facilitate the creation of value) to supply chain actors will be more successful, all the while also capturing value for themselves. Robinson is not explicit about what 'capturing value' entails for ports, but knowledge of the responsibilities and strategic goals of port authorities, this value can be imagined as revenue, employment, innovation, and/or expansion of the portfolio activities undertaken in a port cluster – perhaps even extended to the strategic goals related to the port's societal license to operate, such as sustainability of operations. Another major shift that this conceptual framework should account for is the issue of power and control in global supply chains. Decision-making in these chains is generally dispersed, and balances of power may change over time and differ between value chain systems. Corollaries to this perspective have been introduced by Jacobs & Hall (2007) and Notteboom and Winkelmans (Notteboom and Winkelmans 2001): If we accept Robinson's view of the world, the performance of a port authority in achieving the strategic goals for the seaport cluster increasingly depends on its networked position with global supply chain actors and its flexibility to accommodate the needs of these stakeholders in a rapidly changing environment. Therefore port authority strategy depends on what kind of value chains it wants to position itself in (after defining which value chains it is active in already), and what roles and capabilities it should develop to deliver (and reap) the most value in these chains.

This question ties in with a second, related conceptual discussion in the field. Container transportation is an important sector for most seaports worldwide, but insight into what types of goods are moved through seaports in containers is very limited (Rodrigue & Notteboom, 2015; Woo et al., 2011). In a shift in priority from volume to value, the overall container throughput of seaports alone is not an effective performance indicator for its competitiveness. It is related to the perspective outlined above in that if the position as a network actor in value-driven chain networks should be a focus of port authorities, the perspective regarding container cargoes should shift from the load unit to their contents. Rodrigue and Notteboom call this change in perspective 'looking inside the box' (2015). This dissertation starts from premise that if differentiation in container contents and associated opportunities in requirements is desirable, the reefer container market is an excellent starting place for this differentiation. Within a port's container throughput, reefer containers are obviously a segment that requires differentiated treatment in that they should be handled, stored and transported in a way that meets their need for near-constant energy provision and monitoring. Moreover, in terms of value, the reefer container contents are generally time-sensitive, ready-to-consume, high-value goods. As a high-value, sensitive category of containers that requires differentiated treatment, this dissertation extends this observation to the question how port-oriented actors in cold logistics chain networks can accommodate these flows in a way that furthers their goals in the broadest sense possible, extending from value and efficiency to innovation and sustainability.

These two conceptual discussions in the field of port studies frame the overarching narrative of this dissertation. However, every chapter also incorporates an additional theoretical framework that best fits the topic and question addressed, in line with the multidisciplinary and eclectic nature of the field of port studies. In the narrative of this dissertation, each theoretical angle provides a complementary perspective on the embedding of containerized cold supply chains in port clusters.

## 1.3 Research problem

The goal of this dissertation is to advance our understanding of *how seaport-related actors can effectively accommodate reefer container supply chains in a seaport cluster, meeting demands for efficiency and competitiveness, as well as sustainability*.

Section 1.1 outlined the reasons why this question is relevant for supply chain practice and policymakers, namely due to the opportunities from a growing market, the stringent demands these chains place on logistics processes, energy provision, quality control, and coordination, and the implications of the growth of this market for energy management in port areas. Section 1.2 described the research field to which this study contributes, and identified the main scientific contributions this study aims to make, namely contributing a disaggregated view of the container market in product-based niche markets (in this case the reefer container market) to the question of port positioning and competitiveness in specific value chain systems, and the related questions of associated multi-stakeholder coordination and policymaking.

On a conceptual level, the question has been raised already how ports can position themselves and compete as elements in value-driven supply chain systems, in a global logistics environment that is becoming more fluid and fast-paced (Robinson, 2002). Robinson argues that ports as well as other logistics service providers compete by being "embedded in chains (or supply chains) that offer shippers greater value" (p. 250), while this embeddedness is derived from the value they deliver to shippers and other supply chain actors, and the effectiveness with which port processes are integrated with processes of other actors in the supply chain. This 'new' supply chain environment is encountered most of all in containerized trades: homogenous flows of standardized load units in fast-paced supply chains that are easily shifted from one port or service provider to another.

The developments sketched above suggest that the reefer market itself and the position of this market in container ports is still very much in flux, with ongoing growth, modal shift and complementary technologies and activities being developed (see also chapter 5). Important issues related to the growth of this sector arise, regarding efficiency, competitiveness, sustainability, energy use, waste reduction, and innovation, but how this multitude of questions will be addressed in reefer container supply chains is still very much open ended. As outlined above, reefer container supply chains are a globalized and complex multi-stakeholder system, with not only ongoing developments that pose challenges and opportunities to actors, but also routines and structures that are already locked-in and therefore hard to change. This dissertation will explore which directions for change in this sector are the most promising. In this dissertation this will be conceptualized as the development of a complex socio-technical system, with a wide range of stakeholders with their own interests, resources, needs, and preferences. The section below explains this research approach in more detail.

## 1.4 Research approach

Port research is a still developing field, that relies heavily on ‘borrowed’ theoretical frameworks and methodological approaches from other, perhaps more established disciplines (Pallis et al., 2010; Woo et al., 2011)., The unifying aspect is the topic of study, rather than the perspective or approach. Nevertheless, the majority of studies are carried out from an economic, geographical, or operations research perspective, with economic and mathematical modeling approaches dominating (Woo et al., 2011). Increasingly, the field has shifted to include more behavioral and qualitative approaches as well, including methods such as case studies, interviews, surveys, and panel studies (labeled as ‘people’s perception-positivist’ approaches, according to Woo et al. (2011, p. 681)), allowing researchers to capture more tacit concepts and in-depth understanding of considerations, decision-making and behavior – all driven by actors’ perceptions of themselves, their environment, and other actors. This study also predominantly takes this ‘people’s perception-positivist’ approach, focusing on change in port-oriented reefer container supply chains as constrained by actors’ perceptions of what is possible or acceptable, and hence directions of change to which they are willing to commit.

The research question formulated in section 1.3 above is of an explorative nature (i.e. a ‘how’ question, to be answered with an in-depth explanation covering all relevant parts of the mechanism) and moreover explores a contemporary phenomenon, which is still ongoing, in its real-world context – elements that warrant a case study approach (Yin, 2009). Within such a case study setup, it is possible – and depending on the question to be answered even beneficial – to triangulate multiple sources of evidence obtained and analyzed using mixed methods.

Chapters 2 and 3 tie in more with existing theoretical debates in the field of port studies, regarding port choice, port competitiveness and intra-port coordination, and the relevant dimensions of port policy (Pallis et al., 2010). With such concepts to be analyzed in a context with limited cases available (in these chapters the case of Western European ports), in-depth interviews and secondary data are used to explore the interrelations between these concepts. Interviews are used to elicit the considerations underpinning actors’ decision-making regarding supply chain and port choice, as well as to invite actors to reflect on quantitative data on port’s competitive positions in the container market. Having these interviews with respondents in decision-making roles in leading firms in the sector provides new insights in what drives decision-making and ultimately behavior of these firms.

With these concepts and their interrelations in mind, chapter 5 and onwards explore new territory by focusing on one specific segment of the container market, namely reefer containers and the role thereof in seaport clusters.

Before that, chapter 4 sets the scene regarding the reefer market, outlining its distinguishing characteristics, structure, and recent development – a mostly descriptive endeavor based on secondary data from various sources. To obtain a clear overview of the present state of scientific knowledge of reefer containers and reefer transportation, the chapter is supplemented with a systematic literature review of the domain, using the well-established PRISMA method for systematic literature reviews (Moher, Liberati, Tetzlaff, Altman, & The PRISMA Group, 2009), and a bibliometric inventory of the attention received by the different research themes within the domain. This exercise shows that while the technical aspects of reefer transportation (refrigeration, monitoring and control, energy provision), research from an actor-focused perspective has been lacking so far. Based on the knowledge gap identified and insights on the characteristics, development and prevalent issues of the sector, this chapter outlines a detailed research agenda to address this knowledge gap. The remaining chapters of this dissertation set out to further explore the most important tenets of this research agenda – most importantly establishing the link between the field of port studies and the reefer-related research conducted so far – hence solidifying the main scientific contributions of this dissertation to present knowledge.

To inform the second part of this dissertation exploring this under-researched perspective, we should conceptualize reefer container chains as complex socio-technical systems based on interactions between technical systems as well as actor networks (De Bruijn & Herder, 2009). In this case, technical systems include the containers themselves and embedded technology, handling and transportation equipment (including their power sources), port infrastructure, energy systems, and logistics networks and facilities. On the other hand, the actor networks include international constellations of public (e.g. governments, regulatory agencies, port authorities) and private sector (e.g. shippers, carriers, terminal operators, service providers), as outlined extensively in section 1.1 and Figure 1.3 in particular. From both perspectives, finding a way to replace the current state of the world with something that is deemed more desirable (as defined by the problem owner, which could include a state that is more efficient, more sustainable, more profitable – as discussed above, in the reefer case, a port managing body can be designated as the problem owner of the widest range of problems related to reefer transportation) is a matter of design (Dym & Little, 2000), respectively substantive design (the type of design familiar to the engineering discipline) and process design (modes of interaction between interdependent actors, and the rules that govern this process (De Bruijn & Herder, 2009).

Chapter 4 shows that in the case of reefer containers and reefer transportation, substantive design has been the predominant focus of research so far, focusing on the technical aspects of the system. Lack of research on the actor side of the system (i.e. the parties that will utilize the technical parts of the system and interact with one another in doing so) means that there is as of yet little insight in the actor networks involved, and the various actor's interests, capabilities, and perceptions of problems. This is problematic, since any change in a system will depend on actors' acceptance of these proposed changes, which again depends on their perceptions (of themselves, of other actors with which they interact, of the sector, of the urgency and relevance of prevalent problems in the sector, and of potential solutions) and the extent to which the technical system design takes into account their requirements, objectives, and constraints (Herder, Bouwmans, Dijkema, Stikkelman, & Weijnen, 2008; Herder & Stikkelman, 2004).

The second part of this dissertation will explore these aspects for the case of the reefer container transport and logistics system, using a process of triangulating findings through mixed methods to identify which solutions are most promising in order to improve the efficiency, sustainability, and competitiveness of this sector in seaports. Chapter 5 utilizes Q-methodology to elucidate stakeholder perceptions of their interests and constraints, problems and challenges in the sector, and possible solutions. The Q-methodology survey format invites actors to rate a large number of statements, together covering all relevant aspects of the subject matter, in terms of agreement and perceived importance along a forced normal distribution (Brown, 1980; Van Exel & De Graaf, 2005; Watts & Stenner, 2012). Respondents were selected that could be expected to have a unique and/or influential viewpoint on the subject matter. Therefore this study purposively included respondents in decision-making positions in firms in various sectors (policymakers, service providers, terminal operators etc.), firms of different sizes (small local firms to multinationals), scopes (national, regional, international), and product market focus (e.g. fruit, flowers, vegetables). Q-methodology is based on the idea that even in very diverse stakeholder settings, there is a limited number of broadly shared viewpoints (so-called 'finite diversity'). Actor responses on the survey are used to identify this limited number of broadly shared – or 'dominant' – perspectives on the full set of issues and questions relevant to the sector. Respondents' elaboration on the considerations underpinning their sorting of the statements provide additional qualitative depth to these perspectives, not only revealing the 'how much,' but also the 'how' and 'why' questions regarding actors' perceptions issues in the sector.

Considering the important role of port policy in seaport clusters, and the contested but widely affirmed importance port authorities and their policies have for the sector (as found in chapter 5), chapter 6 explores what a port authority can do to address issues related to reefer transportation and cold chain logistics in seaport clusters. As discussed above, port-managing bodies are the only type of organization that is formally a problem owner of all questions related to reefer transportation in the port cluster, including port competitiveness, efficiency and added value, as well as energy management and the greening of port-related activities – hence warranting the focus on this type of organizations in a separate chapter. Insofar as port policy should play a role in a transition within the reefer sector, the design space for this is limited by the strategic scope and (legal) responsibilities of port authorities (Herder et al., 2008). Despite the overall lack of empirical studies with a truly global scope in the field of port studies (Pallis et al., 2011; Woo et al., 2011), for those dimensions of port policy related to reefer transportation and cold chain logistics, this chapter is based on a new dataset of the world's 50 largest container ports to elucidate what these port managing bodies do in the way of intervening in this sector, including the associated instruments, goals and stakeholder coalitions. Especially when it comes to port-related policy, regulation, infrastructure or governance, suitable directions for change should be both acceptable to supply chain actors (chapter 5), and be in the scope within which a port authority can take action if its role as a infrastructure provider, regulator, facilitator, innovator or platform leader is desirable (chapter 6) (De Martino, Errichiello, Marasco, & Morvillo, 2013; Verhoeven, 2010).

From chapters 5 and 6, a modal shift of reefer cargoes (and supporting port policy) shows to be one of the most promising interventions that meets acceptance criteria of supply chain stakeholders and can generally count on support from policymakers (who sometimes actively mandate or support modal shift to mitigate emissions and alleviate road congestion (De Langen, Van den Berg, & Willeumier, 2012). Supporting interventions in terms of regulation, infrastructure, and platform leadership are within the strategic scope of (most) port authorities, and supply chain actors are generally open to exploring the possibilities of barge and rail transport as alternatives to trucking, provided that their criteria for land-based transportation are met. Therefore in the last substantive chapter of this dissertation, chapter 7, intermodal solutions by rail or inland waterways transport by barge for reefer transportation are surveyed. In this case taking the intermodal reefer transport system as a sub-system of port-oriented reefer supply chains in general (De Bruijn & Herder, 2009), this investigation focuses on how well these technical systems meet (potential) user criteria. The characteristics of the available technology and logistics models are outlined and compared, and subsequently evaluated by sector stakeholders. Moreover, findings from these stakeholder interviews show where potential barriers to acceptance may be, and what design alterations in the technical system (physical equipment and infrastructure and logistics networks) may help overcome these barriers.

Figure 1.4 below shows how the chapters in this dissertation should be read in relation to one another. To answer the main research question, chapters 2 and 3 first explore more general themes of container port competition and competitiveness, and intra-port coordination in the container handling sector. Subsequently, chapters 4-7 take the example of the reefer sector as a case of specific supply chains to be accommodated and embedded in port clusters and explore how this can be achieved in practice. Chapter 4 sets the scene by outlining the characteristics of the reefer market and identifying the main research gap in the reefer container-related academic literature that this dissertation aims to fill. Chapters 5 and 6 take these market characteristics and academic knowledge gaps as starting points to explore sector stakeholders and policymakers' positions regarding problems in the sector and their perceptions of the relevance, efficacy, and acceptability of different directions for change. One theme, namely modal shift, that is shown to be both potentially acceptable to companies in the sector and within the scope of policymakers, is subsequently explored in chapter 7.

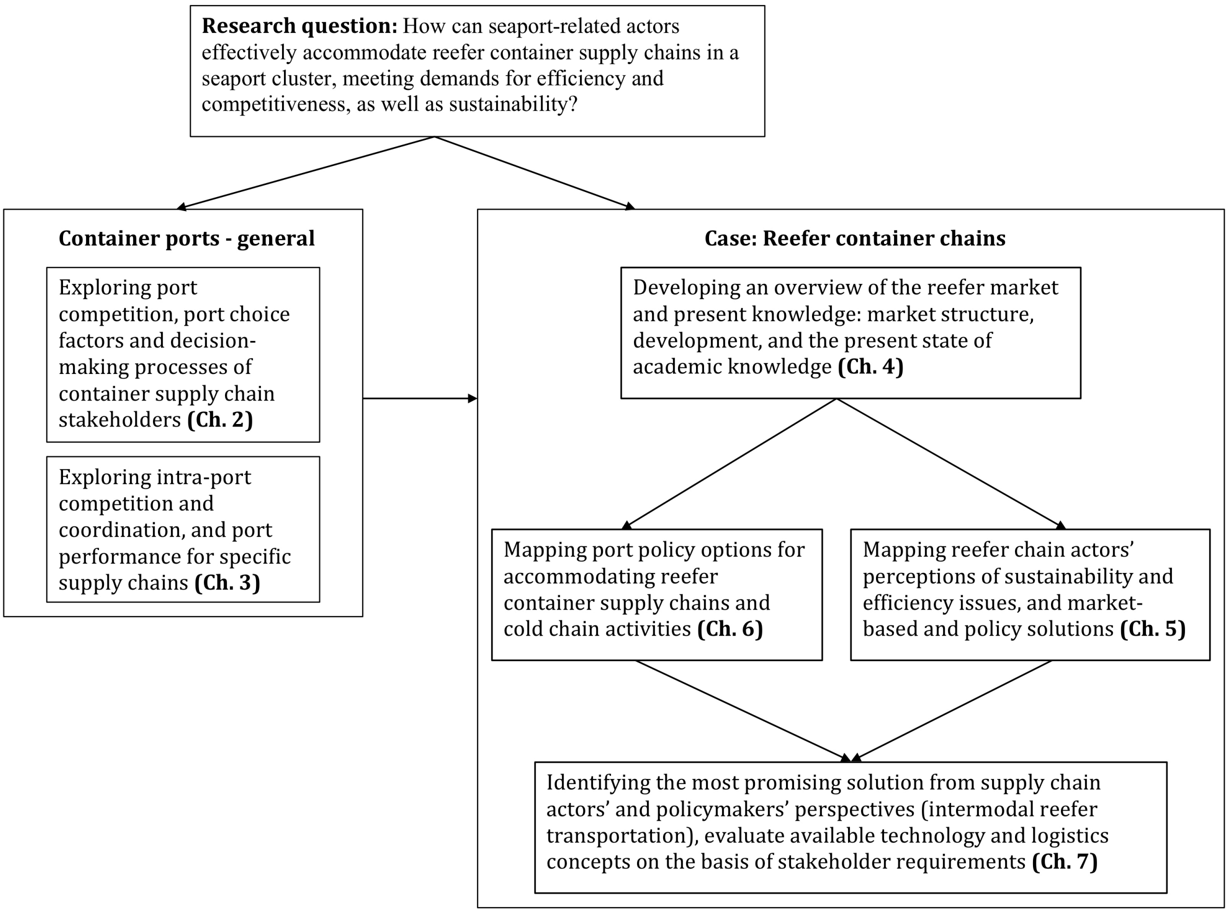


**Figure 1.4. Schematic overview of dissertation structure.**

Now having covered the research approach for this dissertation, the section below outlines how the different chapters fit within the narrative structure of this dissertation to which this chapter serves as the introduction – in other words, how to read this dissertation.

## 1.5 Structure of this dissertation

The overall theme of the dissertation is how seaports are embedded in container supply chains, and container supply chains are embedded in seaports, taking the reefer container market as a case study where this mutual process of embedding is particularly relevant and still ongoing. Each chapter was written (and in the majority of cases published) as a self-contained piece of research highlighting one relevant aspect of the overall theme. Hence the reader with a particular interest or question in mind can easily read the relevant chapter(s) in isolation. Nevertheless, the ordering of the chapters in this dissertation follows an overarching narrative as also outlined in section 1.4 and Figure 1.4 above.
Now having introduced the focal topic, the research field in which it is situated, the research question, and the approach of this dissertation, chapters 2 and 3 deal with container ports in general and the accommodation of container supply chains in port clusters, after which the remainder of this dissertation zooms in to focus on the reefer container segment. Before doing so, the topics of container port choice and inter-port competition are addressed (chapter 2), followed by a chapter on competition and coordination in the container-handling sector of a single seaport (chapter 3).

**Chapter 2. Divergent effects of port choice incentives on user behavior**
In this chapter, it is examined how the main container supply chain actors (shippers, carriers, forwarders, terminal operators, and port authorities) can differ in their evaluation of container port choice criteria. This chapter explores the links between port characteristics, actors' incentive structures, decision-making, environmental factors, and port performance in an overarching framework. Importantly, as actors interact within the network of port-oriented container supply chains, each actor's decision making has consequences for the incentives offered to others, with an important role for learning and strategic behavior. This chapter explores various facets of this framework in the context of container port competition in Western Europe, considering port characteristics, pricing and throughput composition as well as insights in supply chain actors' decision-making processes obtained through interviews. The chapter concludes with recommendations for port policy on how to address the challenge of balancing the ports' marketing efforts and strategic positioning to different categories of users with differing requirements.

**Chapter 3. The ostensible tension between competition and cooperation in ports: A case study on intra-port competition and inter-organizational relations in the Rotterdam container handling sector.**
Chapter 3 extends from chapter 2 through the continued focus on container supply chain actor's decision-making and (strategic) behavior, and the link with port performance. Most major gateway ports have multiple container terminal operators active within their stevedoring sector, based on the intuition that increased competition benefits efficiency and hence port competitiveness. However, consolidation in the container shipping sector, and the growing importance of hinterland transport on consolidated modalities (i.e. rail and barge transport) also require container terminal operators to coordinate activities within the same port. This chapter explores how pressures for competition and cooperation may conflict, what

problems this causes, and the implications for handling efficiency and port competitiveness. The effectiveness of coordination efforts between competing container terminals has a direct effect on port performance: if terminals cannot effectively coordinate container movements, these containers will experience holdup in the port area, hurting overall efficiency. The effectiveness of these coordination efforts has relational underpinnings that are often overlooked in the existing literature.
This chapter explores these dynamics, again in the context of port competition in Western Europe, and specifically in the Port of Rotterdam, and based on this study provides directions for understanding how firms can balance simultaneous pressures for competition on the one hand and cooperation and coordination on the other,.

In the first part of this dissertation, chapters 2 and 3 discuss the links between supply chain actors' behavior, supply chain efficiency and performance, and port competitiveness. Port-based as well as footloose service providers compete and coordinate activities to meet the requirements of sometimes equally footloose customers, within the boundary conditions determined by port authorities: pricing, regulation, land use, and more tacit tenets of port policy such as coordination and innovation. Chapter 2 in particular deals with the way seaports position themselves in container supply chains, competing for throughput and value, whereas chapter 3 deals with the tensions inherent in effectively embedding complex container supply chains in seaports.
These two chapters serve as a higher-level, more conceptual introduction to the topic of this dissertation. Three of the most important takeaways are that 1) actors' requirements differ between supply chains; 2) effective embedding of container supply chains in seaports depends on vertical as well horizontal coordination between supply chain actors; and 3) port policy and stakeholder management can play an important role in enhancing port efficiency and competitiveness.
The remainder of this dissertation takes the reefer container market as a case study of a specific type of container supply chains. This sub-segment of the container market is characterized by sensitive and valuable cargo, demanding customers, and hence high requirements on ports' logistics processes and infrastructure. For service quality improvement and effective policy-making, a focus on the reefer container market requires us to look 'inside the box,' i.e. consider the heterogeneity of cargo types and their characteristics and requirements (Rodrigue & Notteboom, 2015). Whereas in chapter 2 it is argued that considering the contents of shipping containers is *desirable* because of the varying value and potential for value added services, for reefer containers it is *imperative* because every type of conditioned cargo (with different extents of shelf-life) imposes its own handling requirements. Differences between perishable products and their characteristics and behavior, storage temperatures (frozen (<0°C) or fresh (>0°C)), remaining shelf life, and additional handling requirements (e.g. controlled atmosphere, pest control treatment, phytosanitary or veterinary import requirements) make that the containers used to transport them cannot be treated as a commodity with a one-size-fits-all approach. Considering the hold-up risks due to deficient coordination in container handling discussed in chapter 3, the implications of such hold-up for reefers could imply a total loss of the cargo.

**Chapter 4. The reefer container market and academic research.**
This chapter contains a detailed and comprehensive overview of the reefer container market, and takes stock of the present state of academic research on reefer containers and reefer transportation.
The chapter opens with an overview of the characteristics, composition and development of the reefer container market, showing its growth and differentiation into new cargo markets

and niche services. Secondly, the chapter outlines the structure of reefer container supply chains in terms of their relevant stages, stakeholders and processes, and their position as a part of more extensive cold logistics chains. Information on insurance claims shows the most important causes of cold chain failure in the chain. Thirdly, the chapter presents a systematic literature review of existing academic research on reefer containers and reefer transportation. Based on the current mismatch between areas of supply chain risks and areas of research emphasis, the chapter formulates a research agenda addressing previously overlooked aspects, including supply chain coordination issues and implications for port policy.

Chapter 4 has provided the overview of the market to be studied and the associated research domain. The following chapters address the important but so far overlooked issues of this topic, along the lines of the research agenda proposed in chapter 4.

**Chapter 5. Identifying dominant stakeholder perspectives on sustainability issues in reefer transportation. A Q-method study in the Port of Rotterdam**

To be able to effectively address risks and inefficiencies in logistics processes, and sustainability concerns related to energy use and food loss and waste in cold logistics chains, this chapter explores supply chain actor perspectives on the most important issues in this sector and their evaluation of possible improvements and solutions. The reefer transportation sector and the associated port-oriented cold logistics chains should be seen as socio-technical systems with technical components as well as networks of interdependent actors, in which the resolving of problems depends on agreement, commitment and cooperation from a wide range of actors involved. To explore the barriers and facilitators of these processes, this chapter uses Q-methodology (as described above) to explore the interests and attitudes of cold chain actors in and around the Port of Rotterdam regarding efficiency and sustainability issues in reefer transportation and cold chains. Reducing the complexity of a multitude of organizational viewpoints to a limited number of ‘dominant’ perspectives allows one to identify the most important areas of disagreement and consensus – the latter providing promising opportunities for broadly supported cooperation and policy initiatives.

More specifically, in chapter 5, several specific types of initiatives are identified as promising. For example, supply chain stakeholders are broadly supportive of data sharing initiatives and initiatives exploring a modal shift of reefer containers from road transport to more sustainable modes such as barge or rail transport. Moreover, policy initiatives initiated by port authorities are broadly supported, particularly those regarding cluster policies for reefer and cold chain activities, and port authority involvement in coordination initiatives as facilitator or initiator with a more or less neutral position towards the private-sector actors involved. Accordingly, chapter 6 examines the role of port policy in addressing the challenges arising in the cold chain and reefer logistics domain.

**Chapter 6. Cold chain strategies for seaports. Towards a worldwide policy classification and analysis.**

This chapter examines the role of port policy in the facilitation of reefer container supply chains in seaport clusters, with efficiency, competitiveness, and sustainability goals in mind. The central question is ‘what can a port managing body do?’ tying in with questions related to port governance and port authority roles and responsibilities. This chapter presents a new dataset of the policy measures implemented by the world’s 50 largest container ports, outlining the options available to – and utilized by – port authorities worldwide targeted towards this market. The 72 individual policy measures are classified in terms of their goal(s), instrument, scope, and port authority role. The goals port authorities pursue, the instruments they use, and their scope of policy are constrained by their resources, capabilities, and the responsibilities devolved to them from higher-level government (as is commonly the case in corporatized port managing bodies). Examination of the reefer- and cold chain-related policies implemented by port authorities shows the extent to which port authorities go beyond the traditional 'landlord' role, a model in which the port managing body is limited to its functions as a landlord, regulator, and infrastructure manager. Through identifying the scope of port policy in this sector, the chapter clarifies what types of intervention can be expected to receive active support from policymakers, and what roles and capabilities port authorities need to develop to pursue directed policies tailored to the cold chain logistics sector.

One (potential) development that shows to be both broadly supported by cold supply chain stakeholders (chapter 5) and within the scope of port authorities worldwide (chapter 6) is a modal shift of reefer containers from road transport (trucking) to more sustainable modes such as rail or barge transport. The overall willingness of supply chain actors to consider alternatives to trucking for their reefer cargoes comes with the caveat that any alternative should meet their (stringent) demands for quality control as well as speed, flexibility, reliability and cost effectiveness. Due to the potential of a modal shift highlighted in chapter 5, the evidence of this development being a strategic focus of port policy in chapter 6, and the current (near complete) dominance of trucking in hinterland transport of reefers, chapter 7 explores the potential for a modal shift, focusing on the technological, logistical and organizational possibilities, barriers and enablers of such a modal shift.

**Chapter 7. A modal shift of reefers? Investigating User Perspectives and Technological Prospects.**

To address concerns related to transportation emissions and road congestion, governments worldwide have committed themselves to a modal shift of freight transport – including containers – to transportation modes such as rail, barge and short-sea transport. The perishables sector however, including transportation of refrigerated containers, is almost entirely dependent on trucking for (port-oriented) hinterland transportation. In the previous chapters it was shown how a modal shift of reefer containers is both an option that a broad set of stakeholders is open to explore (chapter 5) and an important policy focus of port authorities worldwide (chapter 6). Therefore, this chapter addresses the question what is necessary for rail and barge transportation of reefer containers to become a viable option to stakeholders in reefer transportation and cold chain logistics. This is achieved through surveying the existing options (in terms of technology and logistics) for a modal shift of perishables transport to rail or inland waterways transport.

A modal shift is not perceived as attractive yet: the state of technology in both sectors raises concerns about energy security and monitoring and control options, and both modalities are perceived as lacking on the criteria of speed, reliability and flexibility. Nevertheless, the chapter considers several cases of new logistics concepts for the transportation of reefer containers by barge and rail, and finds that supply chain stakeholders perceive these favorably. Successful experiments with a modal shift apparently challenge thinking in which options other than trucking are simply not considered in current decision-making. Therefore, a modal shift also requires a 'mental shift' within the sector.

Lastly, chapter 8 recaps the most important findings from the substantive chapters of this dissertation, places these in the context of the wider issues and questions sketched in this introduction, and provides conclusions and recommendations for both research and practice.

**Table 1.1. Dissertation structure.**

| | Chapter | Theme | Method |
|---|---|---|---|
| | 1 | Introduction | |
| **Part 1 – Container ports** | 2 | Port choice and container port competition | Interviews, secondary data analysis |
| | 3 | Intra-port competition and coordination | Interviews, secondary data analysis |
| **Part 2 – Reefer container transportation: market, issues, and policy** | 4 | The reefer market: characteristics, trends, and academic state of knowledge | Secondary data analysis; study of grey literature; systematic literature review (PRISMA) |
| | 5 | Stakeholder perceptions of sustainability issues in reefer transport | Q-methodology survey, stakeholder interviews |
| | 6 | Port strategy and policy for cold logistics chains | Policy analysis |
| **Part 3 – Intermodal reefer transportation** | 7 | Exploration of reefer transportation by rail and barge | Technology assessment; stakeholder interviews supplemented with Q-methodology survey findings |
| | 8 | Discussion and conclusion | |

## 1.6 Statement of contribution

The research on which this dissertation is based was conducted in the context of the EURECA project (Effective Use of Reefer Containers through the Port of Rotterdam – A Transition-Oriented Approach) from 2016 to 2020. This project was conducted by researchers at Erasmus University Rotterdam, Delft University of Technology, and Wageningen University and Research, and financed by the Dutch Research Council (NWO), SmartPort, Seamark, and ABB, with representatives of the Rotterdam Port Authority, GroentenFruithuis, FloraHolland and Hutchison Ports ECT Rotterdam serving on the project's supervisory committee. While these individuals and organizations were directly involved in defining the project's scope and provided valuable input for the research, they were not involved in the collection, analysis, and/or interpretation of the data, nor in the formulation of conclusions and recommendations by the scholars involved.

The author of this dissertation, R.B. (Bob) Castelein (BC), was the first and corresponding author of all scholarly papers that form the chapters of this dissertation. Supervisors and (co-)promotors H. (Harry) Geerlings (HG) and J.H.R. (Ron) van Duin (RvD) were – alternatingly – second and third authors of these papers. The research was conducted within the scope of the EURECA project, as formulated by the EURECA project team (Principal Investigator: H. Geerlings). Apart from the contributions of Castelein, Geerlings, and Van Duin, students Josephine Terwindt (TU Delft, JT) and Joeri Jansen (EUR, JJ) aided in data collection for chapters 5 and 7 respectively. The compilation of the separate papers into this dissertation and the writing of an overarching introduction and conclusion were done by Castelein, under supervision of Geerlings and Van Duin. All contributions to the separate chapters are listed in Table 1.2 below.

**Table 1.2. Author contributions.**

| | Introduction | Ch. 2 | Ch. 3 | Ch. 4 | Ch. 5 | Ch. 6 | Ch. 7 | Conclusions |
|---|---|---|---|---|---|---|---|---|
| Study conception and design | BC | BC, HG, RvD | BC, HG, RvD | BC | BC, RvD | BC | BC, HG, RvD | BC |
| Acquisition of data | n.a. | BC, HG, RvD | BC, HG, RvD | BC | BC, JT | BC | BC, JJ | n.a. |
| Analysis and interpretation of data | n.a. | BC | BC | BC | BC | BC | BC | BC |
| Drafting of manuscript | BC | BC | BC | BC | BC | BC | BC | BC |
| Critical revision | BC, HG, RvD | BC, HG, RvD | BC, HG, RvD | BC, HG, RvD | BC, HG, RvD | BC, HG, RvD | BC, HG, RvD | BC, HG, RvD |

# 2 Divergent effects of container port choice incentives on users′ behavior: A case study on container port competition in Western Europe

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**Abstract**
Port choice decisions are often considered to be based on unambiguous choice criteria. The authors examine how port users' evaluation of these criteria can differ and how this may affect actors' incentive structure and decision making, and ultimately port performance. Apart from ports' physical characteristics, this chapter considers port policy and freight market conditions as components of actors' incentive structures. As port users interact, each actor's decision making has consequences for the incentives offered to others – with an important role for strategic behavior. The aggregate of port users' decisions affects a port's throughput, cargo composition, and value added, and has implications for handling efficiency. This chapter combines these insights within an overarching framework linking port characteristics, policy, and freight market conditions to port user choice behavior and the consequences for ports.
The chapter explores various facets of this framework using the case of how the Port of Rotterdam competes along the Hamburg–Le Havre range, drawing on port throughput data on various levels of detail and in-depth interviews with a representative selection of port stakeholders. It shows that there is a downside to ports being particularly attractive to carriers, in that the port that offers the most incentives to carriers disproportionately attracts relatively low-value activities: inefficient calls and a large share of empty containers, along with a strong import/export imbalance. Interview findings contextualize the findings from the data and elaborate further on the mechanisms underpinning these observations. Most importantly, the attractiveness of a port for carriers does not always translate into attractiveness for shippers. The challenge for port policy is to balance the port's positioning toward its different categories of users and achieve a congruent value proposition for all port users.

## 2.1 Introduction

Port competitiveness is generally conceptualized as driven by straightforward and unambiguous criteria, such as port costs, handling efficiency, geographical location, hinterland connectivity, and the quality of infrastructure and services, that draw port users and cargo to the port (Martínez Moya & Feo Valero, 2017). The more efficient and cost-effective a port's operations, the better its competitive position relative to other ports that could theoretically serve the same customers (Parola, Risitano, Ferretti, & Panetti, 2017). From this perspective, characteristics inherent in the port directly link port performance and port competitiveness. A port's performance on criteria that are important to port users steers port users in their decision to prefer one port over another and hence influences a port's competitive position relative to other ports. This chapter proposes a more diverse perspective on port performance and port choice, focusing on the roles of preference heterogeneity among port users, strategic behavior, stakeholder interactions, and contextual factors such as freight market conditions in explaining port choice and port competitiveness. This entails a more ambiguous conceptualization of port performance, including the idea that port choice incentives may have divergent effects on different port users and indirectly affect a port's performance in terms of cargo composition, value added, and handling efficiency.

Port performance is conceptualized as the efficiency with which companies operating in the port and port authorities are able to fulfill or facilitate and align port processes in various transport chains (Borges Vieira, Kliemann Neto, & Goncalves Amaral, 2014). This chapter focuses on seaborne transportation of containers, where port competition tends to be particularly fierce. Port competitiveness extends from performance and is conceptualized as a port's "capacity to provide a unique value proposition under better conditions than competitors" (Parola *et al.*, 2017: 116). A port competes with other ports that could theoretically serve the same supply chains (defined as broadly as possible, as shippers' container supply chains from the exporter's point of consolidation to the importer's location) and/or hinterland (Haezendonck, 2001; Robinson, 2002; Verhoeven, 1981). Earlier studies have discussed inter-port competition (Meersman, Voorde, & Vanelslander, 2010; Slack, 1985; Song, 2002) and decision-making processes of the major categories of port actors: port authorities, terminals, shippers, and carriers (or shipping lines) (Heaver, Meersman, & Van de Voorde, 2001; Martínez Moya & Feo Valero, 2017; Talley & Ng, 2013; Wiegmans, Van Der Hoest, & Notteboom, 2008), with third party logistics providers sometimes acting as shippers' agents (Jayaram & Tan, 2010; Magala & Sammons, 2008). Other studies have provided a broader conceptualization of individual actors' choice behavior and port competitiveness (Button, Chin, & Kramberger, 2015; De Martino & Morvillo, 2008). However, heterogeneity in supply chain actors' preferences and strategic behavior – and their implications – from a multi-stakeholder perspective have received relatively little attention, even though recognizing these elements provides a more comprehensive perspective on port competition and performance.

In the literature, the criteria that underpin carriers' and shippers' port choices overlap considerably (Martínez Moya & Feo Valero, 2017) and are also considered to be drivers of port competitiveness (Parola et al., 2017), but the role of possible divergence in preferences is generally overlooked. Also, strategic behavior and possible inadvertent effects resulting from port choice incentives (policy driven, physical, or a combination of the two) have received little attention. How do different actors value port choice incentives, and what are the implications for a port's competitive position?

This question is addressed by first outlining the present knowledge on port choice behavior in container transport (section 2.2) and combining these in a comprehensive framework (section 2.3). Subsequently, the chapter highlights some potentially interesting interrelations that have not been addressed in the literature so far. These facets of the framework are explored further by considering the case of how the Port of Rotterdam competes with other major Western European seaports along the Hamburg–Le Havre (HLH) range. The case study draws on publicly available data on port throughput and a series of interviews conducted with a representative selection of port actors. By triangulating various sources of evidence (see section 2.4), the chapter presents an in-depth look into how port choice incentives relate to port choice behavior and port performance and competitiveness (section 2.5). Section 2.6 discusses implications of the findings and concludes.

## 2.2 Background – Decision making in deep-sea container chains

A container port's market share (in terms of throughput – one of the most common port performance indicators) relative to nearby competitors depends on the aggregated decisions of actors in the logistics chains that could run through the port. In deep-sea container shipping, four major categories of stakeholders are involved: port authorities, container terminals, container shipping lines (carriers), and cargo owners (shippers or their agents). This overview focuses on the deep-sea part of the supply chain – hence omitting choice behavior regarding hinterland transport and short-sea shipping. The literature so far has focused on these actors' individual strategies and some interactions between two – or mostly three – actors. This study unifies these insights into one overarching framework, considering port choice incentives in the form of port policy, physical port characteristics, and freight market conditions, and their effects on different stakeholders with different preferences and strategies. Moreover, we consider several interrelations within this framework. The sub-sections below discuss insights into supply chain actors' decision making, and present the integrative framework connecting these.

**The shipper**

The initiator of a container supply chain is the shipper, who needs to have goods transported from one location to another and contracts service providers to organize this. A review of port choice research (Martínez Moya & Feo Valero, 2017) classifies shippers' port choice criteria into three categories: location, effectiveness, and connectivity. A port has to be suitably located relative to the origin or destination of the cargo. Of the ports that satisfy this criterion, the port that handles the cargo most efficiently (mainly in terms of costs, transit time, and reliability) and has the best connections with other ports and the hinterland will be preferred by shippers.

However, there are trade-offs that shippers consider on an individual basis, depending on their preferences. Overall, shippers aim to minimize the total logistics costs of their transport chain – monetary and otherwise (Nir, Lin, & Liang, 2003; Talley & Ng, 2013). Faster transit often comes at a premium price, and the time that goods are in transit also imposes costs on the shipper for insurance, depreciation, restricted cash flow, and perhaps the time-sensitive nature of the cargo. Moreover, the level of service may differ between ports and logistics service providers. Depending on their preferences, shippers choose supply chain partners and ports that best suit their time, service, and cost preferences.

This is not always the shipper's decision. The party that makes the port choice is determined in the freight contract, usually along International Commercial Terms (Incoterms) rules. Here, the key distinction is between carrier haulage and merchant haulage. Under carrier haulage, the shipper chooses a container carrier, who is then responsible for the complete transport of a container (often by enlisting subcontractors for the hinterland transport) and can hence decide on the route used to transport the container, including port choice. Under merchant haulage, the shipper or consignee is responsible for arranging the land transportation and hence determines port choice. Secondly, shippers – particularly smaller companies with limited supply chain capabilities – often contract a specialized party for this. These third-party logistics providers (3PL) specialize in consolidating and orchestrating supply chains, and in doing so take over decision making, such as carrier and port choice from shippers (Jayaram & Tan, 2010; Magala & Sammons, 2008). Third, a relatively new development is terminal haulage, where the terminal arranges transport to and from the hinterland (e.g. the extended gate concept (Veenstra, Zuidwijk, & van Asperen, 2012)).

**The carrier**

The shipping line carries the container over sea and is usually the owner of the shipping container. Liners sail on regular routes and schedules between multiple ports and take cargo at publicly listed rates (Stopford, 2009). Shippers (or their agents) lease containers from deep-sea carriers and rent capacity on container ships. Depending on the demand for transportation and port selection criteria, shipping lines adjust their planning to minimize costs and maximize volume and profits (Andersen, 2010; Meng, Wang, Andersson, & Thun, 2014).

Indirectly, shippers' port selection criteria determine carrier port selection through their effect on port-specific demand, both import and export – particularly when the goods are transported under merchant haulage. This works the other way as well, given that shippers prefer ports that are well-connected by carriers' networks. Furthermore, shipping lines have their own considerations that underpin their planning at the strategic, tactical, and operational level (Mulder & Dekker, 2017), including port selection criteria. Many of these relate to location (accessibility and berth availability), effectiveness (terminal efficiency, infrastructure quality), connectivity (deep-sea, short-sea, and hinterland connections) (Martínez Moya & Feo Valero, 2017; Wiegmans et al., 2008), and other factors including the planning of alliance partners (Panayides & Wiedmer, 2011), operational considerations such as repositioning empty containers, and subjective preferences (Button et al., 2015). If they have a choice between multiple terminals in a port, as is the case in most major ports, carriers also select a terminal (Wiegmans et al., 2008). This decision is chiefly driven by terminal performance criteria such as cost, capacity, accessibility, handling speed, reliability, and connectivity. Moreover, there is a role for more tacit factors such as the ease of doing business (Hupkens, 2017) and strategic factors such as carriers' long-term agreements with terminals, investments in terminals, and the terminal arrangements of alliance partners (see section 2.3). When a carrier has a position in (or a good agreement with) a terminal, this may tip the decision between two ports.

**The terminal operator**

Terminal operators handle containers at the interface between maritime and land transport, using dedicated equipment to load and unload containers from container vessels and transfer them to and from hinterland transport modalities (Lun & Cariou, 2009).

There are two distinct business models in the container handling industry. First, a company may see opportunities to profit from stevedoring activities as its core business and operate independent terminals. This is the business model of horizontally integrated global terminal operators (Slack & Frémont, 2005): these companies operate multi-user terminals that provide services to multiple shipping lines. Secondly, a shipping line may integrate vertically and operate its own terminals to cut costs and ensure capacity. Hybrid forms also exist, with terminals being joint ventures between one or multiple shipping lines and a specialized Terminal Operating Company.

Carriers not committed to a terminal in a certain port negotiate long-term agreements with multi-user terminals to reserve capacity:

*Terminals commit the carrier to a minimum guaranteed volume and in exchange the carrier is usually provided with guaranteed time slots for vessel berthing and numbers of containers handled per hour. In virtually all cases, the terms of the contract are based on container moves, irrespective of size or type. There is usually a price differentiation between full and empty containers as well as a special allowance for transshipment boxes. (European Competition Commission, 2009)*

Particularly, empty containers and transshipment containers are less profitable for the terminal operator, regardless of the operational costs incurred in handling these containers.
Shipping lines define the terminal handling charge (THC) as "based on the cost of handling the container in the terminals, including loading and discharging containers to/from the vessel" (Maersk Line, 2017) – a port-specific flat-fee surcharge to the shipper. However, carriers' terminal costs are the outcome of negotiations between carriers and terminals, reflecting not only handling costs, but also the relative bargaining positions of carriers and terminals. Because these market conditions play a role in the process in which THCs are established, shippers are charged a container handling fee that is not necessarily representative of a port's true handling efficiency.

**The port authority**

Port authority policy aims to balance demands from the three main functional roles of the port: transportation node, industrial cluster, and logistics cluster (Nijdam & Van der Horst, 2017). For each function, the focus is on a different user: for the port as a transportation node, the most important users are shipping lines, but, for the port as a logistics cluster, the shipper is the most important user. Naturally, the criteria are different for the different roles. For shipping lines, nautical accessibility and servicing efficiency are important, whereas for shippers, hinterland connectivity also is particularly important. However, as discussed, a port also attracts shipping lines through their attraction of shippers and their cargo.
Nowadays, European port authorities generally take a landlord role, in that they grant land concessions to terminal operators in exchange for a concession fee and additional stipulations that ensure that the broader societal goals of the port authority are also met (Notteboom & Verhoeven, 2010; Theys, Notteboom, Pallis, & De Langen, 2010). Although a port authority aims to have terminals within the port that function as well as possible to make the port attractive for carriers and shippers, the port authority's key performance indicator is not exactly the same as for the container terminals it facilitates: whereas (multi-user) terminals strive to maximize efficiency and profits, port authorities tend to aim at maximizing throughput and revenue (Talley & Ng, 2013).
Apart from concession fee revenues, port authorities charge port dues to vessels calling at the port, usually based on gross tonnage, cargo volume, or both. Port authorities can strategically adjust port dues to attract as much cargo to their ports as possible. Many ports offer discounts for transshipment cargo, second calls (i.e. a ship calling at the port twice within a few days) and volume discounts that grow incrementally as the carrier loads and/or unloads more cargo.

A framework exploring the factors underpinning these actors' decision making, their interactions, and implications for ports is elaborated in section 2.3.

## 2.3 Stakeholder choice criteria and interactions – an integrated framework

Table 2.1 summarizes the literature on the supply chain partner choice behavior of the four main stakeholders discussed above.

**Table 2.1. Choice behavior in maritime transport chains – a literature overview.**

| Partner / Decision maker | Shipper (or agent) | Shipping line | Terminal operator | Port (authority) |
|---|---|---|---|---|
| Shipper (or agent) | n.a. | Minimize total logistics cost (Tran, 2011); service costs, availability, transit time, frequency (fleet size, network convenience), service quality and relationship with carrier (Tiwari, Itoh, & Doi, 2003) | Depends on carrier choice | Under merchant haulage, carrier makes port choice. Aims to minimize total logistics cost (Talley & Ng, 2013; Tran, 2011); costs, location, and transit time (Anderson, Opaluch, & Grigalunas, 2009; Malchow & Kanafani, 2001); infrastructure quality, hinterland connections, and port area congestion (Fan, Wilson, & Dahl, 2012; Wiegmans et al., 2008); port connectivity (Yuen, Zhang, & Cheung, 2012); port services (Parola et al., 2017); relation with port service providers (Debrie et al., 2013) |
| Shipping line | Can strategically position itself in certain supply chains by attracting shippers with certain preferences through its service offer (Talley & Ng, 2013) | n.a. | Maximize chain profits (Talley & Ng, 2013); berth availability; handling efficiency; terminal costs; shipper satisfaction; make or buy decision – buy capacity at multi-user terminal or invest in own handling capacity (Wiegmans et al., 2008); negotiations with terminals, price agreements, alliance configurations (European Competition Commission, 2009; Panayides and Wiedmer, 2011); ease of doing business (Hupkens, 2017) | Chooses ports through network design and can decide on port choice for containers shipped under carrier haulage. Aims for chain profits (Talley & Ng, 2013); port location and network compatibility (Mulder & Dekker, 2017), accessibility, berth availability (dedicated terminals), cargo volume availability (shipper preferences), distance from origin and destination markets (Malchow & Kanafani, 2001); port costs, range of services (Tongzon & Sawant, 2007); handling efficiency (Tang, Low, & Lam, 2011); carrier strategy, alliance agreements, hinterland connections (Panayides & Wiedmer, 2011; Wiegmans et al., 2008); constraints and incentives presented by port authority (Talley & Ng, 2013) |
| Terminal operator | Depends on shipping line clients | Depends on multi-user or single-user (dedicated) terminal (Wiegmans et al., 2008); multi-user terminal can do business independently with carriers<br><br>Multi-user terminal: price negotiations (Fung, Cheng and Qiu, 2003; European Competition Commission, 2009); shipping line alliances (Panayides & Wiedmer, 2011) | n.a. | Depends on multi-user or single-user terminal<br><br>Single-user terminal: Shipping line decision<br><br>Both: port authority negotiations and concession contract stipulations (throughput, environment, investment (Notteboom, Pallis, & Farrell, 2012); local container market conditions, cargo availability, competitive environment (driven by carrier and shipper decisions, see Notteboom and Verhoeven, 2010; Langen, Berg and Willeumier, 2012); relations with port authority (Van der Lugt, Rodrigues, & Van den Berg, 2014); quality of institutional environment, political and economic outlook (Notteboom, 2002) |
| Port (authority) | Can strategically attract cargo, expand its captive hinterland (De Langen, 2007); ports with a contested hinterland compete for discretionary import cargo (Talley & Ng, 2013) | Can strategically attract carriers; port pricing (Acciaro, 2013); long-term contracts with shipping lines, incentives to increase port calls and/or throughput volume; cargo volume, discretionary import cargo (Talley & Ng, 2013) | Total contract value; competition; volume (expected); strategy (cargo control); environment; use of hinterland modes (including cooperation); security; capacity; quality of handling concept; flexibility of design; operator's experience (De Langen et al., 2012; Notteboom & Verhoeven, 2010) | n.a. |

Source: Own elaboration, based on literature overview in section 2.2.

Earlier work (Talley & Ng, 2013) noted that actors select their partners strategically, based on the criteria that they value in their supply chains. Hence, ports compete not just for cargo, but also to attract certain supply chains (Robinson, 2002). Shippers and forwarders seek to minimize their overall logistics costs and select their supply chain partners accordingly. Port authorities and terminals – despite being geographically bound – engage in the same selection behavior by negotiating long-term contracts with shipping lines (as terminals do) or long-term leases with terminals (as port authorities do). Moreover, through their pricing strategies and service offering, they attract shippers and carriers with certain preferences.
For a deeper understanding of container port competition, one should consider heterogeneity in supply chain actors' preferences. Moreover, these heterogeneous decision-making processes should be considered in relation to one another. Earlier work has highlighted interdependencies and interaction effects between supply chain actors' decision-making processes (Heaver et al., 2001; Talley & Ng, 2013; Van der Lugt et al., 2014), but a completely integrated perspective with the four key stakeholder categories, port competition, and heterogeneity in port users' preferences and requirements has been lacking. Based on the survey of choice behavior literature above, augmented with theories on competition and competitive strategies, this section presents a conceptual framework integrating these elements (Figure 2.1).

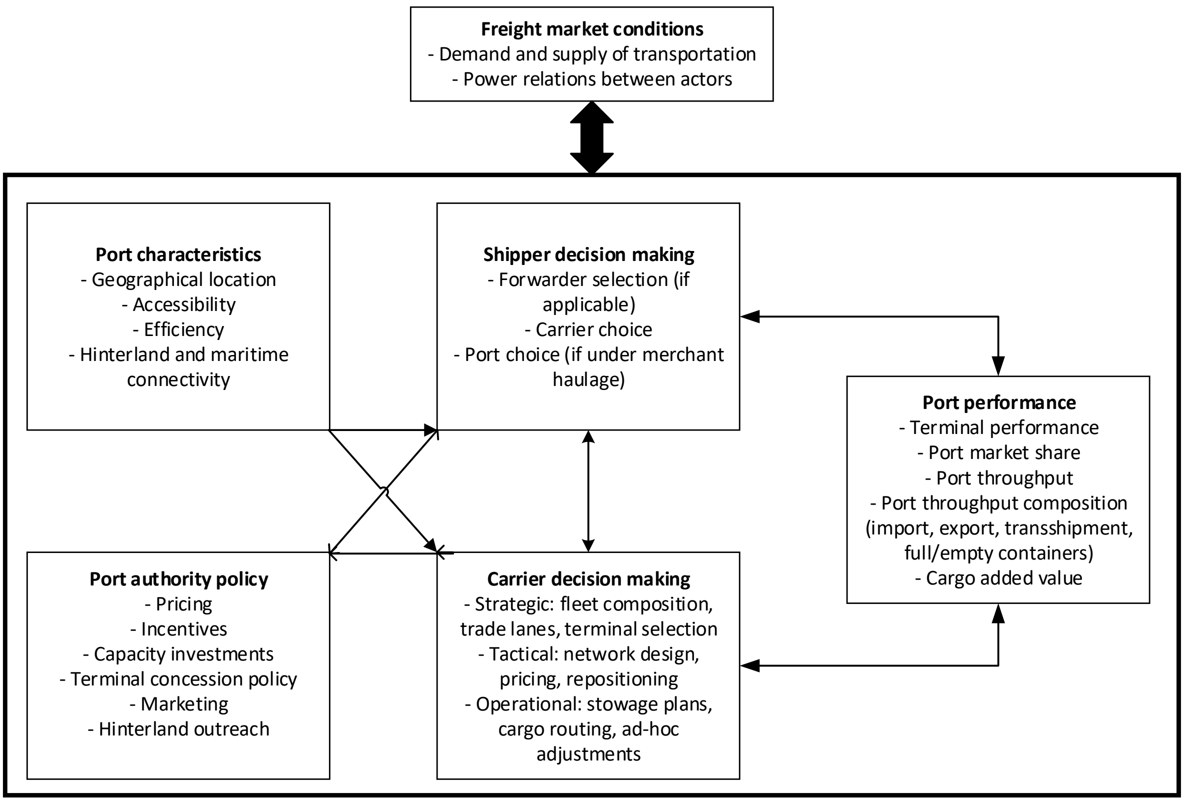


**Figure 2.1: Conceptual framework on port choice criteria, port user choice behavior, and implications for ports.**

Source: See the literature overview in Table 2.1.

The model contextualizes choice behavior. The supply chain choices of shippers and carriers (the most footloose port users) are considered in the broader context of a local freight market (demand for and supply of container transportation capacity, including import, export, and transshipment) and factors relating to port characteristics and policy. For the sake of parsimony, the broader context of more structural factors such as the state of the world and local economy, developments in world trade, and technology developments are considered exogenous. In aggregate, actors' contextually bound choices result in a freight market equilibrium and the respective cargo mixes and market shares of ports (i.e. their competitive position relative to other ports that compete for the same hinterland).

Market developments also influence power relations between actors, influencing the outcomes of their interactions (Parola & Musso, 2007). First, as terminals invest in capacity based on concession agreements lasting 20 to 30 years, supply of handling capacity is inelastic in the short and medium term once the terminal is constructed. However, demand for transportation and hence handling capacity can fluctuate strongly in a short timeframe. When demand for container transport is high and terminals are operating at full capacity, supplier power of terminal operators relative to carriers is high. However, when demand declines and there is excess capacity at terminals, supplier power of terminals diminishes. Secondly, as the liner industry consolidates and operates in closer alliances, its bargaining power vis-à-vis terminals and shippers increases (all else being equal). This can impact negatively on the performance of container terminals. For example, carriers can demand more flexibility from terminal operators, such as extended berth time or more complex handling moves at lower charges (undercutting handling efficiency), or push to renegotiate rates altogether (undercutting profitability).

Port-specific characteristics and incentives from port authority policy (of which the relevant aspects are listed in the boxes on the left side) directly influence the decision-making of shippers (consisting of forwarder, carrier, and port choice) and carriers (consisting of planning at the strategic, tactical, and operational level), as shown by unidirectional arrows. The freight market context not only influences shipper and carrier behavior, but is made up of the aggregate of their choices (hence the two-headed arrow). Port performance (in terms of market share, throughput volume and value, terminal performance, and throughput composition) is influenced by carrier and shipper choices, but is also a choice criterion for both, hence the two-directional arrows on the right side.

Discussing implications for port competition and competitiveness, we focus further on the role of port policy. Port authorities can strategically position themselves in certain transport chains to attract specific types of users. When ports in a region compete to serve the same contested hinterland, they position themselves strategically with a competitive aim. This is done through marketing policies and the incentives offered to port users. Assuming for simplicity that this positioning works along the two main choice criteria for shippers and carriers, namely, cost and service quality (broadly conceived), this positioning can be best understood using Porter's generic strategies framework (Porter, 1980). Porter describes how a company – or port – can build a competitive advantage in two ways: either by having a unique advantage in the perception of customers, or by having the lowest cost in the industry. These two strategies aim at different market segments, namely, customers that value differentiated products or services versus customers for whom cost is the most important criterion. When an organization fails to be the overall cost leader, but does not deliver differentiated service to customers that value this, it becomes 'stuck in the middle', where neither the cost-sensitive customers nor the discerning high-value-oriented customers are attracted. The customers that it does attract are more footloose and are easily whisked away by organizations with low costs or a more differentiated service offer. This can be as much a matter of bad luck as the mistake of not aiming for a clearly defined strategy.

The relevance for port policy is clear if one considers trade-offs between the two major choice criteria: port service quality and costs. A low-cost port attracts supply chains that value low costs more than anything else – probably lower-value cargo that does not require specific servicing and does not generate much value added for the port. On the other hand, ports with a higher level of service quality attract the supply chains of more discerning shippers with cargo that requires more efficient handling, is perhaps more time-sensitive, or in any other way justifies higher costs for better service. This is likely to be higher-value cargo, which provides more opportunities for value added services in or related to the port cluster. Also, even if competing ports in a region all have a cost reduction focus, investments are still necessary to ensure efficiency and long-run competitiveness (Cheon, Song, & Park, 2018). Ports will likely not strike the exact same balance between cost reduction and efficiency investment, resulting in differences between ports that can incentivize port user behavior analogous to price differentiation.

Moreover, considering the different functions of ports, and port users and their criteria, the incentive structure does not necessarily have to be the same for all users: a port that is cheapest for carriers may not be the cheapest for shippers, and the port with the best service offer for shippers may not be the best at servicing carriers.

Section 2.4 discusses how the interrelations inferred from the literature and presented in the model will be explored.

## 2.4 Methodology

Guided by existing theory on port choice behavior, section 2.3 outlined some plausible interdependencies referred to in passing in the literature, but not yet addressed in depth. To provide an in-depth illustration of the working of the interactions outlined in the framework, this study examines how the Port of Rotterdam competes with the other major container ports along the HLH range. The case study draws on publicly accessible information on the ports involved and their competitive positions. Secondly, industry stakeholders were interviewed. It should be noted that the nature of the data does not allow findings to be proven with statistical significance. Rather, the study "relies on multiple sources of evidence with data needing to converge in a triangular fashion" (Yin, 1994, p. 13) to achieve a rich, well-rounded narrative addressing the 'how' question of the proposed interdependencies between context, behavior, and port performance. Interviewing respondents from various types of stakeholder organizations is likely to yield contradictory perspectives on the relations of interest. However, by treating respondents as individual cases of stakeholder positions, the study aims for replication of findings following either a literal replication logic (cases with similar findings to be expected, i.e. representative of similar organizations) or a theoretical replication logic (cases with contrasting results, but for predictable reasons, i.e. representative of different types of organizations) (Yin, 1994). Combining these approaches, the case study helps to formulate a well-rounded, coherent narrative of how the relations outlined in section 2.3 work, which may serve as a template for theory for future work.

From October 2016 to February 2017, three representatives from the container terminal industry, three representatives of the Port of Rotterdam authority, two representatives of two major (top 10) container shipping firms, and three representatives of two major global freight forwarders were interviewed. Forwarders (as 3PLs) were approached to elicit the shipper perspective on port choice. Many shippers are relatively small firms, making up a miniscule share of all container movements, whereas the forwarders interviewed arrange the transport of millions of containers per year for their clients. The interviewees were selected on the criterion that they should be directly involved in their firm's decision making, resulting in respondents in management positions in commercial or strategic departments. Each interview lasted between one and two hours and was conducted in a semi-structured format, with five guiding questions based on the relationships of interest discussed in section 2.3. This semi-structured format left room for respondents to raise relevant issues themselves, while also inviting them to share their perspectives on our conjectures. The following guiding questions were used:

*1. How do you evaluate the competitive position of the Port of Rotterdam as a container port relative to nearby competitors, and what are the most important developments and their drivers?*

*2. How attractive is the Port of Rotterdam to carriers and shippers, and how do you see the positioning of the Port Authority and the container terminals in this market? How does this positioning/strategy compare to other ports in the region?*

*3. What factors are – from your perspective – most important for the competitive position of a container port?*

*4. Considering some aspects of Rotterdam's current competitive performance (import/export imbalance, large share of empty containers, relatively smaller call sizes), from your perspective, what are port users' considerations that could drive these trends?*

*5. How would you describe the relations between carriers, shippers, and terminals, and how does this relate to their chain partner choice behavior, in particular port choice?*

Some respondents preferred to make statements in a personal capacity, rather than as a formal representative of their company, and therefore asked for the interviews not to be recorded. Notes were taken during the interviews and later transcribed into interview reports – rather than verbatim transcripts. Hence, the statements discussed are paraphrased rather than quoted literally. Vogt *et al*.'s (2014: 55) handbook on research methods suggests that for the purpose of our investigation (asking "informational questions about matters of fact and interviewees' interpretations") interview notes suffice. Furthermore, to mitigate potential inaccuracies, a draft of this chapter was presented to the respondents to verify whether their viewpoints were represented accurately, and whether they identified factual inaccuracies in the data or the information gathered from other interviews – of course differences in perspective between stakeholders aside. This validation round did not yield major discrepancies, suggesting that the various information sources helped highlight complementary aspects of the same phenomenon.

## 2.5 Case outline and findings

The relations outlined in section 2.3 are explored further using the case of how the Port Rotterdam competes with other ports along the HLH range.

**World trade and container shipping**

Since the crisis of 2008, the world economy has gradually recovered, but trade recovery was sluggish (IMF, 2016; OECD, 2015). This led to financial distress in the shipping sector, with excess supply and a downward pressure on freight rates. The sector's capacity to cut costs is limited in the short run, as liner companies still have to service their fixed schedules, even if demand is low (Stopford, 2009). As recently as 2016, the container shipping sector posted annual losses over $5 billion and witnessed the bankruptcy of Hanjin Shipping, until then one of the largest carriers (Drewry Maritime Research, 2016a). Remaining firms have pushed for consolidation to mitigate losses through scale and to improve competitiveness by expanding their market share, evidenced by several mergers and acquisitions (Wackett, 2017). Moreover, a rearrangement of the alliances in the liner market has brought the number of alliances down to three, with a number of (minor) carriers still operating independently.

This consolidation has consequences in the freight market, in that consolidation increases the buyer power of liners vis-à-vis ports and terminal operators and liners' supplier power toward shippers.

**Container port competition along the HLH range**

The ports along the HLH range handle a major share of Europe's import and export flows, and four of the world's 25 largest ports are located on this relatively short coastline.

The ports are different in overall cargo composition, but all have in common that container handling makes up an important part of their throughput. Moreover, a large share of the containers are transported under merchant haulage (on average 70% of container cargo) (Notteboom, 2008), implying that shipper decision making on port choice is highly relevant. Considering container throughput alone, the Port of Rotterdam has the largest total throughput, followed by a growing Antwerp, a recently declining Hamburg, and a somewhat smaller Bremerhaven (Figure 2.2).

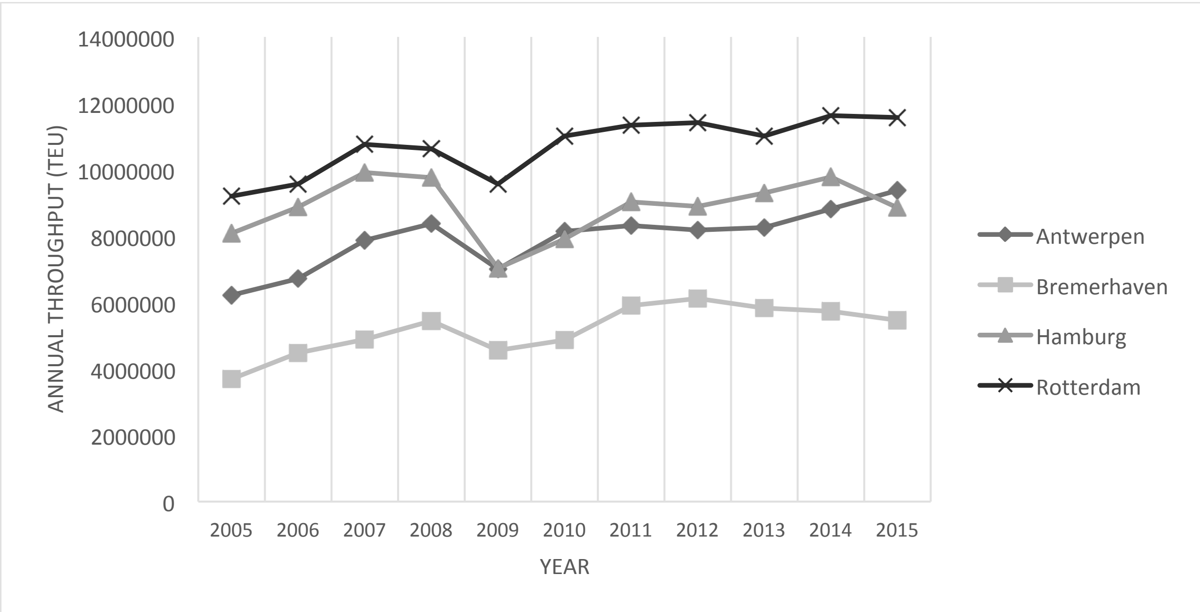


**Figure 2.2. Annual throughput (TEU) for four largest ports on Hamburg–Le Havre range.**

Source: (Eurostat, 2017a).

The ports have different physical characteristics. The Port of Antwerp lies upstream along the Scheldt, posing constraints on the port's accessibility: the newest container vessels of 20,000 TEU and over cannot enter the port fully loaded because of depth restrictions. In the Port of Rotterdam, the Tweede Maasvlakte has been created to expand the port's container handling capacity. This new extension is easily accessible from sea by ships of all sizes. The container terminals in Rotterdam – particularly those at the newly constructed Tweede Maasvlakte – are considered to be state-of-the-art (De Langen et al., 2012). However, with the opening of the Tweede Maasvlakte in 2013, more capacity became available than was demanded in that generally depressed freight market. In Bremerhaven, the four deep-sea container terminals, all located on one stretch of 5km-long quay, are easily accessible for deep-sea vessels. However, as the current quay stretches to the city-state limit, further port expansion is unlikely. Lastly, the Port of Hamburg lies along the Elbe, some 80km inland from the sea. Because of the draft restrictions imposed by the Elbe, the port cannot accommodate the largest container vessels fully loaded.

**Pricing and throughput composition**

The section above shows that the ports differ considerably on physical indicators of port competitiveness, i.e. geographical location and accessibility. Whereas Rotterdam and Bremerhaven are easily accessible for deep-sea ships, Antwerp and Hamburg cannot be accessed by the largest container ships fully loaded because of draft restrictions.
In terms of the port choice framework distilled from the literature, this section surveys all relevant findings on port choice incentives (port characteristics and policy) and port performance for the four major HLH ports. Given that important performance indicators are the result of the aggregate of shipper and carrier decision making, two specific interrelations are explored further. First, the authors draw on interview findings to explore how port choice incentives impact upon actor choice behavior and in turn on performance. Secondly, the authors explore how freight market conditions and power relations impact on decision makers' incentives, choice behavior, and ultimately port performance.

To shippers, a port is priced through the THCs (Terminal Handling Cost) listed by carriers. These are the same in both directions: i.e. a container shipped from Hamburg to anywhere in the world has the same handling charge as a container shipped from anywhere to Hamburg.

**Table 2.2: Terminal handling charges of selected carriers (euros per container).**

| | **Rotterdam** | **Antwerp** | **Hamburg** | **Bremerhaven** |
|---|---|---|---|---|
| Maersk | 210 | 180 | 237 | 237 |
| MSC | 205 | 190 | 220 | 220 |
| Hamburg Sud | 205 | 190 | 225 | 225 |
| **Average** | **206.7** | **186.6** | **227.3** | **227.3** |

Source*:* Corporate websites (2017).

Antwerp tends to be the cheapest, the German ports are most expensive, and Rotterdam is in between (see Table 2.2.). These THCs charged to shippers likely deviate from the costs incurred by the terminal and carriers, and from the rates negotiated between carriers and terminals – in the scenario where this is negotiated with an independent terminal, rather than a dedicated terminal simply operating as a cost center for a carrier. However, as these are the rates offered to shippers, they likely have a real effect on port choice.
The cost structure of carriers is composed of several factors apart from the handling rates negotiated with terminals, including port dues, quay, buoy, and dolphin dues, mooring services, and tugs and pilotage. An inventory made by the Port of Rotterdam Authority shows that, in terms of total call costs, Rotterdam is the cheapest, followed by Bremerhaven, Antwerp, and Hamburg, respectively (personal communication, 2017).
Another part of the pricing structure faced by carriers is the incentives that port authorities offer to attract port calls and volume. The most common incentives are discounts for vessels calling twice on the same leg of a route, discounts for transshipment containers, and volume discounts. Table 2.3 shows that Rotterdam offers the most generous price incentives – at least in a comparison based on those listed publicly on port authorities' websites and publicly available documents.

**Table 2.3: Port dues discounts for four major ports.**

| Port | Second call discount (per call) | Transshipment discount (per container) | Quantity discount (per call, based on total annual volume of carrier) |
|---|---|---|---|
| Antwerp | 50% | n.a. | n.a. |
| Rotterdam | 75% | €5.00 | Up to 22% |
| Bremerhaven | 50% | n.a. | n.a. |
| Hamburg | 50% | Up to €0.50 | n.a. |

*Source*: Corporate websites, most recent versions of tariff specifications (2017).

Considering the cargo composition beyond volume alone, we examine publicly available data on the direction and content (full or empty) of container flows through the major HLH ports. Figure 2.3 shows the balance between incoming and outgoing container flows, and Figure 2.4 the share of empty containers in total outgoing container flows.

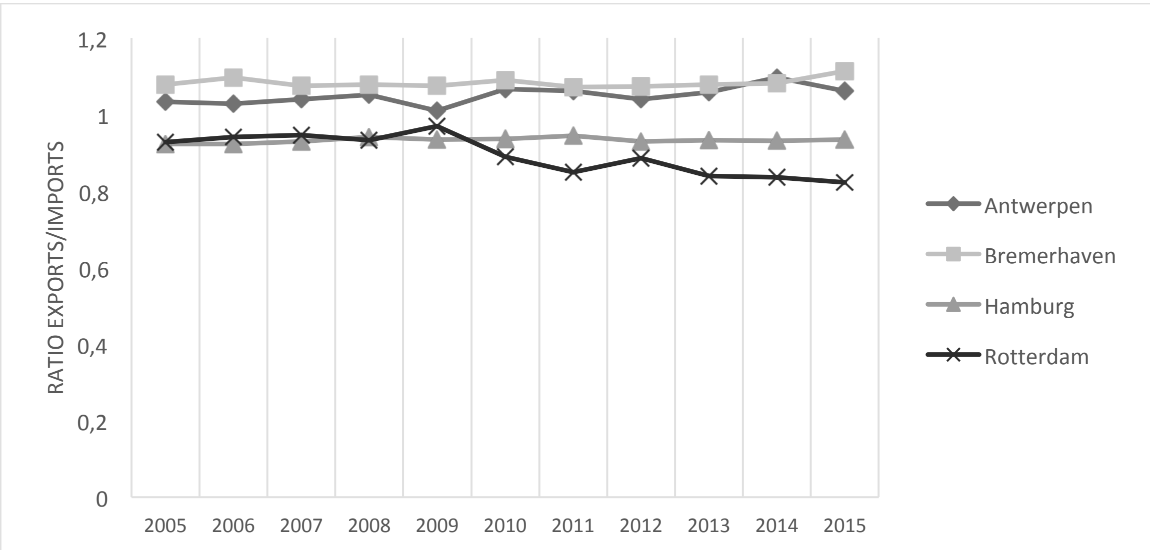


**Figure 2.3: Balance between incoming and outgoing containers (in TEU).**

Source: (Eurostat, 2017b).

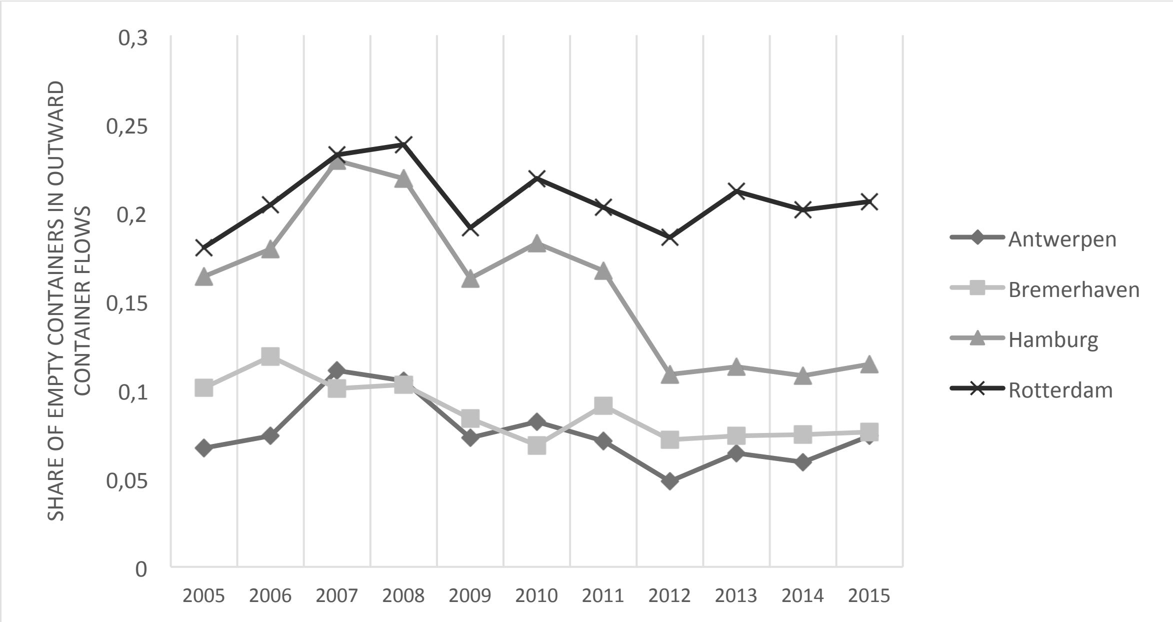


**Figure 2.4: Share of empty containers in outgoing container flows (TEU).**

Source: (Eurostat, 2017b).

This warrants two observations. First, in Rotterdam the balance between incoming and outgoing containers has become more skewed since 2009. In 2015, for every 10 containers coming in, a little over eight – on average – were exported. To illustrate: 10 containers are imported by firms in the European hinterland, but for all that is imported and processed, only eight containers of goods leave. Twenty percent of containers 'disappear,' to reappear in the ports that serve the same hinterland, but have a positive export/import balance, such as Bremerhaven and Antwerp. In the long run, this may not be a good sign for a port, as it indicates that it is relatively less attractive to exporting shippers in its own hinterland.

A second observation relates to the share of empty containers. Empty containers are transported through a port at the discretion of the carrier, so a larger share of empty containers indicates that a port is relatively more attractive for carriers to do their repositioning. These are, however, less valuable cargo, relatively less profitable for container terminals to handle – as discussed in relation to the fixing of the THCs between terminals and carriers – and indicate that a port may be transporting less value than throughput statistics alone may suggest. Antwerp, Bremerhaven, and Hamburg have gradually reduced the share of empty containers exported, but in Rotterdam one in every five containers exported is empty. These trends suggest that, despite a stable throughput, the competitive position of the Port of Rotterdam warrants two critical remarks: A lot more cargo is imported than is exported through the port, and a large number of the containers that go out are empty.

Combining container throughput data with data on container vessel calls results in Figure 2.5.

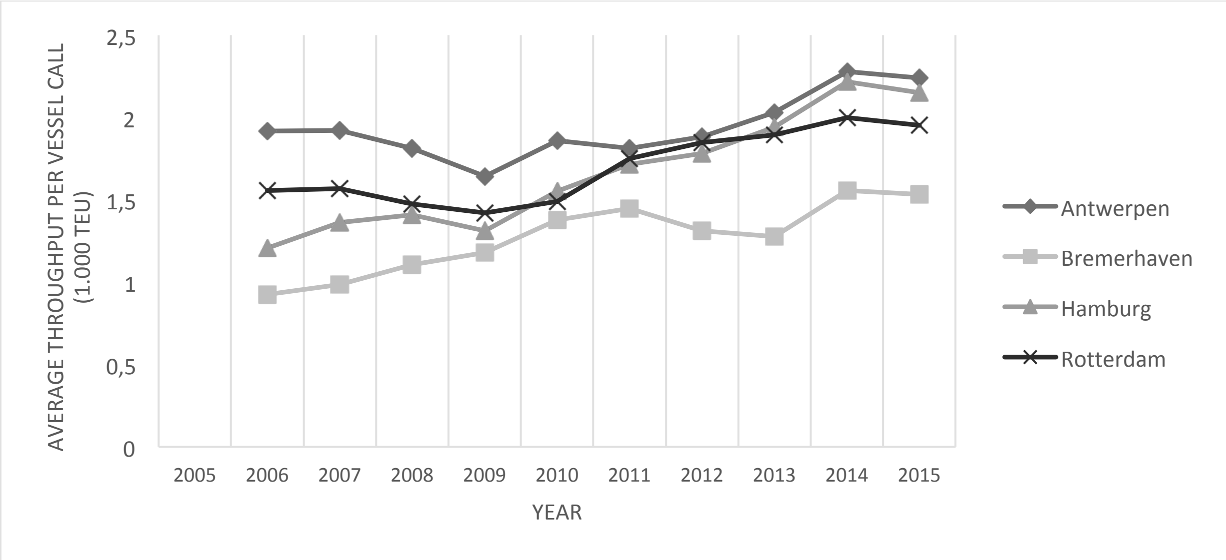


**Figure 2.5: Average throughput (1,000 TEU) per vessel call per year 2005–2015.**

Source: (Eurostat, 2017a).

As the average vessel size increases, one would expect the number of containers loaded and unloaded per call (the call size) to increase as well. This is visible for all ports (with the possible exception of Bremerhaven), but Rotterdam has started lagging behind in terms of call size relative to Antwerp and Hamburg – two ports in which one would expect it to a lesser degree given their draft restrictions. Assuming that the same liner vessels call on the major HLH ports, container terminals in Rotterdam are handling relatively fewer containers per call on the same trades than the ports with which it was on par some years ago. Given that container terminals incur costs for each call (idle time of quayside resources while the ship is mooring or leaving and any window of time that the ship may be arriving early or late), this hurts the efficiency of the Rotterdam container terminals.
Last, in terms of port efficiency, on the World Bank 'Quality of Port Infrastructure' indicator, the Netherlands scores 6.8, Belgium 6.3, and Germany 5.6 (World Bank, 2016). Assuming that the largest ports are highly representative of a country's overall port infrastructure quality, these figures suffice as a rough proxy measure of the focal ports' infrastructure quality.

The data surveyed warrant several observations. First, the price structure facing shippers does not necessarily correspond with the price structure facing carriers: the cheapest port from the perspective of a carrier (based on port costs) is not the cheapest from the perspective of a shipper (based on port-specific THCs). Second, the cheapest and one of the most accessible ports for carriers with the best infrastructure – Rotterdam – does not attract the best business: relatively few containers per vessel call, a sharp import/export imbalance, and a large share of empty container movements.

**Interview findings**
This section draws on observations from the interviews conducted to contextualize the observations made above.

*Port choice incentives*

The major HLH range ports compete to a large extent for the same hinterland. Shippers and carriers make their port choice based on their own preferences and the ports' price/quality offer. Through the incentive mechanisms consisting of port characteristics and port policy, ports attract clients with certain preferences and over time develop a certain profile of certain types of users and activities.

Per port, different incentive structures for shippers and carriers, and different stakeholders' policies, can be distinguished. Antwerp offers the lowest THCs, German THCs are relatively high, and Rotterdam is in between but differentiates itself by offering greater incentives to carriers than other ports do. However, the interviewees made some remarks with regard to these numbers. One forwarder emphasized that large German shippers have long-term agreements with carriers, with lower THCs than those quoted publicly. A port authority representative affirmed this and estimated that the difference in effective THCs between Rotterdam and the German ports has diminished. Unequivocally, the interviewees agreed that Antwerp is the cost leader along the HLH range. The terminals, equipment, and infrastructure are not state-of-the-art, but costs are kept low for price-sensitive shippers. Carrier MSC uses Antwerp as a home port, focusing on low costs and high volumes, and various interviewees estimated that the throughput growth in Antwerp resulted mainly from MSC cargo.

The Port of Rotterdam distinguishes itself by offering the most generous port dues discounts, but this comes with some caveats. One carrier representative acknowledged that the Port of Rotterdam was more public about its discounts but mentioned that, in all ports, discount deals are made regularly with carriers. Another carrier representative was particularly appreciative of the "aggressive" discounts offered by the Port of Rotterdam relative to other ports. All interviewees affirmed that, in terms of total call costs (port dues, including discounts, pilotage, tugs, quay dues), Rotterdam is the cheapest of the HLH ports for carriers – along with the geographical advantages of its location, its efficient infrastructure, and terminals that work around the clock. One forwarder noted that these cost advantages accrue primarily to carriers: shippers are quoted the THCs as listed and make their port choices accordingly.

Terminal representatives noted that terminals' cargo profiles differ considerably. Apparently, Rotterdam attracts a disproportionate share of empty containers, transshipment cargo, and repositioning requests from carriers. This is ascribed to a combination of factors, namely, the ease of access to Rotterdam, the handling efficiency of the terminals, and the overall low costs of port calls. Carriers reposition empty containers at their own cost, so they prefer to move these through the port with the lowest costs and the most efficient infrastructure. One carrier representative affirmed that Rotterdam has always attracted a large share of empty containers and transshipment cargo through its geographical position and relatively low costs for carriers.

Apart from cargo composition, ports' shipper profiles differ. One forwarder illustrated how Hamburg and Antwerp have relatively large shares of carrier haulage, whereas Rotterdam has a larger share of merchant haulage. Carriers earn more on carrier haulage, whereas shippers using merchant haulage tend to have greater demands on service quality and handling speed, as well as a cost focus. Hence, between ports, the client profile and demand factors differ considerably.

Total logistics costs – of which the THC is a component – are an important criterion for shippers' port choice. However, other preferences are also relevant. All carriers, terminal operators, and forwarders noted that German clients tend to be somewhat "chauvinistic" in their choices and prefer doing business with someone who speaks their language (literally and figuratively) and therefore are oriented predominantly toward German partners and German ports. Carrier and terminal representatives stated that port authorities do not recognize this dimension of port choice enough. This cultural component is also visible in Antwerp and

Rotterdam, according to forwarder representatives. Clients of the Port of Antwerp tend to ship lower-value cargoes and are more tolerant of hold-ups and longer transit times, as long as this reduces costs (a "very Belgian attitude" according to one forwarder). Clients with Rotterdam-oriented supply chains tend to ship higher-value cargoes, and expect both low costs and high-quality service. These clients tend to be footloose and willing to shift their cargo to another port – either to the cost leader or to parties that they feel offer preferred services at an acceptable premium – if they feel that a port underperforms.

This seems indicative of a pattern along Porter's generic strategies, but not the same for carriers and shippers alike. Concerning shippers, THCs and service differentiation in a port can make a difference. To a predominantly German hinterland, German-port-oriented supply chains offer services for which shippers are willing to pay. Antwerp is a cost leader, whereas Rotterdam attracts shippers with both cost-driven and quality-driven preferences. This is seemingly a more footloose segment than those focusing only on cost or those willing to pay a premium for service regardless. Concerning carriers, the incentives work differently. Apart from attracting shippers' cargo, ports can attract carriers by being accessible and (cost-)efficient. Rotterdam's geographical characteristics make it attractive to carriers, who can enter with fully loaded container ships at any time. Accordingly, Rotterdam is usually the first port of call for lines deploying the largest container ships and the preferred port for import cargo (shipper's choice), transshipment, and repositioning (liner's choices).

*Freight market conditions and strategic behavior*

The interviewees affirmed that market conditions, through their effects on power relations between supply chain stakeholders, have indirect effects on port and terminal performance. One carrier representative stated that

*When the market was booming, carriers were worried that they would not be able to secure terminal capacity in HLH ports, so many invested in positions in deep-sea terminals. When there is overcapacity in ports, carriers have more leverage in negotiations with terminals. For carriers, excess capacity and competition between terminals are convenient, as they allow them to push rates down. In a sense, carriers play out competition between terminals.*

Various respondents noted that carriers have their choice of multi-user terminals in Rotterdam – as these terminals nearly all have excess capacity – and can demand concessions regarding price, guarantees, and service. A Port Authority representative expected this intensified competition to be temporary:

*With the Tweede Maasvlakte and developments in the liner market, the terminal market in Rotterdam has been disrupted, and it is still being settled who serves which clients. This has intensified competition, but once the market settles back into equilibrium and terminals are fully operational, relations and cooperation will go back to normal.*

In this context of relatively high buyer power, liner planning affects port and terminal performance. The number of containers handled per call has stagnated in Rotterdam – even though the vessel size increases continue to be reflected in the figures for the other HLH ports – and the share of empty containers is particularly high. Some respondents attribute this to liner companies' planning.

A stylized example: As Rotterdam can be entered fully loaded, this is usually the first port of call on the major lanes. This first call is used to discharge import cargo and reposition containers on the ship, as the containers are usually stacked as low and as flat as possible to minimize the container tiers-based toll at the Suez Canal, but this does not make for the most efficient stowage plan to call on multiple ports. Subsequently, the ship sails on with enough draft reduction to access Antwerp and/or Hamburg. Before leaving Europe again, Rotterdam is called on once more to collect the last export shipments and some last repositioning. For carriers, this second call is cheap, because of considerable discounts and overall relatively low call costs. However, this routing is unfortunate for the terminals in Rotterdam: Import and export cargo is split between two separate, but overall less efficient, calls. Also, the first call involves some repositioning on the ship, but these are not profitable moves for a container terminal as no container is loaded or unloaded. One terminal representative estimated that, per call, at most one hundred repositioning moves take place, but with moves between different bays of the ship, they entail inefficient use of equipment.

The implications of carrier planning for port and terminal performance extend beyond these first and last port of call issues. A forwarder mentioned an increase in ‘cut and run’ calls in Rotterdam, where a ship leaves a port before the loading and unloading is finished, in order to be at another port in time (either to benefit from a high tide or to meet a time window at the next terminal). When consequently containers have to be rerouted, shippers pay the price. If they experience problems like this often, they will consider routing their containers through another port. The same forwarder noted that carrier schedules generally have become more erratic and port calls in Rotterdam less punctual, causing uncertainty for the port’s terminals and shippers. In this case, carriers use the most easily accessible and most efficient port to pick up the slack in their operational planning.

## 2.6 Discussion and conclusions

The findings reveal an interesting paradox. For carriers, Rotterdam is the cheapest and most convenient port, but these benefits are not reflected in shippers’ incentives. In fact, the price structure along the HLH range may even leave Rotterdam ‘stuck in the middle’ – between cost leader Antwerp and German ports that seem to naturally attract cargo from the German hinterland – with a demanding and footloose clientele of shippers. While carriers’ relative market power is high, Rotterdam’s good geographical position may even be disadvantageous, as carriers use the cheapest and most convenient port for relatively low-value activities and activities that make less efficient use of terminals. These include moving empty containers and strategies to compensate for restrictions imposed by other ports, such as on-ship repositioning, ad-hoc schedule changes, and double calls.

The findings from the case are obviously specific to the situation of Rotterdam and the HLH range, but some general considerations for port policy can be offered by considering the behavioral mechanisms highlighted. In particular, a twofold challenge for port policy can be identified: First, ports that are attractive to carriers are not necessarily equally good at appealing to shippers, inviting a question relating to how incentives to attract shippers to opt for the port can become better aligned with incentives to attract carriers. Secondly, when a port is relatively more attractive to carriers, a larger share of its handling activity and throughput consists of relatively low-value activities (e.g. repositioning, empty container transport, inefficient calls). Apparently, translating or extending the properties of the port that attract carriers into properties that attract shippers remains a challenge. How can a port’s physical advantages – location, infrastructure, equipment, etc. – and competitive pricing that attract carriers also help to attract valuable cargo and value-adding activity to the port?

These considerations come with some caveats. Although we assume that shippers make decisions in their capacity as cargo owner, and carriers make decisions in their capacity as deep-sea liner operator, there are likely cases in which these distinctions may blur. An example would be a container shipped under carrier haulage. However, as in Western Europe the majority of cargo is shipped under merchant haulage, shipper decision making can be expected to be a major factor, separate from carrier planning. Another limitation of this study is that the mechanisms described cannot be proven with statistical significance. Instead, we triangulate evidence from various quantitative and qualitative sources to provide a plausible behavioral explanation for observed phenomena. The rich information gathered from individual interviews and quantitative data on port throughput did not produce factual contradictions, but in fact highlight complementary aspects of the interdependency of port users' decision making, suggesting that the findings could serve to deepen theoretical perspectives on interrelations and complexities between port actors' choice behaviors.

Generally, the findings present interesting theoretical questions for future research. So far, port choice criteria have been assumed to be roughly similar for carriers and shippers, but we have shown that their effects on choice behavior and implications for ports can diverge substantially, with unexpected implications such as those highlighted in this chapter. Therefore, it is desirable to elucidate systematically when and under what conditions which port characteristics and policy attract which actors with what type of cargo and activity to the port. This extends further to the question how container flows contribute to value creation in ports. Some containers travel long distances to and from the port without being opened, but, for other cargoes, consolidation and deconsolidation activities – and perhaps even other activities such as packaging, assembly, or production – may be concentrated in the port cluster. The question remains how ports can attract more high-value cargoes and activities to the port cluster.

# 3 The ostensible tension between competition and cooperation in ports: A case study on intra-port competition and inter-organizational relations in the Rotterdam container handling sector

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**Abstract**
Strategic alliances in the container shipping sector, and requirements imposed by consolidated hinterland modalities such as trains and barges, have resulted in container terminals facing increasing pressures to cooperate to handle increasingly intertwined container flows. However, concession agreements and market conditions often also pressure terminals to compete. This chapter aims to help understand how pressures for competition and cooperation conflict, what problems this causes, what drives these tensions, and how these can be resolved.
The drivers of port competitiveness are generally conceptualized as straightforward criteria related to costs, efficiency, location, and infrastructure. Because of the focus on these 'hard', quantifiable factors, the qualitative relational underpinnings of port performance are often overlooked. This chapter explores how inter-organizational relations function as a major underpinning of port performance and competitiveness. Interviews with a representative selection of stakeholders in the Port of Rotterdam reveal the problems that can occur when cooperation between terminals is under pressure. These problems relate to deficiencies in inter-organizational relationships, which do not tend to arise spontaneously in a competitive context. This chapter provides a framework that helps understand how firms can simultaneously balance pressures for competition and imperatives for cross-firm integration and cooperation. Several technical and organizational solutions are suggested, but effective implementation depends on various tacit factors – including trust, shared values, and a sense of community – that determine stakeholders' willingness to commit and cooperate.

## 3.1 Introduction

In Western Europe there is traditionally strong competition between several major neighboring ports, in particular Antwerp, Rotterdam, and the German ports Hamburg and Bremerhaven. This competition is generally recognized, but within container ports themselves, there are also competitive dynamics that may in turn affect port performance and competitiveness.

Container port competitiveness is generally conceptualized as driven by straightforward criteria, such as port costs, handling efficiency, hinterland connectivity, and the quality of infrastructure and services (Parola et al., 2017). The more efficient and cost-effective a port's operations are, the better should be its competitive position. The authors argue, however, that these 'hard', quantifiable factors cannot be seen in isolation from the more tacit and qualitative relational underpinnings of the way a port functions. On a deeper level, port performance itself – as evidenced by conventional measures such as efficiency and throughput growth – critically depends on the way in which port actors relate and interact in the logistics processes taking place within a port.

Competition in the container shipping sector can be distinguished at the intra-port level (e.g. between actors within one port competing for the same cargo) and at the inter-port level (e.g. between different ports serving the same supply chains and/or hinterland) (Haezendonck, 2001; Verhoeff, 1981; Kun Wang & Zhang, 2018). So far, inter-port competition – between different ports competing for users' business – has received the most attention in the maritime and port economics literature (e.g. De Langen and Pallis 2010; Figueiredo de Oliveira and Cariou 2015; Van Hassel et al. 2016; Lagoudis et al. 2017; Castelein et al. 2019). Intra-port competition – and more broadly inter-organizational behavior within ports (including competition, as well as cooperation and other configurations of interaction and mutual dependence) have received relatively little attention, with some exceptions that do address the complexities in relations between port actors (De Langen & Pallis, 2006; De Martino et al., 2013; Hall & Jacobs, 2010; Jaffee, 2017; Van der Horst & De Langen, 2008; Verhoeven, 2010). In addressing intra-port inter-organizational relationships however, authors predominantly focus on the formal aspects of port policy and governance (i.e. the position of Port Authorities and its relations with port users, such as concession agreements) and deliberate stakeholder management strategies of port authorities (Parola, Pallis, Risitano, & Ferretti, 2018). Other studies have focused on the more tacit dimensions of inter-organizational relations, but often between firms that are not necessarily direct competitors (i.e. either vertically linked in the same logistics chain or operating in different chains) (De Martino, Carbone, & Morvillo, 2015; De Martino et al., 2013; Jaffee, 2017; Van der Horst & De Langen, 2008). Of particular interest is the tension that arises when direct competitors also face pressures to cooperate. Recently, Clott et al. (2018) considered horizontal coordination within the liner shipping sector, and a series of recent papers explored the relatively new idea of cooperation between competing seaports from various perspectives (see Notteboom et al. (2018) for an overview). However, while the ostensible balancing act between competition and cooperation has been researched for the liner shipping sector and seaports, these dynamics at the intra-port level are of considerable practical and academic interest as well, considering the often fierce competition between neighboring terminals in contrast with their shared interest in the overall performance of the port's logistics functions. So far the tension between competitive and cooperative relationships between directly competing neighboring container terminals has not been researched yet. This study aims to explore this missing perspective by analyzing horizontal coordination and cooperation between competing container terminals in a seaport, based on a case study on the Port of Rotterdam.

To function effectively as a transportation hub, ports should seamlessly integrate various logistics chains and processes that pass through the port. This integration may have to take place between processes of competing port users. Therefore, in contrast to competition between port actors, earlier work has shown that there is considerable pressure on firms in ports to engage in coordination and cooperation to ensure the overall efficiency of port-oriented supply chains (Van der Horst & De Langen, 2008). Apart from cooperation to align and coordinate logistics processes, also innovation processes in port clusters depend on the degree to which (sometimes competing) organizations interact and cooperate (Acciaro et al., 2018). The authors researching these issues conclude that cooperation often does not arise spontaneously, and that the link between competition and cooperation within ports deserves further scrutiny. This chapter further engages with this challenging question, and focuses on competitive dynamics and inter-organizational relations within container ports to explore the challenges that may arise when terminal operators compete directly, but also face pressures to cooperate.

The questions that need to be answered in this context are: *What tensions may arise when port actors have to balance the pressures for competition and cooperation? Secondly, what factors drive this tension? And lastly, how may this tension be resolved?*

These questions are addressed using insights from the fields of marketing, business management, and supply chain management on how barriers to, and facilitators of, supply chain integration work and can be managed. This is linked to the issue of how firms can simultaneously manage cooperation and competition. These insights are applied to the case of the Port of Rotterdam, where the importance of balancing competition and cooperation and inter-organizational relationships has recently become particularly relevant. In 2013, the terminals at the newly created Tweede Maasvlakte port extension became operational, with the Port Authority paying special attention to the competitive environment in their concession agreement policy as well as sustainability concerns (De Langen et al., 2012; Notteboom & Lam, 2018). In the context of a declining freight market and overcapacity in the container-handling sector, relations between terminals, and between terminals and the Port Authority, became strained. One operator (Hutchison Ports ECT Rotterdam) even claimed €1.3bln from the Port Authority in damage compensation for the perceived unfairness with which the Port Authority granted concessions to new operators competing with the incumbent ECT (Mackor, 2014). Furthermore, hold-up and congestion at and between terminals in the port of Rotterdam worsened, partly due to lack of inter-terminal coordination and cooperation (Pieffers, 2017). This example shows that when relations between terminals become competitive to the extent that cooperation suffers, this has a direct negative impact on port performance. When these issues persist for longer periods of time, long-term port competitiveness suffers as well. For managers and policymakers, this study offers deeper insights into the drivers of such problems, and possible directions for solutions.

Drawing on publicly available information, information from industry publications, and interviews with decision makers from several different types of key stakeholder organizations in the Rotterdam container transport sector, this chapter illustrates how the abstract notions of inter-organizational relations and supply chain integration apply to the situation within a container port. Based on this case study, this chapter considers a) the problems that can arise when cooperation and coordination fall short, b) the relational and institutional underpinnings of these dynamics, and c) possible solutions.

In addressing these questions, the study contributes to practice as well as academic discussions on several relevant issues. The relevance of the chapter is that it outlines how a port's performance on important criteria – transit time, reliability and intermodal connectivity – is jeopardized when terminals fail to effectively coordinate their activities on the seaside as well as the landside. Tracing the institutional drivers of these coordination problems, the authors highlight the importance of inter-organizational relations between supply chain actors (even competitors) for effective supply chain coordination and ultimately port performance. This leads to recommendations for managers and policymakers, based on technical and organizational solutions discussed in literature. To academic research, the study contributes a missing perspective on coordination within seaports. Earlier research in this area focused predominantly on vertical coordination in container ports (notably Van Der Horst and De Langen 2008), or horizontal cooperation within the liner shipping sector (Clott et al., 2018) or between seaports (Notteboom et al., 2018), whereas this study explores horizontal coordination between directly competing terminals. Following a qualitative case study approach, the study provides in-depth understanding of all aspects involved in an environment where competing terminals also face pressures to cooperate, including port policy, the institutional environment, terminal behavior, and the linkages between these. Moreover, the authors link these intra-port dynamics to port performance and competitiveness. In doing so, the chapter contributes a unique and so far missing perspective to the academic discussion, on a set of issues with an urgent relevance for practice. Deficient coordination between competing terminals impedes the efficient transit of containers in the port area and hence undermines port performance and competitiveness. As these dynamics are the result of ingrained behavioral patterns driven by path-dependent institutional contexts, the resulting problems are persistent. To help address these persistent problems of the sector and the seaport community, this study provides an in-depth understanding of the drivers of these problems, and outlines possible directions for their alleviation.

The chapter is structured as follows. Section 3.2 briefly reviews the literature on intra-port competition and port inter-organizational relations, and outlines the framework uniting the concept of supply chain integration with competition and cooperation in business networks. Section 3.3 outlines the methodology used. Section 3.4 introduces the case study of the Port of Rotterdam, illustrates how pressures for competition and cooperation create problems for the port's container handling industry, and identifies the institutional drivers of these coordination problems. Section 3.5 presents recommendations on how to overcome these problems. Section 3.6 discusses the findings, their implications for research and practice, and some caveats. Section 3.7 concludes.

## 3.2 Literature overview and theoretical background

This section presents a background sketch of the business environment in container ports, the pressures on port actors to engage in various types of interactions, and the theoretical lens through which these issues are addressed in this study.

**The roles of a container terminal**

This chapter focuses specifically on the container handling sector in seaports. In a typical container supply chain, containers are loaded on a deep-sea container vessel (some with over 20,000 TEU (twenty-foot equivalent unit) capacity) and shipped to some destination (importing) port. Upon arrival, the containers are unloaded at the container terminal contracted by the deep-sea carrier and from there transported to their destinations. Transport to the port's hinterland can take place via inland waterways by barge, over rail by train, or over road by truck. Moreover, some containers are transshipped to smaller destination ports in the hub port's vicinity. For example, containers destined for Scandinavia are often first shipped to larger hub ports in Northern Europe and subsequently transported to Scandinavia by feeder. Of course, in the case of exports, the containers are transported from the hinterland on various modalities *to* the port and subsequently loaded onto a deep-sea or short-sea vessel.

The processes occurring at an individual deep-sea container terminal are summarized in Figure 3.1.

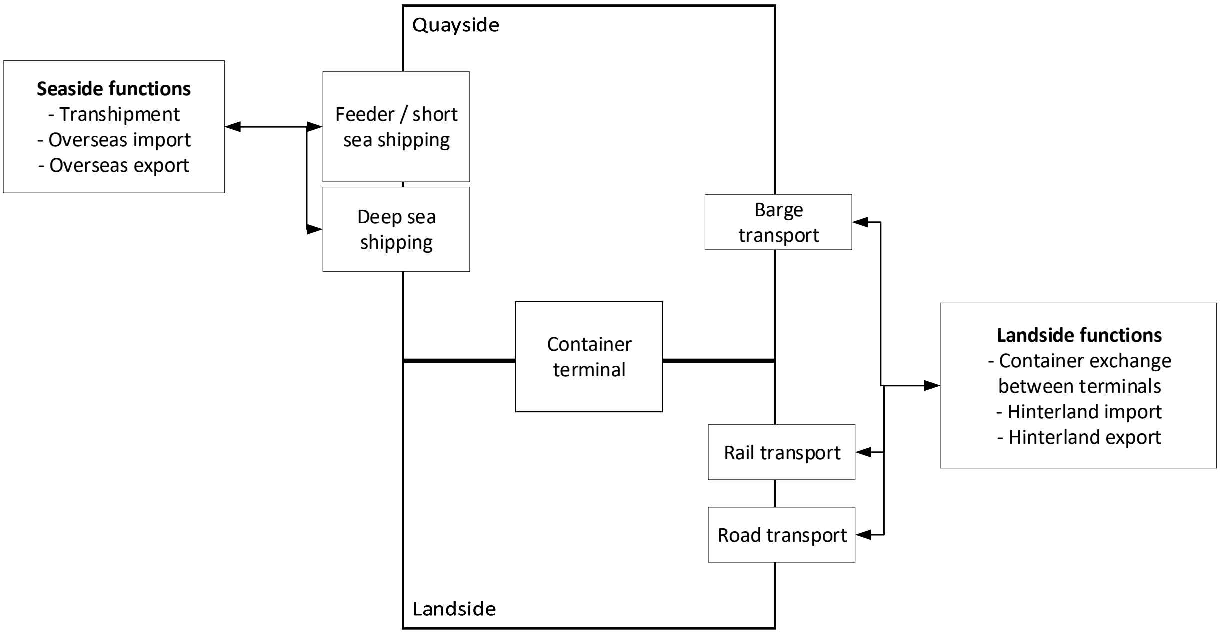


**Figure 3.1. Processes at and around a deep-sea container terminal.**

*Source:* Authors' own elaboration.

The terminal can be divided into three sections: the quayside (where ships moor), the landside (where containers exit or enter through the terminal gate for or from overland transport), and the stack or yard (where containers are stored temporarily). For simplicity, the stack is omitted from Figure 3.1, focusing on container movements in and out of the terminal. The quayside in particular is a bottleneck for container terminals (Carlo, Vis, & Roodbergen, 2015): they have a limited length of quayside and a limited number of cranes to service ships. This requires them to balance demands from deep-sea carriers and feeders that fulfill seaside functions, and barges, that predominately fulfill landside functions towards the hinterland or within the port. Another complication is introduced when, in ports with multiple container terminals, the different operators all have to optimize their own landside and seaside processes, while containers also have to be exchanged between different terminals to end up on the designated deep-sea vessel or feeder.

In this context of demands for optimization and trade-offs in the terminal's own operation, and factors that require coordination with other parties, this analysis explores how container terminals relate to one another and other parties in the port.

## Conflicting pressures

Container terminals in ports with multiple operators face two conflicting pressures, namely, to a) compete with one another (intra-port competition), but also b) cooperate, as they have a shared interest in the efficiency and competitiveness of the port in which they are operating (relative to other competing ports).

Since the late 20$^{th}$ century, Port Authorities in Europe have evolved from (municipal) government agencies into more autonomous corporatized entities (Borges Vieira et al., 2014;

Brooks & Cullinane, 2006). Ports may vary in the degree to which the infrastructure, superstructure, port labor, and other functions are managed by public and/or private actors. The World Bank (2007) specifies a typology of port governance models, ranging from fully public to fully private, and two categories in between. On this spectrum, they recommend the 'landlord' model of port governance: an autonomous Port Authority granting land concessions to port users (in this case competing terminal operators) in exchange for a concession fee and additional stipulations ensuring that the broader societal goals, such as sustainability requirements, of the Port Authority are also met (De Langen et al., 2012; Debrie et al., 2013; Notteboom & Verhoeven, 2010).[1]

The pressure for intra-port competition stems from these dominant views on port governance. When the port superstructure, labor, and other functions are left to market actors, it is assumed that competition between port users with similar functions benefits port efficiency and hence competitiveness (De Langen & Pallis, 2006; World Bank, 2007). Stevedoring activities within a port, including container handling, lend themselves well to natural monopolies, making it prudent for the Port Authority to actively stimulate competition between various operators competing for the same cargo to reduce costs and improve efficiency in the process (De Langen & Pallis, 2010). For most Port Authorities, this push for lower costs and higher efficiency is an imperative in an environment in which ports compete for their position in increasingly fluid global supply chains (Robinson, 2002).

Juxtaposed to these pressures for competition, competing terminals within a port have significant shared interests and several imperatives for cooperation. First, in the alliance structure of the container shipping sector, carriers share capacity on each other's ships that call at different terminals, and thus containers have to be exchanged between terminals for hinterland, deep-sea, or feeder transport. Secondly, hinterland transport by train or barge may require containers from different terminals to be consolidated on one modality. In addition, because of sustainability concerns and road congestion in port areas, some Port Authorities have already started to demand that terminals transport a larger share of containers to the hinterland by barge and rail, instead of truck (De Langen et al., 2012; Van den Berg & De Langen, 2014). Thirdly, as shippers and carriers consider hinterland, short-sea, and deep-sea connectivity and service reliability as major port choice criteria (Martínez Moya & Feo Valero, 2017; Parola et al., 2017), it is in the interest of all stakeholders in the port that these processes run smoothly and reliably, or else the port risks losing its position in these supply chains (Castelein, Geerlings, et al., 2019b). The integration of various processes and activities between actors is an essential underpinning of the efficiency and competitiveness of the port cluster overall (Lavissière & Rodrigue, 2017).

### The integration imperative

The terminals' interest in cooperation stems from a need to integrate logistics processes within a port to strengthen the port's efficiency and competitiveness. Supply chain integration is defined as "a firm's objective to attain operational and strategic efficiencies through collaboration among internal functions and with other firms" (Richey, Roath, Whipple, & Fawcett, 2010, p. 238). In the port context, this concretely entails a "pressure for seamless

[1] Another restructuring has taken place in the terminal operating industry in the last decades, whereby the management of container terminals has increasingly become concentrated in a handful of globally operating terminal operating companies (TOCs) (Slack & Frémont, 2005). This global management structure and the shifting away of decision making from the local terminal to a global HQ has implications for the position and behavior of individual terminals in ports. However, in attracting clients to their terminal in a given port, the individual terminal has considerable discretion that makes competition between individual terminals at the port level a justifiable focus: different terminals of the same TOC may have different client portfolios, and similarly carriers may call at terminals from competing TOCs (in different ports or even in the same port). For the purpose of this analysis, it is assumed that terminals operating in the same port are exposed to similar institutional pressures that drive the inter-organizational relationships between these terminals.

integration and rapid transit" (Jaffee, 2017, p. 732). Considering supply chains as linear constellations, this integration requires the alignment of the transfer of containers from carrier to terminal to hinterland transporters to its destination. However, in more complex supply networks, logistics integration in seaports may also require coordination of container movements between terminals, either in more complex transshipment arrangements or in the consolidation of cargoes from various terminals on one hinterland modality (i.e. barge or train). To some extent, these issues are addressed in existing research on synchromodal transport (Van Riessen, Negenborn, & Dekker, 2015), but relational barriers to integration and synchronization have received scant attention in the literature.

This concept of integration – and factors that can enhance or impede it – deserves further attention. Barriers to integration include lack of trust, failure to understand the importance of integration, fear associated with losing control, misaligned goals and objectives, poor information systems, short-term as opposed to long-term focus, and supply chain complexity issues (Moberg, Speh, & Freese, 2003). Richey et al. (2010) distill these barriers down to three dimensions: unwillingness to share information, preference for keeping other parties at arm's length, and an internal focus (i.e. on sub-optimizing the firm's own processes to the detriment of processes *across* firms and the overall performance of a chain or cluster).

Other factors may function as facilitators of integration. These include "inter-organizational teams, developing new performance measures, improving communication and information exchange [and] a 'united front' […] to develop a level of commitment among cross-company members of an alliance" (Richey et al., 2010, p. 241). These facilitators work on five dimensions, namely, alignment, communication, structure (risk, rewards, and cost-sharing schemes), quantification (of performance measures), and interdependence.

This brief overview shows that facilitators of integration depend to a great extent on the relations between organizations in the chain, horizontal as well as vertical. Bad relations, evidenced by a lack of trust and an inward-looking focus, impede integration, whereas good relations, evidenced by communication and shared values, facilitate integration.

The value generated in a supply chain is created through exchanges between organizations. In Allee's (2008) 'value network' (opting for the network rather than the chain metaphor) approach, tangible exchanges include the exchange of goods and money within a network, whereas, more interestingly, intangible exchanges can entail everything from coordination, planning and process knowledge to support, trust, expertise, or affiliation. The key takeaway is that these exchanges create value not only for the recipient, but also for the network overall – an insight that readily applies to terminal operators in a port. However, the extent to which these exchanges arise depends on the strength and quality of the relations between the organizations in the network.

**Port inter-organizational relations**

Although the 'landlord' model of port governance is the most common in Europe, local implementations of this model vary between institutional contexts, resulting in considerably different governance structures and positions of Port Authorities (González Laxe, Sánchez, & Garcia-Alonso, 2016; Ng & Pallis, 2010). Debrie et al. (2013) argue that port reform constitutes an evolutionary process in which the realized reform is always a compromise between a formal and deliberate reform attempt (i.e. a generic governance model) and bottom-up forces that facilitate, resist, or redirect these reform attempts. These forces are shaped by the local institutional context, the balance of power between public and private stakeholders, the distribution of local decision-making power, and local market conditions.

Port inter-organizational relations between competing terminals are driven by a similar dialectic process. On the formal and deliberate side, Port Authorities and government actors impose formal rules and requirements on terminals, and employ stakeholder management strategies, aiming to stimulate healthy competition that drives costs down and efficiency up, contributing to the performance and competitiveness of the port. Additionally, emergent factors from the local context also influence port inter-organizational relations. Relevant factors for the local stevedoring sector include the institutional environment (how do businesses, and particularly competitors, relate to one another?), local freight market conditions (how much pressure can clients put on terminals and take advantage of the presence of multiple competing operators in a port?), public–private relations (what path-dependent dynamics are there in the relation between port operators and Port Authorities?). Although port policy may *prescribe* a certain competitive structure, the way port actors relate to one another is determined by these bottom-up factors.

Competitive pressures may impose barriers to logistics integration between competing operators. As discussed above however, other factors can mitigate these barriers and shape a climate that is more conducive to cooperation. Analogous to Richey et al.'s (2010) notion of a united front, Porter and Kramer introduced the term 'shared values' as a force that contributes to the competitiveness of a cluster, such as the container handling sector in a port (Porter & Kramer, 2011). This theory attempted to show the way to connect business and society (Vroomans, Geerlings, & Kuipers, 2017). The concept of shared values resonates with a concept introduced by Fukuyama (1995), namely the "belief system", or the way people associate with one another. If this belief is profound, one can assume that the shared values will be more present than when this belief is lacking. Such a shared belief system is necessary to enhance trust between parties in a given system. Geerlings (Geerlings, 1997) elaborates on this by stating that a system that might enhance this interaction between people (or actors within a system) could be described as an 'economy of touch': "…the informal contact that influences the management structures and decision making processes" (Geerlings, 1997) – a crucial concept for the relationships between and within government and the private sector. Lun et al. (2016) explore the concept of social capital in this context: relationships and interactions between stakeholders that allow them to establish linkages, develop synergistic activities, and facilitate collective action. The stronger these inter-organizational ties and relationships are, the better they can be leveraged to enhance performance and generate added value for the port cluster and the region.

**Coopetition**

Hall and Jacobs (2010) argue that inter-organizational relations in a port fall somewhere on the spectrum between competitive and collaborative. Too much of one is never good: a too collaborative environment will lose efficiency because it lacks competitive pressure, but too much competition can depress inter-organizational relations to the point that necessary cooperation in certain areas is impeded. In terms of the container handling industry, competition between a port's terminals enhance efficiency, but when competition and rivalry gets in the way of collaboration, this undercuts the port's performance.

This analysis takes a somewhat different perspective and explores how companies may compete and cooperate at the same time, with both types of relations having their own spectrum of intensity, independent of each other. While the tension between competition and cooperation may still be there, it can be alleviated in areas where cooperation is desirable – hence this ostensible tension may be there, but it does not have to be a given obstacle in all interactions. This type of two-faced relationship is called 'coopetition' – a portmanteau of competition and cooperation (Bengtsson & Kock, 2000). Song (2003) and Heaver et al. (2001) have explored this concept in relation to inter-port competition and Clott et al. (Clott et al., 2018) for the liner shipping industry, but it has particular relevance for the business environment within ports as well. Competition and cooperation are driven by fundamentally different and even conflicting conceptions of how organizations relate to one another, or "logics of interaction" (Bengtsson & Kock, 2000), but a context of competitive pressures and mutual dependence may require companies to engage in both. Among container shipping companies, this is done through strategic alliances (Clott et al., 2018; Panayides & Wiedmer, 2011), but such global formal cooperation agreements between competitors may not be feasible in the stevedoring industry, as, at port level, operators compete on the basis of local rules, customs, and market conditions.

The sections above outlined how companies within ports are competitors but also have a shared interest in the port being able to integrate logistics processes effectively. Whether this integration occurs despite competitive pressures depends to a great extent on the quality of inter-organizational relations. More formally, competing terminals within a port would benefit from a *coopetitive* relation in which competitive and collaborative modes of interaction coexist rather than produce friction.

Bengtsson and Kock (2000) outline two conditions for effective coopetition. First they observe that, between firms that manage effectively to cooperate and compete simultaneously, there are "clear norms of the interaction partly based on formal agreement and partly on social contracts" (Bengtsson & Kock, 2000, p. 419). Secondly, apart from this tacit understanding, they note that firms in a coopetitive relation formally ensure that competition and cooperation never occur in the same functional areas – e.g. firms compete for customers' business in sales and marketing but cooperate in upstream activities, such as research and development (R&D) and sourcing. By separating competitive and cooperative logics of interaction across functional areas, there is no ambiguity about the nature of single employees' or departments' interactions with other firms in the sector.

In the case of a container port, terminals can separate competition for carriers' business from cooperation in other aspects. Formally, this can be achieved by separating functions internally, but, more importantly, Bengtsson and Kock (Bengtsson & Kock, 2000) emphasize the importance of tacit norms and agreements within and between firms that separate the contradictory logics of cooperation and competition and allow firms to attain the best of both. In the interaction between actors at the intra-port level, this may require attention for community building and the 'soft' elements of port management. These include shared values, trust, a sense of a united front, and a shared vision on future port development.

This conceptual framework is used to address the study's research questions on the basis of a case study on the container handling sector in the Port of Rotterdam. First, how does the tension between pressures for competition and for cooperation manifest itself at the port level? Secondly, what formal and informal factors drive this tension? Thirdly, how can this tension be resolved?

## 3.3 Methodology

To illustrate how these dynamics can be applied to understand coordination problems in seaports, the situation in the container handling sector in the Port of Rotterdam – the largest container port in Europe – is used as an illustrative case study. Apart from publicly accessible information about the port's recent developments, we draw on information from interviews with key stakeholders. Between October 2016 and February 2017, we interviewed three representatives from the container terminal operating industry, three representatives of the Port of Rotterdam authority, two representatives of two major (top 10) container shipping firms, and three representatives of two major freight forwarders (both top 3 global forwarders in terms of sea-freight volume). The freight forwarders were selected as a category of respondents to represent cargo owners (shippers). The majority of shippers tend to be small parties moving small quantities, whereas forwarders deal with demands from the many cargo owners by whom they are contracted and could therefore appropriately voice their perspective. Respondents were selected on the basis of the different categories of stakeholders outlined above: we wanted to speak with several representatives from each major category of port users (shippers, carriers, terminal operators) and the Port Authority. Our criterion for approaching respondents within these organizations was that the respondents had to be directly involved in the organization's strategic decision making. Each interview, lasting between 1 and 2 hours, was conducted in a semi-structured format on the basis of general discussion questions about the Port of Rotterdam's competitive position and internal dynamics. We also proposed several of our conjectures as formulated in section 2 as discussion points.

We agreed with our respondents beforehand that the conversations would not be recorded, as some of them preferred to make statements in a personal capacity rather than as a formal representative of their company. Extensive notes were taken during the interviews and later transcribed into interview reports – rather than verbatim transcripts. Hence, it should be noted that the statements below are paraphrased rather than quoted literally. In instances where it is not possible to obtain verbatim transcripts, interview notes are generally accepted to be a sufficient alterative (Vogt et al., 2014). During the interviews, two of the authors were present, one in the capacity of interviewer and the other as observer who could ask for clarification when needed.

The analytical approach to the findings from the case interviews is rooted in the exploratory nature of the question, namely *how* container terminals balance pressures for competition and cooperation and *why* certain problems arise and persist (see Yin 2009). The section above sketched the important aspects of the case setting (terminal's operating environment and the conflicting pressures they face) and the conceptual categories one should explore when considering supply chain integration and simultaneous cooperation and competition (theory on barriers and facilitators). Drawing on the interview findings, the role and relevance of these concepts for the case can be explored to a great level of qualitative depth and understanding of the mechanisms involved. Using information from different sources serves to highlight complementary aspects of the topic under study, while discrepancies between respondents can be addressed by critically considering their positions and perspectives and juxtaposing these. Ultimately, having identified the main relations and relevant concepts, the recommendations from literature can be tailored to the case context.

To mitigate the potential inaccuracies arising from using written interview notes only, a draft of this chapter was presented to our respondents to verify whether their viewpoints were represented accurately – as is good practice in qualitative case study research (Yin, 2009). As another validity check, we presented our conclusions to 10 other, 'out-of-sample' experts from Germany, Belgium, and the Netherlands, asking them whether they recognized the findings, and whether any relevant elements were wrong or missing. These validity checks did not raise major issues or omissions. The next section describes our findings.

## 3.4 Case study and findings

This section describes the case study of the container handling sector in the Port of Rotterdam, identifies coordination problems between terminals, analyzes these in terms of the framework outlined above, and discusses the institutional factors identified by port stakeholders as the main impediments to intra-port cooperation.

**Case study background**

The Port of Rotterdam is the largest container port in Europe. It is located along the Hamburg–Le Havre range, which contains four of the 25 largest ports in the world, namely

Rotterdam, Antwerp, Bremerhaven, and Hamburg. Together these ports handle the lion's share of (Western) Europe's container trade. Recently, the port was extended with the Tweede Maasvlakte project – including the commissioning of three new, fully automated container terminals – to facilitate a projected throughput growth from 11mln to 33mln TEU per year by 2033.

The container terminals in Rotterdam – particularly those at the new Tweede Maasvlakte – are considered to be state-of-the-art (De Langen et al., 2012). The Port Authority – a corporatized entity owned by the municipality of Rotterdam and the Dutch government – stimulates competition between container terminals in the port to enhance efficiency, and at the moment three global terminal operating companies have one or more deep-sea terminals in the port, besides several smaller operators focusing predominantly on short-sea and barge shipping. In the 1990s, APMT was invited to open a container terminal and compete with the incumbent ECT (now part of Hutchinson Port Holdings), which previously had a monopoly position in the port. When awarding concessions for the newly created land at the Tweede Maasvlakte, ECT and APMT both obtained concessions for additional terminals, and Rotterdam World Gateway, a consortium of DP World and several liner companies, was attracted as a third large competitor within the port (De Langen et al., 2012). The Port Authority maintains a strategy of non-interference and keeps the container terminals at arm's length, emphasizing the importance of free competition within the port (Vroomans et al., 2017).

When the terminals at the Tweede Maasvlakte were commissioned, more capacity became available than was required in a generally depressed freight market. This overcapacity was disadvantageous for all terminal operators, as their new deep-sea quay acquisitions were not operating at full capacity, and their competitive position vis-à-vis their clients is weaker. The relationship between the Port Authority and the terminals, particularly ECT, became strained as a result (Van der Lugt et al., 2014), even culminating in a court case in which ECT accused the Port Authority of irresponsible decisions in creating the new capacity at the Tweede Maasvlakte and demanded indemnification (Mackor, 2014).

**Integration problems arising from conflicting pressures**

Our respondents identified several problems related to deficient cooperation between the competing terminals. For an overview, the separate issues raised by the different categories of stakeholders are listed in Table 3.1, with their direct consequences for port performance indicated with arrows:

**Table 3.1. Inventory of problems in inter-terminal coordination (and their effects on performance), as identified by respondents.**

| Forwarders | Terminal operators | Port Authority | Carriers |
|---|---|---|---|
| Hold-up of barges at terminal (deep-sea lines get priority)<br>→ Containers may 'miss the boat' | Uncertainty of container arrival times at other terminals<br>→ Less efficient handling, longer transit times | Hold-up problems regarding rail and barge, modal shift towards these modalities hard to achieve<br>→ Large share of truck transport to hinterland (more congestion and environmental impact) | Inefficient exchange of transshipment containers<br>→ Longer transit time, containers may miss their boat |
| Rail and barge cargoes are not consolidated efficiently between terminals<br>→ Longer transit times | Exchange of transshipment containers inefficient<br>→ Longer transit time, containers may miss their boat | | Hinterland rail and barge connections inefficient<br>→ Longer transit times |
| | | | Congestion at and between terminals (unreliable barge service)<br>→ Longer transit times |

Source: Authors' own compilation from interviews.

This inventory serves to give a well-rounded view of various coordination problems that may arise between terminals within a port. Of course, if one actor did not mention a certain problem, this does not necessarily mean that he/she does not perceive the problem as relevant. Respondents may also refrain from mentioning a problem in which they have a role. Nevertheless, by eliciting a wide range of stakeholder perspectives and introducing additional validity checks, we aim to paint as complete a picture as possible.

The key takeaway from these statements is that coordination problems between individual terminals have a direct negative impact on key port performance indicators, such as transit time, service reliability, and hinterland connectivity. Our respondents affirm the conjecture that lack of coordination undercuts the competitive position of the port overall. The forwarders we interviewed were most vocal about this issue: for their clients, transit time is a critical decision criterion, as they operate on lean, 'just-in-time' inventory management strategies and have considerable amounts of their cash bound up in merchandise shipments. Too much hold-up and uncertainty in a port will – over time – make shippers consider moving their transport chains through other ports. One forwarder stated that:

*Particularly in Rotterdam, inter-terminal container exchange and consolidation of cargo on hinterland modalities has become more problematic […] The average transit time for a container destined for Germany used to be three days, now it is close to five […] Terminals' own processes and prioritization hurt port performance [in terms of transit time] as well, in that they prioritize the deep-sea calls over inland barge calls, sometimes jeopardizing the timely arrival of our clients' export drops.*

Another carrier representative added that "fragmentation of rail and barge cargo across terminals is not dealt with adequately in Rotterdam due to lack of cooperation and information exchange between terminals", causing considerable hold-up. Generally, they note – like the forwarders – that clients may switch to other ports if hold-up problems persist.

Having established the seriousness of the consequences of inter-terminal coordination problems, these problems themselves deserve further scrutiny. From Table 3.1, these are identified along the lines of 'hold-up,' 'inefficiency,' 'uncertainty,' and 'unreliability.'

Regarding the locus of these problems, four rough categories of problems can be distinguished:

- Hinterland barge (quayside)
- Hinterland rail (landside)
- Inter-terminal barge and feeder (quayside)
- Inter-terminal land transport (landside)

Several of Moberg et al.'s (2003) categories of barriers to chain integration can be recognized in the problems sketched.
First, there is the problem of sub-optimization: this is particularly visible regarding barge transport (whether inter-terminal or hinterland transport). At terminals that do not have a dedicated barge quay, barges moor at the same quay as deep-sea lines. However, with the deep-sea carriers being the only paying clients of container terminals, and the risk of high demurrage costs with these calls, the deep-sea lines get priority in quay and equipment allocation – to the detriment of barge servicing. Consequently, the barge service becomes more unreliable, and shippers may find their containers delayed when "their ship [– literally – ] has sailed". The container terminal optimizes its quayside resource allocation (i.e. quay space and quay crane capacity) for their paying and demanding container line clients, but as a result the performance of the chain in general suffers.
Secondly, there is the problem of information exchange. Respondents mention 'inefficient' container exchange and hinterland transport connectivity, and 'uncertainty' with regard to arrival times of containers. Even if information that could help increase the efficiency of operations is available to the terminal operator, it is not shared with other parties to the extent that the chain in general benefits from it. The question remains to what extent terminals possess complete and accurate information that could increase efficiency if disseminated.
The third relevant barrier is supply chain complexity. Even if parties are working together efficiently, the complex nature of the supply chain (or chains) could impede chain integration in ports. On a small area and within a limited time window, the container passes from carrier to terminal through customs to a hinterland transport operator, a process that in itself is complex enough to streamline without taking into account synchronization with parallel (and intertwining) activities of other operators. This is not to say that cooperation is doomed to fail, but it should be recognized that perfect efficiency may not be feasible.
Moreover, the terms used to identify the coordination problems are subjective and relative by nature (inefficient and unreliable compared to what?). Therefore, concerning inter-terminal cooperation, the comparisons discussed with our respondents are the major ports nearby: Antwerp, Bremerhaven, and Hamburg. Forwarders in particular find the terminal cooperation in Rotterdam more problematic than elsewhere, even stating that the situation regarding hinterland consolidation and inter-terminal exchange of containers has *worsened* compared to the past and to other ports. Additionally, a carrier representative stated that "German terminals are better at cooperating and dealing with inter-terminal container exchange," and "rail services to the German hinterland from Antwerp are more reliable." On the other hand, representatives of the Port of Rotterdam Authority noted that, overall, the Belgian and German ports are generally not more efficient than Rotterdam. Moreover, the Port of Rotterdam has a considerable advantage because of the proximity of its deep-sea terminals to the sea.
It could be a matter of perspective whether Rotterdam under- (or over-) performs. However, it is shown that shippers and their agents evaluate a port's performance based on their own experience and adjust their port choice accordingly, so even a perception or reputation based on anecdotal evidence can have significant effects in practice. The performance measures that

are important to shippers are directly related to the effectiveness of intra-port cooperation. The analysis above suggests that there are several coordination problems that could be addressed, relating to intra-port cooperation and supply chain integration. This in turn depends on the extent to which the inter-organizational relations in the port are conducive to cooperation; this is discussed in the next section.

**Institutional drivers of coordination problems**

Having outlined how lacking cooperation undercuts port performance, this section deals with the main impediments to intra-port cooperation. The interviewed stakeholders' perceptions of the drivers behind deficient cooperation are enumerated in Table 3.2. Particularly regarding the perceived drivers of observable coordination problems, it should be noted that our respondents speak from their own perspective, introducing subjectivity and potential bias into the analysis. We have juxtaposed the perspectives of four different types of port stakeholders to obtain as complete a picture as possible.

**Table 3.2. Inventory of drivers of inter-terminal coordination problems, as identified by respondents.**

| Forwarders | Terminal operators | Port Authority | Carriers |
|---|---|---|---|
| Lack of willingness to collaborate among container terminals<br>Port Authority could take a stronger role in mediating between terminals | Delays at customs produce additional uncertainty | Lack of shared vision ('The great Rotterdam ideal') | Lack of supply chain visibility at terminals |
| Often delays at customs (responsible for checking and clearing containers at the terminal) | Port Authority does not recognize problems stemming from competitive focus and unlevel playing field | Overcapacity gives carriers leverage over terminals, 'play out' intra-port competition to cut costs | Businesslike relations, Port Authority emphasizes competition, does little to enforce cooperation where needed |
| Consolidation in liner shipping market puts pressure on container terminals<br>→ More ad-hoc decision making<br>→ Competition intensifies | Pressure from carriers to cut costs and increase service flexibility on the quayside | Recent port extension has shaken up the stevedoring sector. When market settles again, relations will return to normal | No performance agreements between terminals or between terminals and hinterland transporters |
| Initiatives to stimulate cooperation are not successful due to the noncommittal nature of agreements between parties and lack of enforcement | | | |

Source: Authors' own compilation from interviews.

Several institutional (formal, informal, and economic) factors can be recognized across the responses:

- Market conditions – notably consolidation and growing market power in the liner sector and overcapacity at the Rotterdam terminals – put pressure on terminals on the demand side to compete on costs

- Lack of supply chain visibility at terminals, reluctance to share information, uncertainty introduced by customs procedures
- Low levels of trust and cooperative culture: intra-port relations are described as 'arm's length,' 'businesslike,' and lacking a 'shared vision'
- Absence of agreement on key issues and the noncommittal nature and lack of enforcement of existing agreements.

Some differences in perspective can be observed between the various types of stakeholders. Forwarder, terminal operator, and carrier representatives emphasize their wish that the Port Authority would take a stronger stance in enforcing cooperation when necessary, whereas respondents from the Port Authority tend to emphasize market factors as the main driver behind lacking cooperation between terminals. These perspectives are not mutually exclusive, but it is worth noting that there are considerable differences in different actors' perspectives with regard to what is happening and why.

First, all respondents acknowledge the role of market conditions. As the liner shipping business is consolidating through mergers, acquisitions, and alliance agreements – the latest reshuffling as of April 2017 has concentrated the major carriers from four into three alliances, representing over 80% of the global container trade – the market power of carriers relative to terminals increases. This shows particularly on the quayside of terminals. One forwarder indicated that "carrier schedules become increasingly volatile and ships may change terminals or leave while still unloading (so-called 'cut and run' calls) on an ad-hoc basis" and that terminals have to deal with demands for greater service flexibility towards the deep-sea lines. This can produce hold-up problems with customs, and for shippers and forwarders. A Port Authority representative elaborated further on the supply side of the local freight market:

*With the Tweede Maasvlakte and developments in the liner market, the terminal market in Rotterdam has been disrupted, and it is still being settled who serves which clients. This has intensified competition, but once the market settles back into equilibrium and terminals are fully operational, relations and cooperation will return to normal.*

Secondly, lack of supply chain visibility at the terminal and uncertainty with regard to customs procedures increase uncertainty for other chain actors and increase inefficiency in container transfers. In this case, there is a "one-way flow of process and planning" (Richey et al., 2010, p. 244): the terminal's own constraints determine planning and are not synchronized with the process and planning of other actors. Internally at the terminal, customs procedures and their potential waiting time introduce considerable uncertainty regarding container movements. Also here, a unidirectional relationship exists in which the customs' planning and processes impose constraints on terminals' integration with hinterland transport.

Third, at a more tacit level, there exists what our respondents call "a lack of the 'Great Rotterdam' feeling" (Port Authority) or "pure business," and "arm's length" relations (both carrier representatives). These statements derive from a comparison with other major Northern European ports. As one carrier representative states, "In other ports, relations are more informal, less purely businesslike, and ad-hoc agreements are easily made. […] Also the Port Authority adopts a more detached position than elsewhere." Referring to the theoretical background above, this is congruent with a lack of trust and shared vision. In such circumstances, organizational boundaries are too constraining, and organizations are too internally focused to achieve the relational integration that arises with truly cooperative relations. These social norms make inter-organizational relations rather adversarial, negating the potential benefits from a coopetitive relation. Most interviewees emphasize the need to

reestablish good contact between stakeholders, but at the same time this is an issue of secondary importance, with sub-optimization of their own processes taking precedence.
Along the formal dimension of the institutional environment, our respondents identify – in various contexts – a lack of formal agreements between parties that have to cooperate in container transfers. These include container terminals and customs, and container terminals and hinterland transporters. More abstract, the lack of formal relations leads to an incongruence in performance measures between these parties, inducing misalignment of incentives. One terminal representative identifies the cause of this as “the interests and business models of terminals and [other stakeholders]” differing considerably and not aligning well in many cases. A carrier representative gave the example that a terminal – having the deep-sea carrier as its most important client – has no direct contractual obligations with barge operators (also discussed by Van der Horst and De Langen (2008)). These conditions are not unique to Rotterdam (e.g. Jaffee 2017) but may be particularly relevant in a context where informal relations between supply chain actors are not conducive to cooperation either.
Having identified and conceptualized the main coordination problems in the Rotterdam stevedoring sector, the next section discusses recommendations to improve supply chain integration and discusses their applicability to the coordination problems outlined.

## 3.5 Implications and recommendations for improvement

Considering the impact that deficient coordination between neighboring container terminals can have on the performance and competitiveness of seaports, several highly relevant implications can be derived from the study findings for managers in the sector as well as policymakers.
Freight market conditions are considered exogenous for this analysis: no strategy of any of the surveyed port actors will significantly impact on the working of demand and supply in the global freight market. Also, complete resolution of the inherent complexity in container supply chains is likely not feasible. As discussed above, the various interests and business models of all stakeholders involved diverge considerably, so one overarching solution that fully satisfies all stakeholders is unlikely to be feasible. Moreover, we observed evidence of port coordination as a collective action problem. Nearly all actors interviewed proposed solutions in which another party should take the lead (e.g. “terminals should take hinterland transport more seriously,” “clearly the Port Authority should take a leading role,” “carriers ask too much”) but which would be too costly or risky for one actor alone to implement without guaranteed cooperation from the others. Hence, if the institutional context stays the same, none of these proposed improvements would materialize. Considering generic solutions (contracts, agreements, regulations), as well as context-specific implementations of these, we discuss what stakeholders might do to improve cooperation and supply chain integration at port level, in spite of a current deadlock situation.

**Implications for practice**

Lack of visibility and uncertainty can be addressed through improved communication and information exchange. Technically, this can be done using information technology, in the case of seaports for example by extending the functionality of Port Community Systems (Portbase for the Port of Rotterdam) and other platforms (such as Nextlogic and Container Monitor). Similarly, better synchronization of container movements can be achieved through information technology (IT) solutions. This, however, addresses only the ‘hardware’ side of the problem. For a permanent improvement of chain integration, resources and capabilities are needed, and an informal institutional context conducive to cooperation and integration (the 'orgware'), including trust, commitment, and – most importantly for IT solutions – a willingness to share information. If these are implemented effectively, a positive feedback loop of performance improvement and further integration can result.

On the organizational side, integration can be facilitated through several mechanisms. First, these include incentive alignment and co-performance evaluation among all stakeholders involved. In the case of a port, this could be achieved through more formal arrangements between terminals and parties with whom they do not have a direct contractual relationship. Considering hinterland transportation, a related concept is already being explored by ECT in the Port of Rotterdam, through its European Gateway Service, which arranges hinterland transport under the auspices of the terminal operator. Although this vertically integrated solution is much appreciated by a major carrier interviewed, it may not be feasible to arrange all hinterland transport this way. Horizontally also, coordination may benefit from performance agreements between terminals that impose boundaries on sub-optimization while incentivizing cooperation. It remains a challenge, however, to incentivize terminals to make concessions to the optimization of their own sub-processes, especially if it remains unclear how the costs and benefits of coordination are shared.

Furthermore, several other types of collaborative schemes can be explored. These include inter-organizational teams, risk and reward sharing, collaborative capability building, and more advanced interdependent inter-organizational arrangements (Richey et al., 2010). Referring again to agreements, integration may benefit from performance agreements between terminals that provide mechanisms to share equitably the costs and benefits of integration efforts and hence incentivize cooperation in areas where it matters. Designated inter-organizational collaborative efforts can also facilitate integration. On a deeper level, informal institutions have to change to accommodate these processes by establishing new social norms, greater levels of trust, and a general awareness of shared interests – i.e. a united front. There may be significant barriers to overcome before these changes can be effectuated, including underestimation of the importance or relevance of greater integration, fear of losing control, and key stakeholders' short-term focus.

Bengtsson and Kock (2000) outline how a simultaneously competitive and cooperative relationship can be effectively managed within an organization, providing lessons that are relevant for this case study. They argue that competitive and cooperative inter-organizational relations are based on fundamentally different institutional logics. These can coexist within the same firm, as long as they do not overlap across functions, which would cause ambiguity. Container terminals are a typical example of firms that "are forced to interact with each other [in the same sector], giving rise to rivalry and mutual dependence between them" (Bengtsson & Kock, 2000, p. 414). Like Richey et al. (2010), Bengtsson and Kock (2000, p. 419) emphasize that the interaction should be governed by "clear norms […] partly based on formal agreement and partly on social contracts [i.e. informal norms and tacit agreement]." Their most relevant propositions relate to the separation of competitive and cooperative logics of interaction within the firm, to be defined by the closeness of an activity to the customer: in downstream activities, competition for customers is warranted, whereas in upstream activities firms can benefit from cooperation. An important condition for this coopetitive relation is that the logic of inter-organizational interaction is not ambiguous within the same functional area. For example, a unit engaging in a cooperative interaction with another firm should not treat its counterpart as a competitor, for if it did, the cooperative effort would not reach its fullest potential. The coexistence of cooperation and competition with direct competitors should be internalized in the organizational culture. This places a responsibility on higher management to refrain from 'tribal' or overly competitive predispositions. Even if it is imperative for business areas not to balance incompatible logics, it is imperative for management to do so effectively. Translating this to the container-handling sector, this means that, even when terminals compete for carriers' business, there can be possibilities for cooperation in areas such as hinterland transport and transshipment.

Despite progress made in these directions, the inherent complexity of terminals' operations may impose a limit on the extent to which integration is possible. This is for an important part driven by the fact that the terminal's quayside is of relevance both competitively (terminals offer quay capacity to their client carriers) and cooperatively (because of barge transport and transshipment). Particularly in relation to these complex resource-allocation problems, performance agreements between terminal operators may serve to balance optimization of terminals' own processes and integration across terminals to some degree.

**Implications for policy**

Aside from these general recommendations, the case context also justifies some specific recommendations regarding port policy that can be considered by other ports in similar situations. Two particular aspects of port policy are relevant in the case context, namely concession and competition policy and port extension planning.

First, the Port Authority's concession policy in this case imposed two important conditions on the container terminals. By granting concessions to multiple firms and inviting new entrants to compete with incumbents, the Port Authority stimulated competition among the port's terminal operators. Moreover, the additional requirements included in the concession agreements for the Tweede Maasvlakte – especially the modal split clause emphasizing hinterland transport by barge and rail – put pressure on terminals to cooperate and coordinate with their competitors. It would serve Port Authorities well to consider the tension inherent in these goals and take measures to better reconcile these – for example by attaching performance indicators to various areas in which cooperation is desirable.

Secondly, in the Rotterdam case study, the timing of the port extension was unfortunate: when the new terminals became operational, the freight market was in a depressed state, leading to overcapacity within the port. It was a smart move on the part of the Port Authority not to push to fill all of the newly created land with terminals at once. As a more general recommendation to Port Authorities in the process of extension, it would be wise to consider the possibility of creating overcapacity when the state of the freight market at the time of the completion is less than favorable.

Another, more general suggestion, also made by forwarder, carrier, and terminal operator representatives is for the Port Authority to reconsider its role, and make more use of its position 'above the parties' as a mediator and enforcer (as discussed by for example Van der Lugt 2017). Such 'neutral third party' involvement may guide parties to work towards incentive alignment and stimulate information sharing. At the informal institutional level, the Port Authority as a third party can help bridge differences between stakeholders, facilitate communication, and take the lead in a process of community building. One forwarder in particular emphasized that Port Authorities could do more to enforce cooperation: if agreements are too noncommittal and not enforced, port performance suffers, hurting the interests of both the Port Authority and the port users. This was also emphasized by one of the carriers, who stated that

*[In Rotterdam] cooperation and negotiation between container terminals are weak, and there is little pressure for improvement from the Port Authority, which takes on a more detached position. In other ports, relations are more informal, less purely businesslike.*

Another forwarder has also seen positive shifts in the last few years: Port Authorities in general, and particularly in Rotterdam, have started to move beyond the 'landlord' role and have become more active in bringing parties together and intermediating. From this perspective, Port Authorities can add value by facilitating, and even enforcing cooperation to smoothen coordination.

**Recent developments**

Recently, some initiatives have been undertaken in the Port of Rotterdam to address the problems analyzed in this chapter.

To better facilitate the exchange of containers between terminals, the Port Authority has initiated a project to construct a 'container exchange route' (CER) – a dedicated lane that directly connects the main deep-sea terminals in the port (Dijkhuizen, 2018). Using this lane, containers can be bundled and exchanged between terminals while avoiding congested public roads. The CER is expected to start operating in 2020. Beyond infrastructure projects such as the CER, several other new developments show the Port Authority in a more active role than expected from a traditional 'landlord' Port Authority. An example of a more leading role in community building is the Global Ports Group, a cooperative arrangement between the Port of Rotterdam Authority and four major terminal operating companies (Pieffers, 2016). The agreement specifies "information sharing […] and coordination of joint activities with regard to the efficiency and effectiveness of the container port industry" (quote translated from Pieffers (2016)). Sharing capacity with large call sizes is also said to be being explored. Although this initiative is only a recent phenomenon, some crucial coordination issues can be addressed. First, it signals a commitment to cooperation and an awareness of shared interests. Second, the involvement of the Port Authority as a neutral party may be a way in which commitment and fairness can be enforced. Moreover, a formalized and transparent arrangement with the involvement of a neutral public actor can address competition law implications of cooperation between competitors (Lalkens, 2016). Another example is Nextlogic (Nextlogic, 2018), a cooperation of numerous market actors, including terminal operators, depots, and barge operators, in which the Port Authority also participates. Nextlogic aims for a central platform to coordinate barge calls across container terminals within the Port of Rotterdam. This initiative combines elements of several of the general solutions discussed above, including technology-based information exchange to reduce uncertainty and inefficiency, and more formal arrangements between horizontally and vertically linked organizations. The market has also offered several digital platform-based solutions, such as TEUbooker and 4shipping, to better align demand and supply of hinterland transportation capacity. However, because they focus on matching shippers and hinterland transporters, these initiatives may do little to address the lack of coordination at terminals.

It should be noted that these developments are still fairly new. In light of the theoretical considerations and the analysis of the issues within the port, these have the potential to address persistent issues, but as of now they are too new and operating at too small a scale to gauge their benefits to the actors involved. It is to be expected that their effectiveness in the long run will depend on actors' trust, commitment, and willingness to share information.

## 3.6 Discussion

Having discussed at length the implications of the study findings for practice, some remarks are in order regarding the implications for research and the limitations of the study. In line with the three research questions formulated in the introduction, this study set out to understand the implications and drivers of coordination problems stemming from conflicting pressures for competition and cooperation imposed on container terminals and to offer suggestions on how to overcome these. To our knowledge, this study is the first to explore in depth the linkages between the institutional context, inter-organizational relations, behaviour and port performance. In doing so, this study contributes several new insights to existing knowledge, with useful implications for academic research as well as port policy and management. Multiple coordination problems were identified and traced back to institutional barriers to supply chain integration and collaboration. The urgent need to address these issues is illustrated by examples of how these barriers impact port competitiveness in terms of port users' port choices. Regarding the various areas for improvement (as discussed above), a general conclusion is that 'hardware' (resources and capabilities) alone cannot achieve effective chain integration, but that integration would require the presence of 'orgware' (institutions) conducive to healthy *coopetitive* relations with both competitive and cooperative interaction.

For the field of port management research, the study findings highlight the importance of horizontal coordination for port performance. This adds to the observations of Van der Horst and De Langen (2008) – who focused predominantly on vertical coordination – and affirms their conjecture that cooperation seldom arises spontaneously. Particularly in the case of direct competitors, development of formal and informal governance mechanisms is required to adequately balance conflicting pressures. From both the coopetition and the supply chain integration perspective, an important precondition is the creation of a cooperative culture. Formal governance mechanisms alone, prioritizing competition and arm's length transactions, are not enough to resolve the coordination problems stemming from terminals' ambiguous position with regard to one another. Lacking necessary informal institutions, change has to come either from a 'first mover' among the market parties involved or from a non-market third party – the Port Authority. This study also highlights the relevance of insights from the supply chain coordination and coopetition literature to understand and potentially address persistent inter-organizational issues in port clusters. The link between governance, market forces, behavior, inter-organizational relations, and ultimately port performance is still seldomly researched in the academic literature, and this study highlights the relevance of these linkages and their working in the case context under study.

This last point also pertains to one of the study's limitations. This being a case study within a specific port context, the findings might not be directly generalizable to other seaport contexts. The theoretical underpinnings of the findings, i.e. the conceptual categories of barriers and facilitators of integration, however, have proven to be effective in achieving a deep understanding of inter-firm coordination problems. In other cases where these problems arise, these barriers and facilitators may be relevant to differing degrees. But it is important to emphasize that the conceptual framework itself can be adapted to different case contexts. Another important limitation of this study is that unfortunately the approach does not lend itself well for quantification. Therefore it is not possible to compare the relative impact of different issues (which would be useful in prioritizing interventions) or an assessment of costs and benefits of various solutions, but this research can serve as a starting point to develop new approaches. Therefore, future research can be geared towards this analysis of different cooperative schemes, for example using game theory.

## 3.7 Conclusions

The findings from this study illustrate the complex relation between competitive and cooperative behavior within seaport clusters. Ostensibly, this tension between competition and cooperation requires a balancing act or a single choice of one logic of interaction over the other – as the title of the chapter suggests. The study shows that for port performance, it rather matters in which logistics functions lacking cooperation due to competitive pressures leads to problems. In these areas, specific steps can be taken to resolve the tensions inherent to cooperation between competitors. Logistical problems resulting from deficient coordination between competing terminals in a port area are a persistent problem for container ports, and our study findings provide new insights that can help policymakers and managers understand and resolve these issues. As discussed above, the findings from this study invite questions for further research in various areas, even beyond the integration of supply chain processes between terminals. In particular, the study raises several considerations for port governance and policymaking. Port authorities' concession and competition policy can be fine-tuned to mitigate hold-up due to competitive pressure. Moreover, it can be concluded that the role of a port extension and overcapacity in the case context underlines the need for Port Authorities to consider freight market conditions in their strategic decision-making with regard to port extensions and the granting of new concessions. Earlier research has already identified an evolution of Port Authorities' role beyond the traditional 'landlord' model, including that of a community manager and platform leader (e.g. Hollen et al. 2015). This study provides further suggestions for directions in which Port Authorities may utilize their position to help create value for port users and the port in general. Ultimately, the goal is to function efficiently as a port, but this is underpinned by more tacit factors related to inter-organizational relations that can have a critical influence on the value-creating process in a port. A key step for future research is to more adequately trace and measure these processes, perhaps based on Allee's (2008) 'value network' approach. One key consideration for future work that this study offers is another direction in which to look to broaden the view on how ports create value.

# 4 The reefer container market and academic research: a review study

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**Abstract**
The refrigerated (or 'reefer') container market grows rapidly. Researchers and sector stakeholders increasingly realize that this container market segment has its distinct dynamics and demands. This chapter provides a comprehensive overview of the reefer container sector, its most important characteristics and trends, and a systematic review of the academic literature on reefer containers and logistics. First the authors outline the characteristics, composition, and development of the reefer container market, showing its growth through modal shift (from conventional reefer ships and airfreight) and differentiation into new cargo markets and niche services. Secondly the authors outline reefer chains in terms of their relevant stages, stakeholders, and processes. Data on insurance claims shows that cold chain failure and cargo loss not only occur due to technical failures, but just as often due to organizational errors – especially due to hold-up risk at container transfer points. Thirdly the authors map the present knowledge on reefer containers and reefer transportation through a systematic literature review. The current body of research on reefer containers consists mostly of highly specialized, technical studies on product characteristics and quality preservation, monitoring and control, refrigeration technology, and temperature management. While technological advances in these fields have largely enabled the containerization of cold logistics chains, the first sections of this chapter also highlight that many current pressing issues in reefer transportation are logistical and organizational in nature. Therefore, the authors propose a research agenda addressing these overlooked aspects, including supply chain coordination issues and implications of reefer market developments for port policy.

## 4.1 Introduction

Within the container shipping market, reefer containers are the fastest growing market segment (Drewry Maritime Research, 2016b). Reefers – insulated intermodal containers with an integrated refrigeration unit and climate control capabilities – are used for temperature-sensitive products: predominantly food (fruit, vegetables, meat, fish, poultry etc.), but also flowers, plants, pharmaceuticals and numerous minor product categories (e.g. chemicals, film, sensitive equipment, and even some types of clothing). Due to various factors, demand for transport of these products is likely to increase in the future. Globally, due to rising incomes in developing countries, more consumers demand 'exotic' products, such as food and vegetables that cannot be grown in their home market (Darmon & Drewnowski, 2008). On the supply side, more sophisticated preservation techniques and efficient transportation at lower rates make it possible and economically feasible for these products to be transported over longer distances. Furthermore, the gradual replacement of 'bulk' reefer ships by conventional container ships carrying reefer containers had opened the possibility of maritime transport for a wider variety of conditioned cargoes in more fine-grained supply chains (Arduino, Carrillo Murillo, & Parola, 2015). To this backdrop, it becomes more and more relevant to address the issues arising from this growing market for containerized conditioned transport.

The food sector is particularly known for its sustainability issues. First of all, this stems from the large amount of product loss. Globally, approximately one-third of all food produced for human consumption is lost or wasted (FAO, 2011), amounting to 1.3 billion tonnes of food lost each year, including losses during transportation. Secondly, transportation of temperature-sensitive produce requires a near-constant supply of energy to cool, freeze, or otherwise condition the goods to prevent product waste during transport (Fitzgerald, Howitt, Smith, & Hume, 2011; Wilmsmeier, 2014). As transportation of food over longer distances to expanding consumer bases increases, also does the energy use along the supply chain.

So far, a coherent body of academic research on the maritime reefer market has not developed yet. A quick scan of publications related to reefer containers and reefer transportation shows that knowledge of this sector is scattered between fields as diverse as refrigeration technology, horticulture and 'Internet of things' (IoT) sensor networks. Moreover, the existing research seems – at a first glance – to be predominantly technically oriented, with logistics and organizational questions receiving relatively little attention. The *reefer container market* itself, has rarely been the focal topic in academic research. This suggests that issues encompassing the sector in general, and the cold chain in its entirety are not addressed in a comprehensive manner yet. This is understandable, considering the fact that it is only in the last 10-20 years that the reefer container market has shown the spectacular growth to the point where, to policymakers and sector stakeholders, its relevance is extending beyond it simply being a subsector of the container market. It should be noted that a small number of studies have already addressed the reefer market as their focal topic, with attention for overall reefer market developments – primarily growth and modal shift – (Arduino et al., 2015; Thanopoulou, 2012), container contents and differentiation (Rodrigue & Notteboom, 2015), port-related sustainability issues (Castelein, Van Duin, & Geerlings, 2019), port policy (Castelein, Geerlings, & Van Duin, 2019a), logistics and technology (Behdani et al., 2019). However, as of yet, there is little agreement – or even substantive discussion – on what the main questions should be, nor is there a comprehensive understanding of the reefer chain in its entirety and its associated problems. This chapter aims to structure existing knowledge of this market, and further facilitate academic and practical discussion on this increasingly relevant topic.

The chapter is structured as follows. First, to set the scene, in Section 4.2 the authors provide an overview of the development and composition of the reefer container market, addressing the long-term trends that drive the development of this market. Section 4.3 of the chapter outlines the cold chain with its relevant stages, stakeholders, and issues. Third, in Section 4.4, the results of a systematic literature review are presented, including a bibliometric appraisal of the most important sub-streams of research to identify the most important topics addressed – and those overlooked. Based on this, the authors conclude in Section 4.5, and formulate an agenda with directions for future research.

## 4.2 The reefer container market

The reefer container market is characterized by the need for continuous temperature control of the container cargoes. Temperature-sensitive goods (food, flowers, chemicals, pharmaceutical products etc.) require near-constant cooling to keep the product at a temperature at which its quality can be preserved for a longer period of time – a so-called ‘cold’ supply chain, or cold chain for short. For maritime transport of these goods, the integrated intermodal refrigerated (or ‘reefer’) container has become the standard solution. The name summarizes the most important properties of this container. The integrated refrigeration unit cools down the air that is circulated by two fans. Cold air flows into the cargo hold at the bottom of the container, through the profile of the container floor, and warmer air is fed back into the cooling unit at the top, all the while circulating cooled air through and around the container’s contents. The temperature of the warmer air fed back into the reefer unit is monitored in order for the cooling unit to keep the cargo temperature at the desired ‘setpoint’ temperature. The containers itself are well insulated to prevent the ambient temperature from affecting the cargo, and painted recognizably white to limit the temperature effect of solar radiation. Although the reefer container market has been highlighted as a increasingly important niche within the container shipping market (Guerrero & Rodrigue, 2014; Rodrigue & Notteboom, 2015), academic research has so far not addressed its composition or long-term development. The following section outlines these aspects.

**Conventional reefer ships versus reefer containers**

The development of the reefer container market has been one of growth and modal shift. Until the introduction of the integrated reefer container in the 1970s, seaborne temperature-controlled transport predominantly took place in reefer ships: dedicated ships with cooled cargo holds in which the products are loaded as breakbulk or on pallets (Arduino et al., 2015; Thanopoulou, 2012). These ships – recognizably painted white to maximize the solar radiation reflection (or albedo) of its refrigerated holds – sail from the port of loading to the port of destination in one direct voyage, often at high speeds to limit the reduction in product shelf life at sea. To ensure a continuous cold chain, they are ideally loaded and unloaded (by quay cranes or forklifts at the terminal, or the ship’s own cranes in case of a geared reefer ship) from and into cold storage facilities located directly at the quay. Since the introduction in the 1970s of the integrated reefer container as we now know it (Riccardo Accorsi, Manzini, & Ferrari, 2014), and its large-scale uptake by the major container lines in the 1980s and 1990s, the reefer container sector has steadily been eroding the market share of conventional reefer ships and growing strongly (documented by Arduino, Carrillo Murillo and Parola, 2015). The reefer container offers several advantages over conventional reefer ships, namely that the minimum required shipment size is smaller, that the temperature of small consignments can be controlled more accurately, and the intermodal compatibility that allows land-based transportation by train, truck, or inland waterways without opening the container and risking a breach of the cold chain. Moreover, carrying reefers on conventional containerships allow carriers and clients to benefit from economies of scale, bringing down the price of transportation considerably. Due to this shift towards containerization, shipping temperature-sensitive cargoes over long distances became more accessible and more attractive. Combined with global income increases and an increasing demand for 'exotic' products, these dynamics have made reefer shipping the fastest-growing segment in the container shipping market, as described by Drewry, a maritime research and consulting firm (Drewry Maritime Research, 2016b).

In 2015, of the estimated total worldwide perishables trade of 191.7mln tonnes, 105.8mln tonnes was carried over sea, and the remainder over land or by airfreight. The seaborne perishables trade was split between reefer containers (84.8mln tonnes, estimated to be 7.66mln TEU (Twenty-Foot Equivalent Units – or the capacity of a standard 20-foot intermodal container) and conventional reefer ships (21mln tonnes). The recent development of the relative market shares of the two maritime modes is shown in Figure 4.1 below.

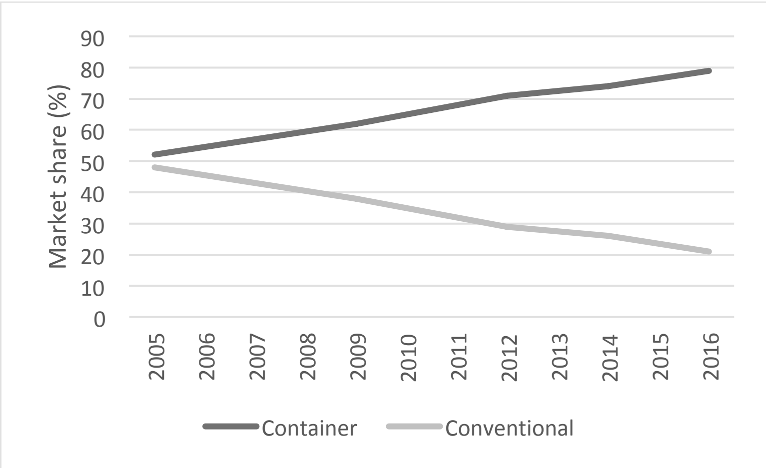



**Figure 4.1. Modal split of seaborne reefer cargo.**

Source: Data from Lloyd's List (Nightingale, 2015; Osler, 2019; Tan, 2017).

Earlier studies that addressed this development (Arduino et al., 2015; Behdani, Fan, & Bloemhof, 2018; Rodrigue & Notteboom, 2015; Thanopoulou, 2012) have mostly shown developments in the relative capacity of the two modes, sketching a sharp divergence up to the point where 90% of all maritime refrigerated transport capacity was containerized (Rodrigue & Notteboom, 2015, p. 218). Figure 4.1 shows that this focus on capacity tends to understate the role conventional reefer ships still play. This is due to stark differences in operating models. Whereas an average reefer container makes around five intercontinental trips per year, conventional reefer ships make 7-8 trips per year on average (Van Marle, 2011), with intra-regional services making considerably more (Seatrade, 2019). The difference is due to the higher sailing speed and direct port-to-port services of conventional reefer ships, as well as the direct unloading of conventional reefer ships at the quayside, as opposed to reefer containers being moved into ports' hinterlands, being stored in depots, and requiring cleaning, maintenance, and inspection before every new trip.

At the point in time where Figure 4.1 starts, container lines had been capturing market share from conventional reefer ship operators for decades, and in 2005, the division of seaborne temperature-controlled cargo was approximately 50-50 between containers and dedicated reefer ships. Since then, the reefer container's dominance has increased steadily to a market share of almost 80% in 2016. According to research from UNCTAD (2012), Drewry (Drewry Maritime Research, 2016b) and Dynamar (Dynamar, 2017), the specialized reefer market will stabilize to provide volume on specific trades that still demand conventional services (e.g.

ports with underdeveloped infrastructure, seasonal demand peaks around harvests, transloading fish at sea), while further market growth is likely to come from reefer container services.
Nevertheless, hybrid options have also come to the market in the form of conventional reefer ship operators incorporating reefer containers in their business model (Thanopoulou, 2012). This ranges from older conventional reefer ships being retrofitted with container racks and reefer plugs, to operators ordering newbuild hybrids (with both conventional and container carrying capacity) and fully containerized reefer vessels. An example of this trend is Seatrade, the largest specialized reefer ship operator worldwide with a market share of approximately 30% (Dynamar, 2017). As of 2019, the average reefer vessel operated by Seatrade Reefer Chartering is approximately 23 years old (built in 1996), whereas the average specialized reefer container vessel is only 6 years old (built in 2013) (Seatrade, 2019). Even with fully containerized vessels, conventional operators still operate on a ‘Fast, Direct, Dedicated’ model (a term first introduced by Seatrade): fast-sailing ships sailing directly from origin to destination (no multiple ports of call or transshipment), and specializing exclusively in refrigerated transport (Drewry Maritime Research, 2016b). This relatively recent development may illustrate the future differentiation between traditional container lines and reefer ship operators, where both offer containerized capacity (preferred by most shippers for the smaller parcel size, flexibility, and intermodal compatibility), but shippers can opt for fast, direct, and dedicated services from specialized operators at a premium.

**Products and services**

To consider what the current market for seaborne perishables transport looks like, Figure 4.2 below shows the total volume of seaborne perishable reefer cargoes (container and conventional), broken down by product category, between 2005 and 2015.

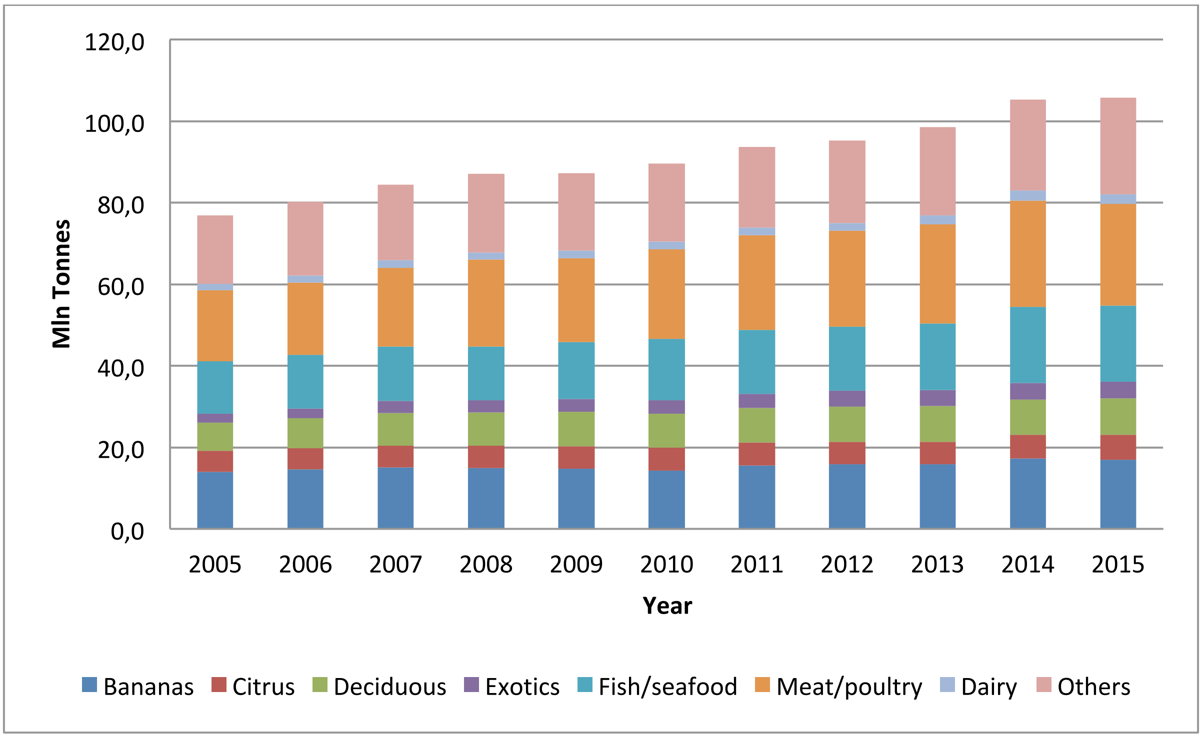



**Figure 4.2. Seaborne perishable reefer cargoes, volumes by product category, 2005-2015.**

Source: Data from Drewry (Drewry Maritime Research, 2016b).

Figure 4.2 serves to give an overview of what the seaborne perishables transport market looks like. Large product categories are bananas, meat and poultry, fish and seafood, and cargoes labeled ‘other’ (including vegetables, potatoes, and a variety of miscellaneous cargo types, as will be discussed later). Smaller product categories are dairy, and various types of fruit: citrus (oranges, lemons etc.), deciduous (grapes, apples, pears etc.), and exotics (pineapples, kiwi, avocados etc.).
Figures 4.1 and 4.2 illustrate the two main trends occurring in the seaborne reefer market. First, the reefer market has grown steadily (Figure 4.2) in nearly all market segments, at an estimated CAGR (Compound Average Growth Rate) in excess of 3% since 2005 (Drewry Maritime Research, 2016b; Dynamar, 2017). Second, the growth has predominantly been in the reefer container sector, relative to a conventional reefer ship sector that has gradually been losing market share (Figure 4.1).
While 80% of this market is transported in containers and 20% in conventional reefer ships, the containerization rate differs considerably across product categories. Figure 4.3 below shows the split of the main seaborne reefer cargoes between specialized reefer vessels and container carriers:

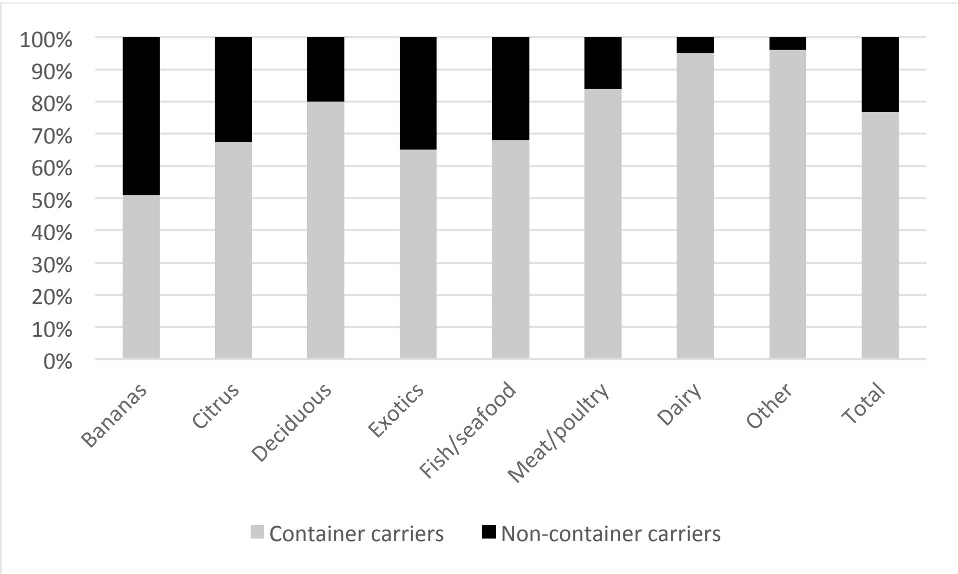



**Figure 4.3. Modal split of main seaborne reefer cargo categories (year 2015).**

Source: Data from Drewry (Drewry Maritime Research, 2016b).

Conventional reefer ships seem to have retained a considerable position in some of the larger product categories such as bananas, fish/seafood, citrus, and exotic fruits. In other segments, in particular dairy and ‘other’, containerization is the norm. Based on other information available from Drewry (Drewry Maritime Research, 2016b), the composition of the containerized reefer market can be described, as shown in Figure 4.4 below.

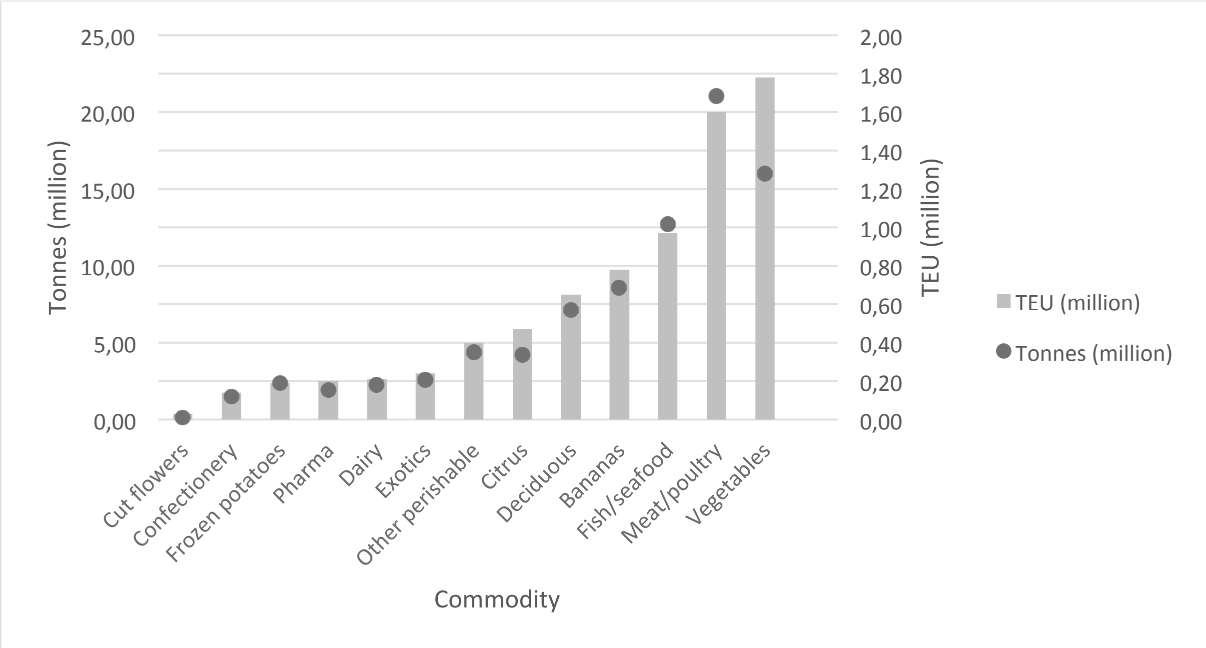



**Figure 4.4. Reefer container volumes by commodity (year 2015).**

Source: Data from Drewry (Drewry Maritime Research, 2016b).

In this data, shown for one year (2015), the category ‘other’ is broken down into its main separate sub-categories. The most important of these is vegetables, followed by several smaller categories such as pharmaceutical products, potatoes, confectionery, and cut flowers. It should be noted that there is still another category labeled ‘other perishable’, which is still quite sizable at approximately 400,000 TEU per year.

Another important aspect of the development of the reefer container market is that not only the *volume* of goods carried in reefer containers per year is growing, but also the *variety* of goods. In a generally mature container market, further growth is likely to come from the development of new niche markets (Guerrero & Rodrigue, 2014), such as reefer shipping. However, also within the reefer shipping market further differentiation of the cargo market and service offer can be distinguished. In essence, every type of product can be transported in a reefer container at the temperature desired by the shipper, which can fall into one of two categories: frozen (generally kept at a setpoint temperature below -10°C) or chilled (kept at a setpoint temperature above -5°C). Frozen cargo makes up approximately 20% of all reefer cargo, with around 80% of fish and 45% of meat being transported frozen as well as most processed potatoes, and smaller shares of fruit and vegetables (Dynamar, 2017). For a wide range of chilled and frozen products, ordinary reefer containers can be used, but increasingly more specialized reefer container technology is introduced for particularly demanding niche markets. Table 4.1 lists (non-exhaustive) examples of these technologies, their application, and examples of service providers offering it, based on information gathered from industry journals such as Lloyd’s List, Port Technology, and Journal of Commerce.

**Table 4.1. Examples of innovation and differentiation in the reefer container market. Information sources indicated in right column. Note: List of innovation does not include improvements to 'standard' integrated reefer container equipment, such as improved insulation, energy efficiency, or reefer unit functioning.**

| Technology description | Application | Examples of services and operators (non-exhaustive) |
|---|---|---|
| Reefers with water tanks inside, include filtration and oxygen regulation | Transport of live lobsters and other live seafood | CMA CGM AquaViva (Barnard, 2016); Maersk/Aqualife collaboration (now defunct) (American Journal of Transport, 2010) |
| Controlled atmosphere: Regulates not only temperature, but also oxygen and CO2, to extend product shelf life | Transport of sensitive foodstuffs (especially with high respiration rates), flowers | Hapag Lloyd ExtraFresh Plus (Doe, 2017); Carrier Transicold Xtendfresh (Sowinski, 2015b); MCI CA (Wold Cargo News Editorial, 2018) |
| Advanced air cleaning technology, including application of UV light and ozone | Removing ethylene, microbes | MCI/Primaira Bluezone (Journal of Commerce Staff, 2014) |
| Liquid cargo solutions: Instead of loading individual pallets with bottles or bulk containers, liquids can be pumped into a flexible 'bag' inside the reefer container | Transport of juices, milk, syrups, concentrates, wine etc. | CMA CGM REEFLEX (American Journal of Transport, 2018) |
| Reefers that can cool down to extremely low temperatures (-60°C instead of the usual -35°C), some with the option of 'blast' freezing (quicker cooling process). | Transport of high-value perishables that require extremely low temperature, such as certain types of fish and seafood (raw tuna, swordfish sea urchins), vaccines, and biologics | HMM Ultra-Freeze (Doe, 2018); Klinge Corp. Deep Freezer Container; Maersk and CMA CGM Super Freezer (Healey, 2018) |
| Reefer containers with two reefer units, offering a back-up in case the primary unit malfunctions. Variants come with integrated diesel-generators to provide independent power supply | Transport of dangerous goods, and high-value, sensitive shipments | Klinge Corp. Dual Redundant Refrigeration Unit (Refrigerated Transporter, 2015) |
| 'Smart' reefers: Reefers with real-time monitoring and control capabilities. | Can be installed on all reefer containers, allows for:<br>Real time monitoring of cargo<br>Real time monitoring of reefer unit's functioning<br>Asset management for container fleets<br>Predictive maintenance<br>Temperature changes during voyage (e.g. on-board ripening, Cold Treatment to meet phytosanitary requirements) | Currently being rolled out among most major carriers' reefer fleets. Examples include Maersk Remote Container Monitoring (RCM) (Sowinski, 2015a), Tranxens, Loginno (Johnson, 2019) |

Source: See references in third column.

The variety of products transported in reefer containers does not only grow through the introduction of these dedicated containers, but also through product categories being transported in conditioned containers that previously were not. Anecdotal examples include electronics, sneakers (with temperature-sensitive glue), paint, and flowers (still predominantly carried by airfreight).

This last category hints at another driver of growth in the reefer container market. Summarizing, the growing global demand for imported perishables due to rising incomes, as well as a shift of cargo from conventional reefer ships to containers were discussed. A third driver of market growth is a modal shift from air transport to (containerized) maritime transport. A distinct advantage of airfreight over seafreight is the shorter transit time, making it an attractive option for urgent shipments and high-value, temperature-sensitive goods with a very limited shelf life and limited options for extending this. Examples include cut flowers, asparagus, strawberries, raspberries, cherries, some tropical fruits, and certain types of pharmaceutical products. Advances in technologies for product preservation and temperature and climate control of reefer containers (including the Controlled Atmosphere containers shown in Table 4.1) open up the possibility of maritime transportation for goods that could previously only be flown.

## 4.3 Description of reefer supply chains

This section describes a generalized overview of the reefer container transport system. Subsequently, in the next section, we can make a systematic assessment of the present state of knowledge of this system.

**The reefer chain**

To achieve an integrated perspective on the reefer chain, we should consider it as part of the ‘cold chain’ or rather ‘cold chains’- i.e. “the equipment, processes and information management used to protect chilled and frozen [cargo, in which] the transport phases (i.e. loading, unloading, handling, and storage) play a fundamental role” (Montanari, 2008). Temperature integrity is an important requirement in the cold chain. Every type of cargo has a temperature range at which it should be kept to maintain product quality (Likar & Jevšnik, 2006; Matthias, Robertson, Garrison, Newland, & Nelson, 2007) (see Hamburg Süd (2010) for a complete overview of temperature requirements per product category). Over the entire course of the supply chain, from production to the consumer, this temperature should be maintained as close as possible to – or at least within a desired bandwidth around – the setpoint temperature. Not all cold chains involve reefer containers; only those that involve goods being produced in one location and transported to another location at a large enough distance and/or at a large enough scale to warrant containerized transport. Moreover, for most goods only part of the cold chain is containerized. In case of containerized transport, the cargo needs to be preserved at the required temperature, so that the reefer container only has to maintain the product temperature, rather than cool it down. ‘Hot stuffing’ (loading goods into a container while their temperature is far above the desired range) may lead to product quality deterioration, as reefer containers typically cannot cool down cargo quickly (Defraeye et al., 2016; Defraeye, Verboven, Opara, Nicolai, & Cronjé, 2015).
In a typical containerized cold chain, this looks as visualized in Figure 4.5 below.

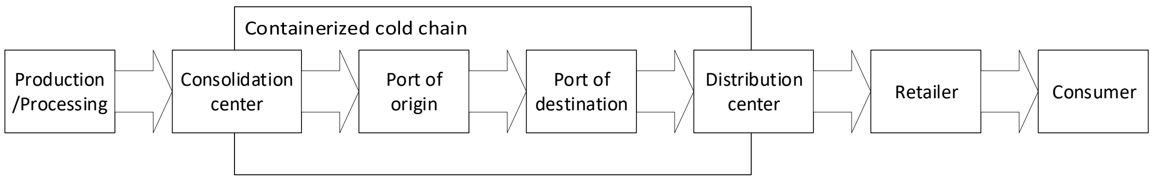



**Figure 4.5. Stylized overview of cold chain.**

Source: Based on the authors’ own research, see section 4.3.

First, the cargo is produced (or grown and harvested) somewhere and sometimes processed. From there it is consolidated into a reefer container and transported to a nearby seaport, to be

shipped to its destination region on a container vessel. At the port of destination, it is unloaded and transported to a distribution center. Here the cargo is unpacked from the container, and distributed further in smaller parcels to retailers. In the case of food, most product losses due to cold chain breaches occur at the location of production and at the retail and consumption stages of the chain (FAO, 2011), but during the containerized part of the cold chain, temperature integrity is just as important. Although the reefer container is designed to maintain a constant temperature at the required setpoint, this depends on the right conditions of packaging, a secure energy supply, and adequate handling of the container at various transfer points.
Zooming in on the containerized part of the cold chain and the various stakeholders involved produces a stylized picture like the one in Figure 4.6 below.

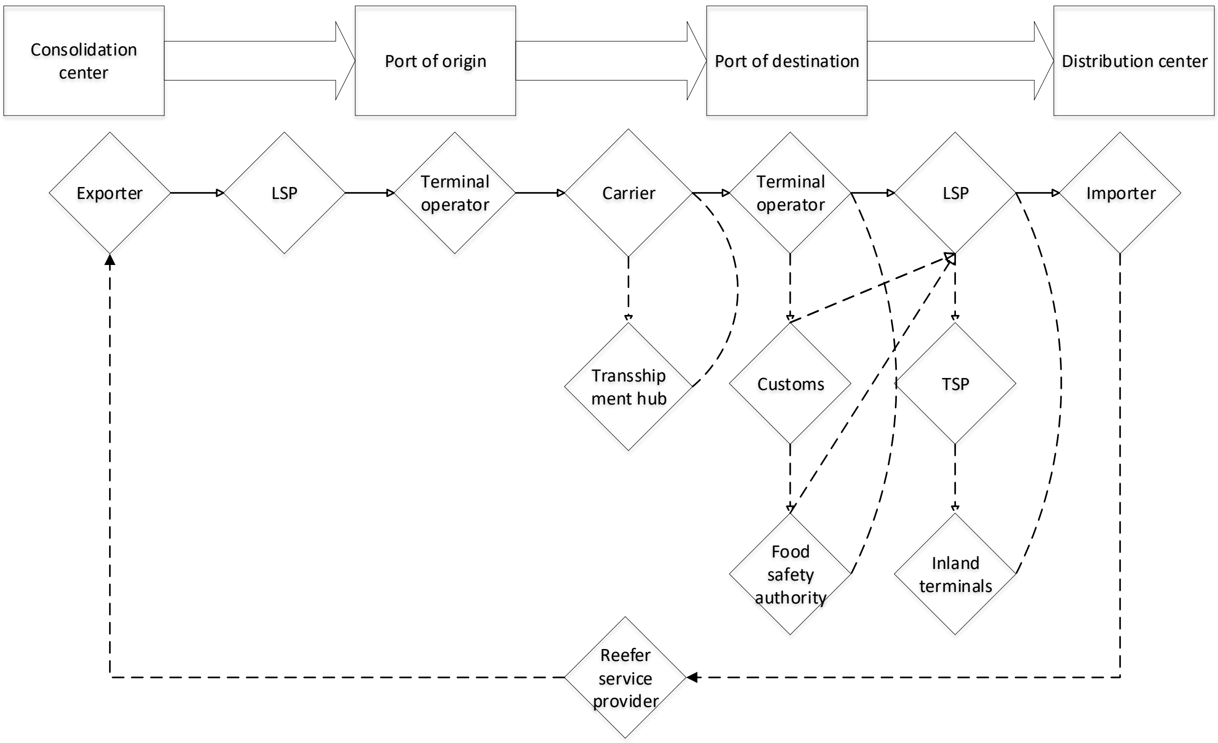



**Figure 4.6. Stylized overview of the reefer container chain and its logistics actors.**

Based on the authors' own research, see section 4.3.

It should first and foremost be noted that this is still just a simplification of the reefer chain. In this case, we assume that the flow of goods is long-distance and warrants maritime transport. Moreover, this figure only reflects the flow of containerized *goods* in the chain, leaving aside – for this moment – the parties that are involved in financial, legal, informational, and administrative transactions that make these container movements possible.
In this stylized example, the exporting party usually contracts a logistics provider to transport the container from the consolidation center to the port of loading. Through a container terminal, the container is loaded onto a vessel, shipped, and unloaded again at the port of destination. The shipping companies carrying the containers over sea are usually the party that owns the container itself (or leases it on a long-term contract) and rents out the containers (as well as their carrier services) to shippers or their logistics service providers. The shipper (i.e. the party ordering the goods in the container to be shipped) usually contracts a third party logistics service provider (abbreviated to LSP) arrange transportation from the terminal gate

(upon release) – either by train over rail, by barge over inland waterways, or by truck over road (or a combination of these modalities, operated by a transportation service provider (or TSP)) – to the distribution center where the container is unpacked and the cargo is further distributed and/or processed. Specific for the reefer chain is that reefers are more complex and maintenance-intensive than standard containers, and that they require a so-called 'pre-trip inspection' (PTI), maintenance, and cleaning of the reefer to make sure that the equipment is working properly before being loaded again for its next voyage. Dedicated firms provide these services, either at their own premises or at container depots.

As mentioned before, it is useful to extend our scope beyond the parties that physically handle the container, and look not only at the physical container movements that constitute the reefer chain, but also the administrative transactions and governing entities. Van Oosterhout (2008) distinguishes three layers of stakeholders involved: primarily the logistics layer (where physical goods are moved), secondly the transaction layer (the 'contracting or transaction activities that encompass all commercial relations between parties in the supply chain'), and thirdly the governance layer (predominantly 'inspection and verification activities'). The figures above summarize a stylized cold logistics chain and identify the relevant actors, but three important governance-related actors are not included yet. First, port authorities are involved in maritime reefer transport. A port authority manages a port's infrastructure and acts as port regulator. Port-based companies, such as terminals and possibly shippers and logistics service providers, depend on port authorities for the quality of their shared infrastructure, cluster management, and have to comply with port regulations. Container lines pay port dues set by the port authority, procure services such as tugs and pilotage (sometimes offered by the port authority, sometimes by independent companies) and also have to comply with regulations. Customs organizations are responsible for controlling transnational transport flows, and hence cold chain stakeholders have to comply with customs regulations when importing or exporting their cargo. Moreover, upon arrival in a port, import containers can be selected for scans or checks by customs. In developed importing markets, reefers tend to be selected disproportionately frequently for customs checks, as many types of fruit tend to come from regions known for drug production. A third relevant type of governing organization is food safety authorities, generally in the country of origin as well as the country of destination. Several food safety regulations apply to the cargoes typically transported in reefer containers, enforced by these authorities. Plants or plant-based products – depending on the type of product and/or the countries involved – often require a phytosanitary certificate from the country of origin (in which the exporting country's food safety authority attests to the product not being affected by pests or diseases), and/or a phytosanitary inspection or treatment upon arrival in the country of destination. Analogously, animals or products of animal origin may require veterinary certificates and/or inspections.

This is still an abstraction and simplification of a real-life reefer chain. Here in particular, we assume that the cargo is containerized from shipper to importer (or consignee) or – equivalently – that the shipper is the party that consolidates the container cargo and the consignee is the party that distributes the container cargo. Also importantly, it should be emphasized that there may be multiple logistics service providers involved in the transportation between origin and port and port and destination, in various contractual arrangements (different parties contracted by shipper, or subcontracted by a principal logistics service provider). Moreover, the financial group of actors (Wagenaar, 1992), namely banks and insurance companies, is left out to keep a focus on the containerized logistics part of the supply chain.

**Causes of breaks in the cold chain**

As discussed above, product quality of reefer cargoes depends on the extent to which a constant setpoint temperature can be maintained during their time in transit. As long as a reefer container is undamaged, the unit is working properly, the container is connected to a power source, and the reefer unit settings are appropriate for the cargo inside, product quality should be able to be maintained as long as possible. Prolonged deviation from the required temperature (and possibly Controlled Atmosphere requirements) can cause product quality to deteriorate and ultimately lead to a total loss of the cargo.

Causes of insurance claims can help shed light on reasons why breaks in the cold chain would occur. Research by the North of England P&I Association (a major marine insurance company) highlights two main reasons for cold chain breaks and claims (2013):

- Reefer unit (and/or Controlled Atmosphere) malfunction: If detected and repaired in time, this does not necessarily entail cargo loss, but monitoring on ships and terminals may be infrequent, and repairs may not be possible due to lack of expertise or spare parts.
- Human error, including excessive time off-power: This may occur due to the container not being plugged in after being moved or transferred from one party to another, or the transfer taking too long.

Two other (relatively) minor causes include hot stuffing (loading the container with cargo at a temperature far above its required preservation temperature, which the reefer container itself is not able to cool down quickly), and exceeding of the product storage life in transit. The UK P&I Club has added to this a more extensive list of claim causes (UK P&I Club, 2017):

- Incorrect settings on container (human error)
- Inappropriate mix of cargo in the container
- Poor cargo quality at loading (old, or otherwise faulty products)
- Late harvest
- Poor packaging
- Cold treatment failure
- Delays

Recommendations to cargo owners include collecting all relevant documentation, ensuring the container's pre-trip inspection (PTI) with report, and installing data loggers on the cargo to monitor temperature and – when necessary – identify moments of deviation.

## 4.4 Literature review on reefer containers and reefer transport

**Literature review research strategy**

When evaluating the current state of the academic literature on reefer container transportation, the authors follow as much as possible a systematic literature review approach to ensure transparency and replicability (specifically the commonly accepted Preferred Reporting Items for Systematic Reviews and Meta-Analyses (or PRISMA) approach – see Moher et al. (2009). PRISMA entails a systematic set of steps to find, screen and include studies for the body of research to be examined. This is visualized in the flowchart in Figure 4.7 below.

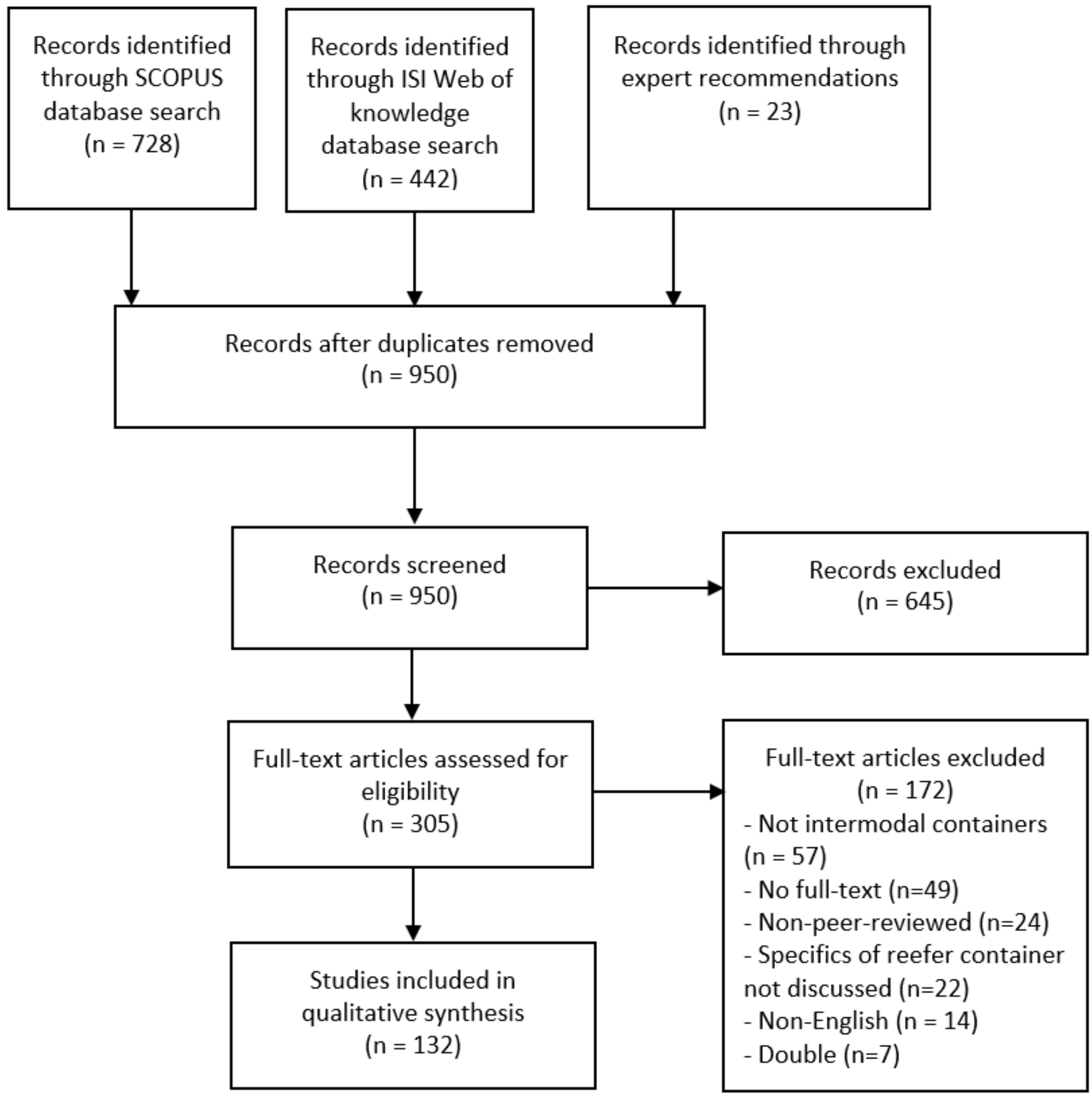



**Figure 4.7. PRISMA flow diagram of research strategy.**

Source: Flowchart adapted from Moher et al. (Moher et al., 2009), conducted through the Covidence systematic review software ("Covidence systematic review software," 2019).

The search for relevant publications was conducted as follows. First the major academic databases Scopus (Elsevier) and Web of Science (Clarivate Analytics, formerly Thomson Reuters) were searched, using the following search terms:

*reefer* OR refrigerat* AND container* AND ( transport* OR port* OR maritime OR intermodal OR ship* OR terminal* OR cargo )*

To obtain all published research related to reefer container transportation, the authors included the main terms 'reefer*' (capturing 'reefer' as well as 'reefers' by using the asterisk), 'refrigerat*' (capturing 'refrigeration', 'refrigerated', and 'refrigerator'), and 'container*' (capturing 'container' as well as 'containers') and included the additional terms in brackets to narrow the selection down to intermodal transport containers. Secondly, the authors consulted

experts (i.e. researchers with a considerable publication and citation record on this theme) for further recommendations. This search was conducted in September 2019, and the web-based tool Covidence ("Covidence systematic review software," 2019) was used to keep track of the steps of the systematic review process and all inclusions/exclusions.
After removing duplicates from the search results, 950 studies were screened for relevance (i.e. evaluated based on title, abstract, and source). The criteria for exclusion in this stage were as follows:

- Research not related to intermodal reefer containers (e.g. cooling technology in other applications, types of containers other than intermodal, refrigeration of products in other settings, dry intermodal containers)
- Non-peer-reviewed research (mostly industry publications such as Naval Architect, Journal of Commerce, Containerisation International etc.)
- Non-English publications (as publications in French, Portuguese, Korean, or Chinese without a translation could not be read by the authors)

After removing studies meeting these exclusion criteria, of the remaining 305 studies the full-text was read, and 173 studies were excluded, based on the following criteria:

- On closer inspection, the study did not address intermodal reefer containers at all (57 removed), or only superficially (e.g. network models treating a reefer container as a separate class of container, but not considering specific characteristics of the containers, their handling requirements, and cargoes) (22 removed)
- No full text was available for screening, neither from the publisher, research institution, or researcher's personal web pages such as ResearchGate.com and Academia.edu (49 removed)
- On closer inspection, the study was not from a peer-reviewed source (24 removed) or not available in English, despite an English title and abstract (n = 13)
- Double studies not filtered out of the search results by Covidence (n = 7)

Having completed this process yields a selection of 132 studies to be examined.

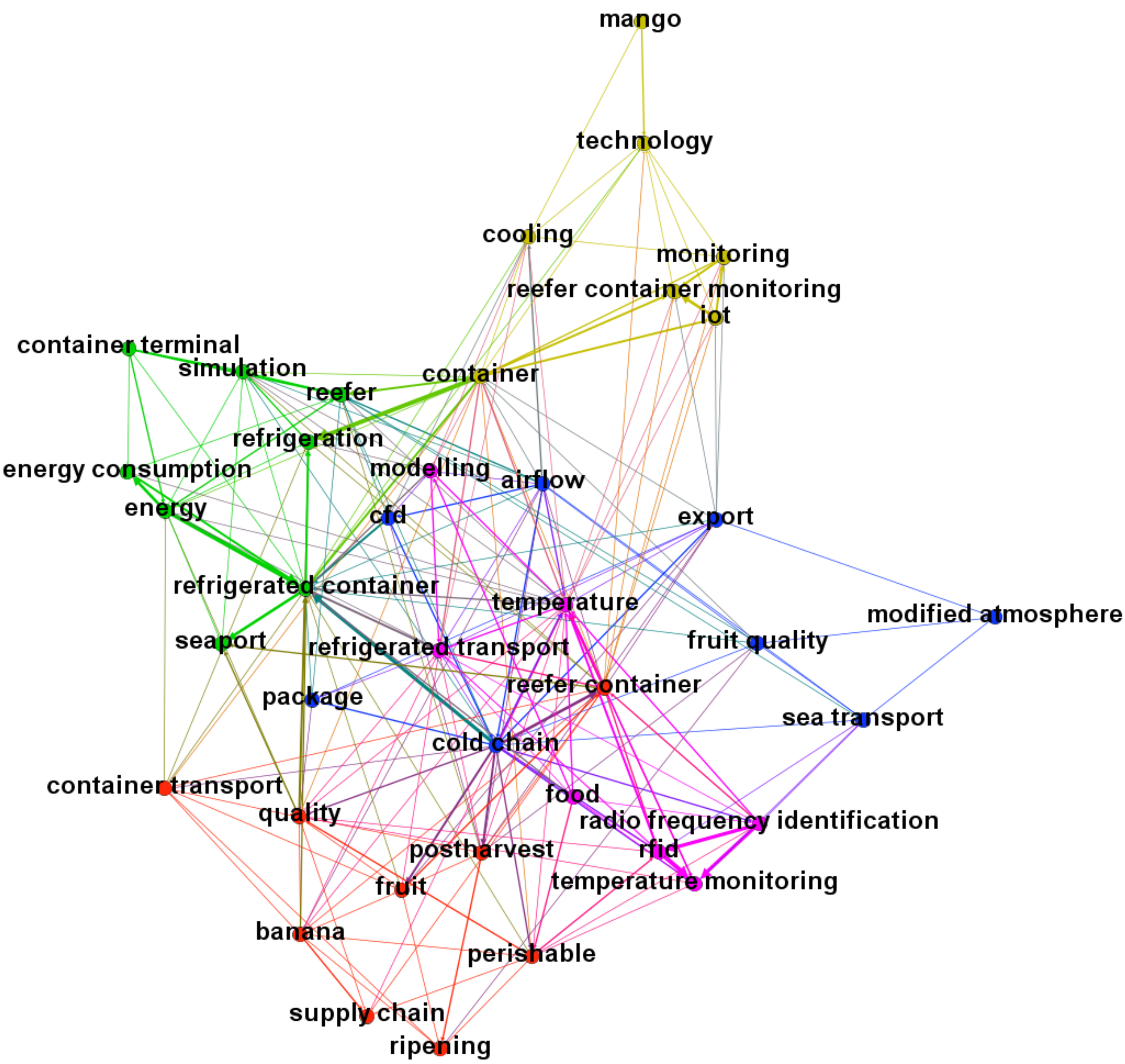
**Bibliometric inventory of key concepts.**
The authors first use a bibliometric approach to obtain an overview of the current literature on reefer container logistics, see which topics receive the most attention, and how bodies of research on these various facets of reefer transportation are linked to each other. For this step, the program VOSviewer[2] is used to visualize as a network the keywords that are used the most in quantitative terms, and in relation to each other. To obtain the most meaningful overview of connections between keywords, authors' keywords of equal meaning but different wording are harmonized. Examples include (phrasing used indicated in bold):

- Air flow vs **airflow**
- Bananas vs **banana** (and other plural/singular: **container** vs containers)
- **Cold chain** vs cold-chain
- Model vs **modelling** (ties in with other terms (modeling and control etc.))

[2] VOSviewer is a tool to visualize bibliometric networks (see http://www.vosviewer.com/) that constructs these networks based on co-authorship, co-occurrence of keywords, and citations between papers. See Van Eck and Waltman (2010) for more information.

- Orange fruit vs **orange**
- **Perishable** vs perishable products, perishable food products
- **RFID** vs Radio Frequency identification
- **Sea transport** vs sea shipment or sea transportation

Moreover, if studies have a focus on product quality, but only include keywords such as ‘quality control’ or ‘product quality’ or ‘quality monitoring’, the authors took the liberty to include the additional keyword ‘quality’ to link studies with analogous keywords. In VOSviewer, the authors limit the keywords visualized to those that are included by at least 5 publications in the search results, yielding a total of 39 frequently used keywords. The network structure of these core concepts is visualized in Figure 4.8 below.




**4.8. The main keywords used in the reefer container literature.**

Source: Publication data collected as described in section 4.4, keywords harmonized as described in section 4.4, network visualized using VOSviewer (Van Eck & Waltman, 2010) and Gephi (Gephi.org, 2017) software.

The VOSviewer program identifies 'clusters' of keywords that are used together particularly often. These clusters represent the major sub-themes within the research on the overarching theme of reefer container transportation. In the case of the literature on this theme, five research clusters can be identified (as color-coded in Figure 4.8). The more central concepts appear in the middle of the network and show – accordingly – the most connections to other concepts. Although these central concepts are assigned to only one cluster, the degree of connectedness to other clusters shows where clusters overlap.

**Cluster 1 (marked in yellow):** The focus of this cluster is on monitoring and control technologies, with specific attention for the possibility of connecting containers to the internet as part of the 'internet of things' (IoT). In a particularly prolific part of the literature, this is called the 'intelligent' or 'smart' container: connected containers, with advanced (remote) monitoring and control capabilities (e.g. Gehrke *et al.*, 2006; Jedermann, Moehrke and Lang, 2010; Dittmer *et al.*, 2012; Jedermann *et al.*, 2014). An interesting application of this capability would be to make adjustments to logistics processes based on improved knowledge of reefer containers' internal conditions and product quality (e.g. Lutjen, Dittmer and Veigt, 2013; Haass *et al.*, 2015; Lin, Negenborn and Lodewijks, 2016; Mees, Lin and Negenborn, 2018).

**Cluster 2 (marked in blue):** Research within this cluster focuses on understanding the internal conditions of the container in terms of temperature, airflow, and atmosphere composition. Other aspects that are touched upon are product packaging and product quality.
Another major keyword in this cluster, 'CFD', refers to computational fluid dynamics, the predominant method of modeling internal conditions of reefer containers (e.g. Smale, Moureh and Cortella, 2006; Rodríguez-Bermejo *et al.*, 2007; Jedermann *et al.*, 2013; Badia-Melis, Mc Carthy and Uysal, 2016; Getahun *et al.*, 2017). With CFD methods appearing in 18 papers, this constitutes a major share of reefer container research, and as such, several papers reviewing research on this approach have been published as well (James, James, & Evans, 2006; Smale et al., 2006; Xia & Sun, 2002).

Findings from this stream of research have an important practical application in addressing temperature differences within reefer containers. Even in a well-insulated container with a properly functioning cooling unit, temperature distribution is not necessarily uniform, leading to temperature deviations in so-called 'cold' and 'hot spots' which – if persistent – result in product quality differences within the same shipment (Issa & Lang, 2016; Jedermann et al., 2013; Jedermann & Lang, 2017; Jedermann, Praeger, Geyer, & Lang, 2014). Different ways of loading pallets with cargo into reefer containers can affect airflow and temperature distribution so as to reduce the risk of cold and hot spots (Luchsinger, Escalona, Montenegro, & Lizana, 2018), as well as changes to the way the reefer unit manages cooling and airflow (Defraeye et al., 2016).

**Cluster 3 (marked in purple):** Overlaps to some extent with the blue and red clusters, but with specific attention for temperature monitoring, and the main technology to do this, namely radio frequency identification or RFID. Where in the second cluster discussed above the focus is on predicting and explaining the internal conditions of reefer containers, this stream of research focuses on accurate monitoring. With 14 papers discussing the application of RFID technology in reefer containers, this constitutes another important sub-stream of research (e.g. Amador, Emond and Nunes, 2009; Ji and Han, 2012; Bollen *et al.*, 2015; Jiménez-Ariza *et al.*, 2015), surveyed by two review of research the use of sensor networks to monitor fruit during transport. (Costa et al., 2013; Ruiz-Garcia, Barreiro, Rodriguez-Bermejo, & Robla, 2007). Important questions include the type of sensors to use and their placing within the container to ensure the most accurate temperature reading (Laniel & Emond, 2010; Laniel, Emond, & Altunbas, 2009, 2011). The link with the second cluster of research (marked in blue) is made by studies incorporating sensor measurement data in the modeling of temperature behavior inside a container (e.g. Amador, Emond and Nunes, 2009; Jiménez-Ariza *et al.*, 2015; Badia-Melis, Mc Carthy and Uysal, 2016).

**Cluster 4 (marked in red):** This cluster also shows a close association with the two clusters discussed above. The most important nuance lies in the fact that research within this cluster tends to focus most on the cargo itself – particularly fruit – and its behavior during temperature-controlled transport. Most studies focus on one type of product specifically, and test how well its quality is preserved under different temperature, atmosphere, and stowage conditions:

- Bananas (Arduino et al., 2015; Jedermann et al., 2013; Jedermann & Lang, 2017; Lin, Negenborn, Duinkerken, & Lodewijks, 2017; Snowdon, 2010)
- Grapes (De Lima, 2015)
- Pineapple (Abdullah, Rohaya, Rosli, & Selamat, 2000; Amador et al., 2009; Chan, 2011; Nor Hanis Aifaa et al., 2011)
- Cut flowers (Shelton, Walter, Brandl, & Mendez, 1996; Woltering, Paillart, Drosou, & Brouwer, 2018)
- Mangos (De Mello Vasconcelos, De Campos Ferreira, De Castro Silva, Teruel Mederos, & De Freitas, 2019; Kienzle et al., 2012; Schouten et al., 2018; Setyawan, Mulyawanti, Setyabudi, & Rachmat, 2013; Van Der Waal & Zongo, 2011)
- Tomatoes (López, Contreras, & Fernandez-Alba, 2003)
- Plums (Punt & Huysamer, 2005)
- Persimmon (Fahmy & Nakano, 2013)
- Papaya (Rohani & Zaipun, 2007)
- Apples (Getahun, Ambaw, Delele, Meyer, & Opara, 2017b; Getahun et al., 2017a)
- Citrus (Defraeye, Cronjé, Verboven, Opara, & Nicolai, 2015; Defraeye, Verboven, et al., 2015; Gazit & Kaspi, 2017; Tauriello et al., 2015; Wu et al., 2018)
- Kiwi (Bollen et al., 2015; Harvey, Harris, & Marousky, 1983)

Other studies focus on multiple types of fruit from one export market (Goedhals-Gerber, Haasbroek, Freiboth, & van Dyk, 2015; Morris, Jobling, Tanner, & Forbes-Smith, 2003) or of the same category (Goedhals-Gerber, Stander, & Van Dyk, 2017; Piala & David, 2016). Some studies also show overlap with the two clusters discussed above, for example reporting on specific experiments with temperature monitoring of shipments of a certain type of cargo.
The most important type of research question in this sub-field is how the quality of a certain type of conditioned cargo can be preserved best during transit in a reefer container. None of these product-specific studies deal with frozen cargoes, which is to be expected due to the fact that fresh cargo is more sensitive, and places higher requirements on transport conditions because of the additional concerns that arise specifically for fresh foods (respiration, transpiration, and ripening).

**Cluster 5 (marked in green):** This last cluster shows a predominant focus on refrigeration technology, and the associated energy use of reefer containers in transit and in ports. Some studies focus on the energy use of the reefer unit itself, including experimental (Fitzgerald et al., 2011) and simulation studies (Budiyanto, Nasruddin, & Zhafari, 2019). Several strategies have been proposed to optimize reefer unit functioning (Filina-dawidowicz & Filin, 2019;

Lukasse, Baerentz, & Kramer-Cuppen, 2011; Sørensen, Skovrup, Jessen, & Stoustrup, 2015; Van Der Sman & Verdijck, 2003) or reefer container design (Copertaro, Principi, & Fioretti, 2016) for energy saving.

The last few years, more attention has been given to the growing relevance of reefer containers for ports' and terminals' energy management. As the reefer market grows and container ships are constructed at increasingly large scale sizes, ports and terminals have to deal with pronounced arrival peaks of reefers. This creates logistical bottlenecks (for example at terminal gates where shippers want to pick up their time-sensitive cargoes as fast as possible) as well as energy demand peaks, that can be expensive for terminals and even result in situations where terminals' power supplies are too limited to power all reefers in the yard at the same time. Recent research has investigated the causes of energy demand peaks and indeed pinpoints arrival patterns as a major driver (Van Duin et al., 2019), as well as suggested ways to reduce these energy peaks (Van Duin et al., 2018). More generally, due to the larger numbers of reefers being connected at terminals at the same time, now up to 40% of energy consumption of European container terminals is consumed by reefers (Van Duin & Geerlings, 2011), with numbers for major exporting regions in Latin America expectedly being even higher. Recognizing the impact of reefers on power consumption, researches have suggested ways to limit the effect of solar radiation on stacked reefers' energy needs (Budiyanto & Shinoda, 2018; Budiyanto, Shinoda, Sunaryo, Nugroho, & Wibowo, 2018; Budiyanto, Sunaryo, Fernanda, & Shinoda, 2019), and proposed new ways of designing and implementing power systems to accommodate growing numbers of reefers (Parise et al., 2018, 2019).

**Major focus areas and miscellaneous research topics**

It should be noted that (due to the threshold of 5 occurrences for the keywords to be included) these given areas discussed above are the *major* focus areas, rather than *all* topics covered. Nevertheless, it should serve as a high-level illustration of the main focus areas in academic research on reefer containers, as well as their linkages.

The majority of research is very focused: Most studies focus on one specific phase of the supply chain (postharvest and container loading operations; container terminal handling; liner shipping with specific attention for reefers; hinterland transport and repositioning), on one specific type of cargo or trade (e.g. banana's, blueberries, or the New Zealand kiwi export), or on one aspect of the technology of the reefer container (e.g. monitoring and control, cooling technology, temperature and airflow behavior, energy consumption, or the issue of making the reefer 'intelligent' using a combination of new technologies such as big data and the internet of things).

Some miscellaneous topics that have not been included in the bibliometric network above include:

- Reefer servicing (Filina-dawidowicz & Gajewska, 2018; Filina-Dawidowicz, Iwańkowicz, & Rosochacki, 2015; Filina-dawidowicz & Ph, 2014; Hartmann, 2013)
- Governance issues including cargo claims (Snowdon, 2014), data governance (Jung & Kim, 2015) and sustainability transitions (Castelein, Van Duin, et al., 2019)
- Comparisons of reefer containers and conventional reefer ships (Arduino et al., 2015; Čudina & Bezić, 2019; Thanopoulou, 2012; X. Zhang & Lam, 2018)
- Logistics issues including port processes (Goedhals-Gerber et al., 2015), fleet planning and management (Cheaitou & Cariou, 2012; Imai & Rivera, 2001; Kai Wang, Liu, Wang, & Liu, 2017) and repositioning (Chao & Chen, 2015; Hjortnaes, Wiegmans, Negenborn, Zuidwijk, & Klijnhout, 2017)

Outside of these miscellaneous research topics, by far the major focus areas have been of a technical (monitoring and control, energy, refrigeration etc.) or biological nature (product behavior and quality), with relatively less attention being paid to logistics, economics, and management-related issues. Only a handful of academic studies highlight the economic managerial aspects of reefer supply chains (Arduino et al., 2015; Castelein, Van Duin, et al., 2019; Galvao & Robles, 2014; Lutjen et al., 2013; Manzini & Accorsi, 2013; Menesatti, Pallottino, Prisco, & Laderchi, 2014; Rodrigue & Notteboom, 2015; Wilmsmeier & Martínez-Zarzoso, 2010). As a result of this scarce attention, our knowledge of supply chain structure, coordination, governance, and stakeholder preferences and decision-making is still limited.

## 4.5 Conclusions: The reefer container market and academic research

The reefer container market has grown considerably, and researchers and sector stakeholders alike have come to realize that this segment of the container market should be seen as a distinct market with its own unique dynamics and demands. To inform further research on this burgeoning market, this study has aimed to provide a comprehensive overview of the development and characteristics of the reefer container market, the structure and prevalent issues of reefer container chains, and the state of academic research on this market so far.

**Findings**

The most important aspect of the reefer market's development over the last decades has been its fast growth, outstripping the growth of the dry container market by far. As shown in Section 2 of this chapter, this growth has occurred due to growing demand for perishables worldwide, and as a result of a shift of cargoes from other modes (conventional reefer ships or airfreight) to reefer containers. Whereas 15 years ago, the maritime reefer market was split approximately evenly between conventional reefer ships and reefer containers, now over 80% of maritime reefer trades are containerized. The conventional reefer market has stagnated in terms of volume, and despite the introduction of fully containerized ships in the FDD (fast, direct, and dedicated services) market, it will likely play only a minor role in the maritime reefer market compared to reefer containers. Not only the volume of reefer container cargoes has grown, but also the diversity of products carried in them. Improved container technology and preservation techniques, as well as the development of dedicated equipment had steadily expanded the range of applications of reefer containers. Typically, the cargoes carried inside reefer containers (predominantly food products, but also high-value niche markets such as pharmaceutical and chemical products) have their own requirements in terms of temperature control, and sometimes controlled atmosphere.

Despite the diversity in reefer cargoes and their specific requirements, a generalized overview of what a typical reefer container supply chain looks like was desirable and outlined in Section 3 of this chapter. The most important characteristic is the reefer container's role in maintaining an uninterrupted 'cold chain,' of the product remaining at or closely around a specified preservation temperature along the entire supply chain. Reefer container supply chains are very similar in structure to conventional intermodal container supply chains, as both involve the consolidation of the cargo inside a standardized intermodal container for the largest part of a transport chain. This unitization facilitates efficient handling, ensures intermodal compatibility, and helps keep costs low. However, with reefer containers, additional sensitivity and complexity are introduced by the technology of the container and the sensitive nature of the cargo. While operating, reefer containers require a constant energy supply and continuous monitoring to ensure that their contents are preserved well. In addition, the containers, and in particular the reefer units, require regular inspections, cleaning, and maintenance to ensure proper functioning. However, risks to cargo can still occur due to a multitude of technical and human errors. To limit product waste and improve reefer chain efficiency, identifying and resolving these issues is paramount.

To evaluate the extent to which the academic research is addressing the most pressing issues encountered in practice, Section 4 of this chapter has provided a systematic review of the academic literature on reefer container transportation. This body of literature on reefer containers so far mostly reflects the technological advances that facilitated the growing containerization of perishable goods, namely research on refrigeration technology, temperature management, monitoring and control, postharvest handling, and product preservation. Not only has this facilitated the growth of the reefer container market, but also made it possible that the rate of product loss during long-range transportation is relatively low compared to other stages in food supply chains (such as agriculture, post-harvest handling, processing, consumption). Data from sector sources indicate that cargo loss in transit not only occurs due to equipment failure, but just as often because of breaks in container power supply (and ultimately breaks in the cold chain) due to human errors. The review shows that particularly the latter is an issue that has not received much attention in the literature so far – compared to the major research areas discussed above. This is not only related to the quality and availability of power supplies, but also a case of coordination between parties in reefer container chains. As discussed in Section 3, risks of cold chain breaks are most prevalent when custodianship of a container transfers from one party to another and the container has to be disconnected, transferred, re-connected, and transported further within a narrow timeframe. Whereas on containerships containers are plugged in for the duration of the voyage without being disconnected or transferred, risks from container transfer and power supply breaks are prevalent in port areas and in hinterland intermodal transport systems. An agenda for future research on reefer container transportation should accordingly include these aspects, in addition to the major areas of research already explored in the literature. The most important focus areas of such an agenda are discussed below, as well as some future prospects for the reefer market.

**Discussion**

The reefer container market itself is still in a phase of strong growth, due to growing demand for perishables worldwide, and shifts of existing trade from other modes, such as conventional reefer ships and airfreight to container shipping. Not only in terms of volume is the market growing, but also a tendency of increasing service differentiation can be distinguished – catering to newly containerized goods, sometimes using dedicated equipment and processes. The development of such niches reflects a maturing market, and the substitution effect from shifts from other modes will likely diminish when the containerization rate of the overall perishables transport market increases. However, sustained growth of consumer demand for perishables and the development of new niches within the reefer container market are both likely to drive future growth.

The existing academic literature on reefer containers reflects a predominantly technological and product-oriented focus. However, this chapter shows that coordination failures and human errors are important causes of hold-up and cold chain breaks, despite being researched relatively little. Future research should take up the challenge to address these organizational issues in reefer container transportation. This includes overall supply chain coordination and prevention of hold-up at container transfer points, but specifically the role of seaports as transportation and logistics clusters where handling operations, container transfers, and hence hold-up risks converge. The position of reefer chains in seaports is still in flux, even though challenges are to be anticipated. Clients favor speed and reliability – criteria met by fast, direct, and dedicated shipping services, and small-scale dedicated terminals – yet increasingly reefer containers end up being handled in congested port areas around container terminals. A major question for carriers, terminals, and other port-related service providers is how to meet customer requirements and deal with the time-sensitivity of reefer cargoes, while still benefiting from the advantages of large-scale container transport. This not only asks for the development of new business models in the logistics sector, but also news ways for port authorities to plan prudently for these changes.

The growing embeddedness of reefer containers in the conventional container system also produces challenges for energy management of ports and terminals. Some academic research has already addressed the challenge of energy demand peaks from reefer racks and the growing number of reefers being connected at the same time (see Cluster 5). As ports face increasingly complex challenges in their energy management, these questions can be extended to the use of renewable energy sources for reefer cargo cooling, and for example the application of smart grids and cold buffers. Similarly, the containerization of reefer cargoes has implications for the coordination between reefer-handling parties in intermodal chains. Earlier research on coordination in container chains has shown the manifold hold-up risks associated with container transfers in intermodal chains. For the reefer container market, the implications of coordination failures are compounded by their impact on cargo loss risk. In this area – as well as others – the lessons from research on container transport in general can be evaluated and adapted to address the specific challenges of the reefer container market. An example would be the stimulation of a modal shift from hinterland trucking to more sustainable modes such as train or barge, that contribute less to traffic congestion as well. For dry containers, this has been hard to effectuate, and due to the sensitivity and perceived time-sensitivity of reefer cargoes, this may be even harder in the reefer market. Therefore, future research should address the development of appropriate intermodal services for reefer containers, including technical solutions for reliable power supply, and temperature and quality monitoring along the chain.

These potential research directions illustrate that supply chain actors and ports not only have to deal with the challenges arising from a modal shift and growth of the reefer market, but also sustainability challenges that extend beyond limiting product loss. Reducing overall energy use, increasing the share of renewables, smarter logistics concepts and modal shift – as well as the governance arrangements along supply chains and in ports that enable these developments – all must be addressed in an evolution to a more sustainable conditioned transport market.

# 5 Identifying dominant stakeholder perspectives on sustainability issues in reefer transportation: A Q-method study in the Port of Rotterdam

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**Abstract**
Driven by global climate concerns, seaports have formulated sustainability goals, which also require sustainability gains in the fast growing temperature-controlled logistics market—increasing energy efficiency, reducing waste, and streamlining logistics processes. This, however, requires cooperation and buy-in from a wide range of stakeholders. To explore the barriers and facilitators of such a transition, we map the interests and attitudes of cold chain actors in the Port of Rotterdam regarding sustainability issues in reefer transportation and cold chains. We identify a limited number of broadly shared perspectives using Q-methodology—a survey-based method to study subjective viewpoints (originating from psychology) that has been used only rarely in the freight transport field. The analysis yields four 'dominant' perspectives that together account for 46% of the variation among stakeholder viewpoints. We label these perspectives "sustainability as part of strategy," "short term constraints," "optimistic about technology, limited role for policy," and "long run willingness under risk avoidance." These perspectives are characterized by multiple factors, including the evaluation of organizational capabilities, expectations from policymakers and technology, and the time horizon stakeholder organizations consider regarding sustainability concerns. From the findings, we derive recommendations for managers and policy makers to facilitate stakeholder dialogue and possibly convergence and coalition building.

## 5.1 Introduction

The reefer container market is growing rapidly, and hence the facilitation of reefer transportation and cold chain logistics is becoming more important for container ports (Arduino et al., 2015). This presents challenges and opportunities, as this market segment with high-value cargoes not only grows rapidly but also places stringent demands on seaports' logistics processes and energy provision to maintain an uninterrupted 'cold' supply chain with continuous temperature control and monitoring (Mercier, Villeneuve, Mondor, & Uysal, 2017). However, in the context of climate change and the Paris agreement of 2015, ports' societal 'license to operate' increasingly depends on their ability to improve their environmental performance (Lam & Notteboom, 2014). These sustainability goals seem at odds with the growing volumes of refrigerated containers (often called reefers), and hence the growing energy footprint of cold chain logistics in ports. As ports wish to operate more sustainably, sustainability gains also have to be made in temperature-controlled logistics, including increasing energy efficiency, reducing emissions and product waste, and streamlining logistics processes. Port authorities have formulated sustainability goals and strategies, but for these to be successful, cooperation and buy-in from actors across the entire chain is required (Acciaro, Vanelslander, et al., 2014). In such a multi-stakeholder environment, divergent perspectives and interests can become a barrier to stakeholder participation (Van Duin, 2012) and hence inhibit the greening of port-related supply chains. Improving the environmental performance of seaports hence requires the management of conflicting stakeholder attitudes and interests (Denktas-Sakar & Karatas-Cetin, 2012).

Temperature-controlled supply chains are an area where these concerns become particularly prevalent, due to the large energy footprint of these chains—it is estimated that some 35% of a container terminal's energy consumption is used for reefer cooling (Van Duin et al., 2018)—and the risks of cargo loss in case of failure of equipment or logistics processes. The objective of this study is to map the interests and attitudes of reefer transport and cold chain actors regarding sustainability issues in reefer transportation and cold chains in the Port of Rotterdam—the largest container port in Europe and the main gateway for a large part of Europe's perishables imports, as well as the main port for the Dutch agrifood sector (the world's second largest in terms of export volume (CBS, 2019)). The study addresses the questions: 1) What individual stakeholders and perspectives on sustainability issues in reefer transportation can be distinguished, and 2) can these perspectives be aggregated into a limited number of 'dominant' perspectives more broadly shared among stakeholders that can help inform policymaking?

We approach these questions using Q methodology, a strategy that mixes quantitative and qualitative research approaches to discern broadly shared viewpoints on an overarching theme among a diverse set of stakeholders, to compare and contrast these viewpoints, and to understand these in qualitative depth (Watts & Stenner, 2012). So far, this method has been most widely used in psychology, health, and environmental studies, with a limited number of studies focusing on transportation, of which—to our best knowledge—only two deal with freight transport. Kim (J. Y. Kim, 2014) developed a typology of port users in terms of port choice decisions, and Van Duin et al. (2017) studied stakeholder perspectives on urban freight consolidation. We also see the relevance of the method when addressing sustainability issues in seaports—a multi-stakeholder setting where the management of conflicting positions is relevant.

The chapter is structured as follows. After the introduction (section 5.1), section 5.2 develops the concourse on the subject matter of the study, namely reefer transportation in the Port of Rotterdam. Section 5.3 describes in detail the Q methodology approach used in the study design, data collection, analysis, and interpretation. Subsequently, section 5.4 presents and discusses the dominant perspectives identified. Last, section 5.5 concludes and discusses the implications of the study for public and private actors, including recommendations for strategy, policy, and further research.

## 5.2 Background: Developing the Concourse

The study is conducted using Q methodology—a survey-based method to elucidate stakeholder perspectives on a topic, and identify the 'dominant' ones: Those most prevalent, and shared across stakeholder groups. Although little used in transportation and logistics research, Q-methodology offers the attractive possibility to discern the most prevalent attitudes and perspectives in a complex context of diverse stakeholders (Van Duin et al., 2017), such as a port or logistics cluster or a transportation chain.
The Q method process starts with defining the concourse on a certain topic, i.e., everything that is thought and said on all relevant aspects of the topic, in this case, sustainability issues in reefer transportation and cold chain logistics in the Port of Rotterdam. The construction of this concourse is based on different types of source material mixing structured and unstructured methods of Q-set generation (Watts & Stenner, 2012). First, we review the academic literature on sustainability in transport and relevant issues in reefer transportation specifically, and secondly, we identify the case specific aspects of the topic by conducting exploratory interviews, focus sessions, and from searching the professional literature.

**Sustainability Issues in Reefer Transportation**
Theoretically, the concourse on sustainable reefer transportation should contain the dimensions of sustainable transportation and logistics, made specific for the context of reefer handling in the Port of Rotterdam. McKinnon et al. (2015) distinguish four general areas in which the environmental performance of transportation can be improved:

- Shift to greener modes;
- Supply chain optimizations;
- Increasing equipment utilization;
- Increasing fuel efficiency.

For the purpose of this study, these factors should be specified further in how they apply to (reefer) container transportation in particular. In long distance transport, the mode of transportation is a reefer container carried on a container ship. These have long eroded the market share of traditional long-haul modes for conditioned cargoes, such as the conventional reefership and air transport, and are now the dominant transport modes (Arduino et al., 2015). In hinterland container transport, a shift to greener modes generally entails a shift from road transport by truck to either barge or rail transport, which have less emissions per container/km and do not contribute to road congestion (Tao, Wu, & Zhu, 2017; Veenstra et al., 2012). A sizable body of academic literature is dedicated to supply chain optimization in container transport, both from the perspective of optimizing firms' own sub-systems and processes (e.g., Carlo et al. 2014) and the optimization of intermodal networks [16]. A particularly interesting aspect in a multi-actor setting with conflicting attitudes and interests is the coordination between supply chain actors. Van der Horst et al. (2008) identified multiple categories of coordination problems that can be addressed to further optimize container supply chains. Another important issue is equipment utilization, which is mainly concerned with the repositioning of empty containers. With reefer containers this is particularly relevant, since perishables-importing regions tend to have proportionally little perishables exports, and

due to the high cost of reefer containers and sensitivity of T-floors and cooling equipment, not all return cargoes are suitable to be transported in a non-operating reefer (NOR). Optimization approaches can be used to reduce the distance empty containers travel before being stuffed again (Hjortnaes et al., 2017). Last, the fuel efficiency of transportation should be considered. This can be achieved through economies of scale, lowering speed, or investing in more fuel-efficient transportation technology.
To McKinnon's four points, Geerlings (Geerlings, 1997) adds two more relevant considerations:

- Reducing the overall amount of transportation, and;
- Reducing transport distances through spatial planning.

Considering that reducing consumer demand for cooled products is not within the scope of this study, reducing the amount of transportation could still be achieved by, for example, reducing the distances travelled by empty containers, or by consolidating shipments together. Spatial planning to reduce transportation needs is also partly within the scope of this study, in so far as land use policies and location decisions can result in a reduction of transport movements and distances. A case-specific example of land use policy in the Port of Rotterdam to facilitate more efficient cold chain logistics is discussed below.
Besides these issues, one should add specific issues introduced by characteristics of cold chain logistics. A cold chain is a logistics chain along which a perishable or otherwise temperature-sensitive product is kept at a constantly controlled temperature to maintain product quality (Mercier et al., 2017; Montanari, 2008). Increasingly, long-range transportation of conditioned cargoes is done using refrigerated containers or 'reefers' (Arduino et al., 2015). These are intermodal containers (usually 40 ft, though 20 ft and 45 ft reefers exist as well) with an integrated cooling unit that circulates cold air through the container to keep the contents at the desired temperature. In addition, reefer containers have isolated walls and an aluminum floor with T-shaped profiles that facilitate air circulation. For this containerized part of the cold chain (i.e., from the point of stuffing in the region of origin to the point of stripping at the destination), additional environmental impacts (apart from the four aspects mentioned above) can be identified: First, the energy use of the container itself, necessary for cooling. This accounts for approximately 19% of the total energy use in reefer transportation, and depends—among other factors—on the container's contents and stowage, the temperature set point, the ambient environment, container age and quality of insulation, and refrigeration technology used (Fitzgerald et al., 2011). The monitoring and control software on the cooling unit can be used to increase the energy efficiency of cooling (Lukasse et al., 2011). At sea or inland waterways, reefers can be plugged in and powered by ship's engines. At a container terminal, reefers are stored in reefer racks where they are plugged in and connected to the terminal's power supply. If there is no option to plug in a reefer during transit, it can be fitted with a (diesel-powered) clip-on genset. Secondly, there are emissions from handling operations at container terminals (e.g., cranes and stacking equipment) depending on the type of equipment used, the way it is utilized, the energy source, and energy mix (Geerlings & Van Duin, 2011). Next, one should also recognize the environmental impact of product waste in the case of cold chain failure (FAO, 2011). When in transit the temperature deviates too much from the specified set point (often due to failing equipment or being off-power for too long), cargo quality is jeopardized and the products may be lost entirely. Last, reefer containers are increasingly being connected to the Internet of Things (IoT), which makes it possible to monitor in real time the location, temperature, and status of containers (Dittmer et al., 2012; Gehrke et al., 2006). Although still in an early stage, this development may in the future create possibilities for better quality control and decision-

making on the part of carriers, shippers, and transportation service providers (Lutjen et al., 2013).

**The Port of Rotterdam Case**

In addition to these more general issues related to reefer transportation, some aspects of the case context—the Port of Rotterdam in the Netherlands—are worth mentioning. In terms of throughput, including containers, the Port of Rotterdam is the largest port in Europe, and the largest in the world outside of Asia. In 2018, Rotterdam had a container throughput of approximately 14.5 million TEU (twenty foot equivalent unit), of which 10% to 15% were reefer containers (Port of Rotterdam, personal communication, 24th March 2019). For the case of reefer transportation, the Port of Rotterdam is a particularly interesting case, since the Netherlands are the world's second largest exporter of agricultural products (CBS, 2019), an important part of which is re-export, underlining the position of Rotterdam as a perishables hub for Europe.

For hinterland transportation of containers—including reefers—trucking remains the most used modality, despite modal shift targets formulated by the port authority. With a recent port expansion, the awarding of new container terminals was based partly on sustainability criteria, including environmental monitoring systems, air quality, $CO_2$ emissions, and a modal shift commitment to reduce the share of hinterland transport by road, in favor of rail and barge transport (De Langen et al., 2012). Since committing to a modal split target of 35% of containers being transported by road to the hinterland, the share of road transport has reduced from approximately 50% to 45%, but has stagnated in the last years.

Another important development in the Rotterdam case is the CoolPort initiative: A cold logistics cluster newly constructed at the location of a former container terminal (Port of Rotterdam, 2015). In this case, the port authority steered its land use policy towards the clustering of activities related to cold chain logistics, including cold storage, value added services, quality and veterinarian inspection, container depots, and intermodal connectivity. In addition to the earlier literature (Acciaro, Vanelslander, et al., 2014; Denktas-Sakar & Karatas-Cetin, 2012), these examples illustrate the relevance of port policy for making port activities more sustainable and efficient.

Having outlined the relevant dimensions of sustainability in reefer transportation, the following section outlines how this concourse is operationalized in the Q methodology study design.

## 5.3 Methodology

As described in the section above, the first step of a Q method study is to establish the concourse on the subject matter. The construction of this concourse was based on different types of source material mixing structured and unstructured methods of Q-set generation. The first literature-based exercise helped establish the topics within the concourse, geared towards those issues relevant in a multi-actor setting:

- Attitude towards sustainability (general);
- Hinterland transportation modalities and modal shift;
- Supply chain coordination and information sharing;
- Equipment and energy use;
- Reefer containers and technology;
- New technologies (including 'smart' containers);
- Port policy.

Secondly, we drew on professional publications and exploratory interviews and focus sessions with reefer chain actors to gather statements related to the topics within the concourse from which to sample the Q-set. These statements were collected verbatim from these stakeholders or closely paraphrased to ensure that they would come closest to the actual utterances representative of actors' viewpoints, while also ensuring clear and concise formulation of the statements. Moreover, some statements with provocative wording were explicitly included to invite active engagement rather than passive response (as suggested by Watts and Stenner (2012)). Ultimately, we reduced the 100 to 200 statements covering the full concourse to a Q-set of 37 statements that met the criteria of coverage (i.e., the sample of statements is representative of the full concourse in terms of topics and viewpoints covered) and balance (i.e., 'seamless' coverage, not biased towards one particular viewpoint) (Watts & Stenner, 2012), while retaining a manageable number of statements to not make the sorting process too cumbersome. Moreover, we aimed to include those statements that would be meaningful to the broadest range of relevant stakeholders—for example, including statements on cross-chain information sharing rather than terminal yard process optimization, or on the attractiveness of barge transportation rather than specific engine configurations. Table 5.1 shows the Q-set as used. It should be noted that these statements were originally compiled and presented to our respondents in Dutch, and translated to English for the purpose of reporting in this study.

**Table 5.1. Statements in the Q-set.**

| | |
|---|---|
| 1 | For our company/organization, sustainability is important |
| 2 | In the near future, we want to be able to offer CO2-neutral services to our clients |
| 3 | Making reefer chains more sustainable is an impossible task for our company |
| 4 | It is easy for our company/organization to make reefer transportation more sustainable |
| 5 | When facing a choice between cost reduction and sustainability improvements, we opt for cost reduction |
| 6 | Cost reduction and sustainability improvements go hand in hand |
| 7 | We are actively improving the sustainability of our services |
| 8 | Sustainability is an important strategic value of our company/organization |
| 9 | The port authority can play an important facilitating role when it comes to improving sustainability |
| 10 | Most sustainability gains can be made by using renewable energy sources |
| 11 | Energy saving is possible without compromising product quality |
| 12 | We can expect an exponential growth in the use of reefer containers in the future |
| 13 | We address the sustainability of our operations because other companies in our sector do this as well |
| 14 | The port authority is doing everything possible to help us to operate more sustainably |
| 15 | Initiatives such as CoolPort have great added value for our company/organization |
| 16 | The port authority can play a major facilitating role in improving hinterland transportation |
| 17 | We are willing to share parts of our data with other companies to further optimize the reefer chain |
| 18 | We are willing to share parts of our data with other companies involved in the reefer chain to improve the overall sustainability of the chain |
| 19 | In the future, data sharing will play a larger role in improving punctuality, quality, and sustainability |
| 20 | The current business model of the port authority (renting out land and collecting port dues) is no longer suitable for the current economy |
| 21 | We expect the port authority to push for sustainability |
| 22 | We are very dependent on the port authority |
| 23 | We prioritize reefers over dry container |
| 24 | Reefers are an important component of our business model |
| 25 | There are better ways to transport conditioned cargoes than outmoded reefer containers |
| 26 | The development of technology for new (smart) reefers goes too slow |
| 27 | Smart reefers will contribute to our company operating more sustainably |
| 28 | In the future, we only want to work with newer, more sustainably operating reefer containers, instead of poorly isolated, inefficient, old reefers |
| 29 | Hinterland transport of reefer containers by barge is a good option |

| | |
|---|---|
| 30 | Hinterland transport of reefers by rail is a good option |
| 31 | A lot of sustainability gains can be made in hinterland transport |
| 32 | The infrastructure for hinterland transport of reefer containers by rail meets our expectations |
| 33 | The performance of hinterland transport by rail meets our expectations |
| 34 | For us, good hinterland transportation performs well on cost, quality, and reliability criteria |
| 35 | We find the costs of hinterland transportation by rail too high |
| 36 | We find the costs of hinterland transportation by truck too high |
| 37 | We find the costs of hinterland transportation by barge too high |

Next, we selected the sample of respondents—the P-set. This should include all types of stakeholders that can be expected to have a unique and/or original viewpoint on the topic and that operate in a shared context, in this case reefer transportation in or through the Port of Rotterdam. For this study, we aimed at including different stakeholder types (the port authority and the most important types of port actors, including shippers, carriers, terminal operators, logistics service providers (LSPs), transportation service providers (TSPs), etc. (Castelein, Geerlings, et al., 2019b)), as well as different types of organizations within these categories: Small and large organizations, locally and internationally operating, and, for example, deep-sea as well as short-sea carriers, LSPs that include cold store operators as well as traditional forwarders, and shippers with a focus on different types of products, such as fruit, vegetables, or flowers. Within each stakeholder organization, we recruited respondents in expert or decision-making roles to ensure that their responses would reflect as closely as possible the real considerations of their organization. Q-methodology operates on the assumption that on a certain topic, there will only be a limited number of distinct coherent viewpoints that one can have, which tend to be shared by groups of like-minded stakeholders—so-called 'finite diversity' (Barry & Proops, 1999; Matthew, Muellerleile, & Akers, 2015). Therefore, the sampling process is purposive rather than random—focusing on including organizations that can be expected to have differing viewpoints, as explained above—and the sample size does not have to be large: A general rule of thumb is that the number of participants should not exceed the number of statements in the Q-set (Watts & Stenner, 2012). Considering the size of the Q-set (37 statements) and the fact that in practice, other Q-methodology studies in transportation or closely related fields tend to have sample sizes between roughly 20 and 35 participants (Byrne, Byrne, Ryan, & O'Regan, 2017; J. Y. Kim, 2014; Matthew et al., 2015; Van Duin et al., 2017) (notwithstanding examples with as little as 18 (Rajé, 2007) or as many as 75 (Cuppen, Breukers, Hisschemöller, & Bergsma, 2010) respondents), we had 30 respondents complete the survey. Of these, two respondents working in different departments of the same company preferred to complete one survey together on behalf of their employer (an LSP, participant company nr. 25), and one respondent we interviewed (a transportation service provider executive) did not manage to complete the survey during the interview session, hence yielding a total of 28 completed Q-sorts. Table 5.2 shows the organizations and positions of respondents included. For confidentiality, the names of the organizations are omitted, and respondents will be referred to by their number and/or stakeholder organization type.

**Table 5.2. Respondents in the P-set.**

| Participant nr. | Type Stakeholder | Position Respondent |
|---|---|---|
| 1 | Shipper (flowers) | Supply Chain Consultant |
| 2 | Shipper association (fruit and vegetables) | Director |
| 3 | LSP | Management trainee |
| 4 | Shipper (fruit) | Logistics manager |
| 5 | LSP | Manager |
| 6 | LSP | General manager |
| 7 | Terminal (rail) | Manager |
| 8 | Carrier (deepsea) | Manager reefer depot |
| 9 | LSP | Logistics manager |
| 10 | Terminal (deepsea) | Consultant Business Development |
| 11 | Carrier (deepsea) | Managing director |
| 12 | Carrier (deepsea) | Director operations |
| 13 | Terminal (deepsea) | Manager |
| 14 | Carrier (shortsea) | Country manager |
| 15 | Port authority | Product lead |
| 16 | LSP | CFO |
| 17 | Carrier (shortsea) | Business development reefers |
| 18 | Port authority | Business manager agrifood |
| 19 | Carrier (deepsea) | Reefer sales |
| 20 | Inland barging and terminals association | Junior policy advisor |
| 21 | Carrier/LSP | General manager logistics services |
| 22 | Inland trucking association | Secretary |
| 23 | Terminal (shortsea/barge) | Commercial manager |
| 24 | Inland barging association | Policy advisor |
| 25 | LSP | Manager import/export and container department |
| 26 | Shipper/LSP association | Policy advisor |
| 27 | LSP/TSP (multimodal) | Manager |
| 28 | TSP (barge) | Managing director |

The Q-sorts were elicited from the respondents following the generally recommended protocol for Q-method data collection (Molenveld, 2019; Van Exel & De Graaf, 2005). The respondents were presented the 37 statements from the Q-set in random order. They were first asked to distinguish between statements they generally agreed with, disagreed with, or were neutral towards. Following this rough ordering, we asked them to assign an explicit score to each statement reflecting the degree of (dis)agreement relative to the other statements in the Q-set. This scoring followed a forced normal distribution recommended for Q-sorting (Watts & Stenner, 2012) as shown in Figure 5.1, ranging from –5 (strongly disagree) to +5 (strongly agree).

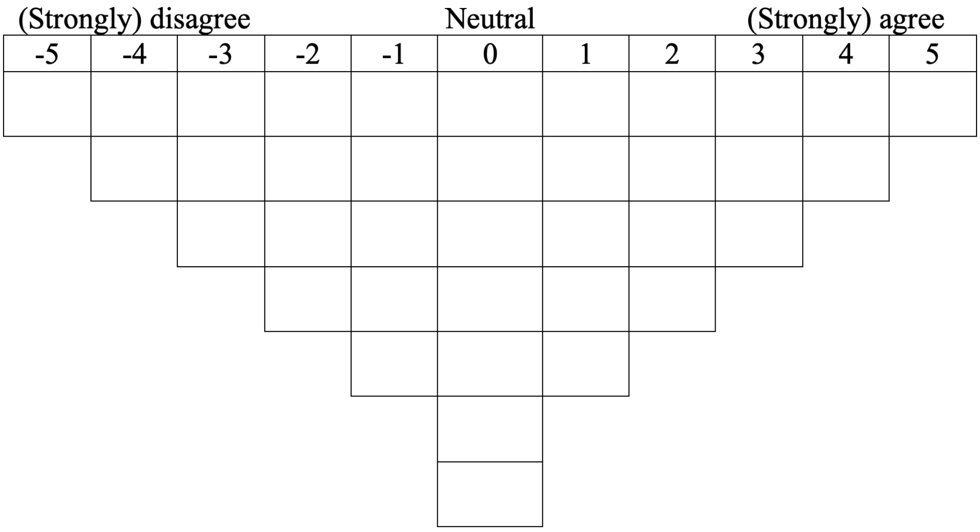


**Figure 5.1. Q-sort template.**

Source: based on Watts and Stenner (2012)).

Moreover, in addition to having them perform the Q-sort exercise, respondents were asked to provide some information about the organization they worked for, including:

- The type of organization they worked for;
- Their position;
- Annual turnover of the organization;
- Estimation of their modal split (respective percentages of containers being transported by inland waterways, rail, or road transport).

We asked respondents to comment more elaborately on the topics that are most relevant to their organization, and elaborate further on those statements with which they (dis)agreed the strongest. The combination of reducing stakeholders' perspectives on aspects of an issue to a manageable number of dominant perspectives, and the contextual depth provided by their elaboration, yields a rich insight into the most important perspectives on the issue. At the end of the survey, we asked respondents whether they felt that any important aspect of the topic was missing. This yielded no important areas of omission in the Q-set.
To analyze the data, we used the Ken-Q Analysis for Q Methodology v.1.0.3. web application (Banasick, 2018). First, a correlation matrix between the Q-sorts is produced. The intuition behind Q methodology is that when Q-sorts correlate between respondents, there is a degree of congruence in their viewpoints on the subject (Kroesen & Bröer, 2009). These clusters of respondents with shared viewpoints can be identified using factor extraction. As suggested by Brown (1980) and Watts and Stenner (2012), we started by extracting seven factors from the data. In this process, the first factor that is extracted accounts for the largest amount of common variance in the data. The second factor is subsequently extracted from the residual correlation matrix, and this is repeated until the desired number of factors is extracted. Usually, in practice, after a handful of factors has been extracted from the data, the residual correlation matrix will no longer contain any meaningful residual common variance for an additional factor. These factors were rotated using the Varimax method, as is standard procedure in Q methdology (Brown, 1980; Watts & Stenner, 2012). To assess the relevance of a factor, we adhered to the Kaiser–Guttman criterion to retain those factors with an

Eigenvalue higher than 1 (Kaiser, 1958; Watts & Stenner, 2012). Of the seven factors extracted, five satisfied this criterion. As a robustness check, we repeated the process by extracting eight factors instead, which yielded an eighth factor with an Eigenvalue of 0.1771, which does not meet the Kaiser–Guttman criterion. Furthermore, we introduced the criterion to only include those factors that have at least two respondents loading significantly after rotation (Brown, 1980). This reduced the number of factors to four, since the sixth factor obtained only had one significant loading. The factors and the loadings per respondent are shown in Table 5.3 below.

**Table 5.3. Four dominant perspectives and factor loadings generated with the Varimax method, significant loadings ($p < 0.05$) shaded and indicated with *.**

| Respondent No. | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|
| 1 | 0.2339 | −0.0112 | 0.3272 | 0.4756 |
| 2 | 0.0381 | −0.028 | 0.6724* | 0.2001 |
| 3 | 0.1945 | 0.0244 | −0.0715 | 0.616* |
| 4 | 0.6764* | −0.1316 | 0.368 | 0.3621 |
| 5 | 0.3972 | 0.224 | 0.3088 | 0.088 |
| 6 | 0.1686 | 0.5274* | 0.2208 | 0.3312 |
| 7 | 0.0356 | 0.8418* | −0.1556 | −0.2221 |
| 8 | 0.6879* | 0.0531 | 0.0673 | 0.1678 |
| 9 | 0.556* | 0.353 | 0.2205 | 0.2093 |
| 10 | 0.41 | 0.1798 | 0.4 | 0.3801 |
| 11 | 0.4169 | 0.0405 | 0.5153* | 0.1243 |
| 12 | 0.5261* | 0.1424 | 0.1006 | 0.0078 |
| 13 | 0.1639 | 0.1644 | 0.6011* | 0.1342 |
| 14 | 0.2194 | 0.4121 | −0.2324 | 0.275 |
| 15 | 0.5118 | 0.2437 | 0.0397 | 0.4747 |
| 16 | 0.0422 | 0.4426* | 0.2262 | −0.0111 |
| 17 | 0.2955 | 0.3717* | 0.1104 | 0.0215 |
| 18 | 0.8218* | 0.1668 | −0.0852 | 0.198 |
| 19 | 0.4532 | 0.2124 | 0.1677 | 0.3504 |
| 20 | 0.3535 | 0.5889* | 0.1937 | 0.3047 |
| 21 | 0.1309 | 0.1332 | 0.6537* | −0.0436 |
| 22 | 0.4867 | 0.2947 | 0.3957 | 0.056 |
| 23 | 0.3674* | 0.1761 | 0.1057 | 0.0715 |
| 24 | 0.044 | 0.0795 | 0.2352 | 0.7201* |
| 25 | 0.0824 | 0.2773 | 0.4246 | −0.3363 |
| 26 | 0.4477 | 0.4685 | 0.2866 | 0.2905 |
| 27 | 0.0059 | −0.0032 | 0.0424 | −0.0039 |
| 28 | 0.5129* | 0.0188 | 0.3672 | −0.0161 |
| % Explained Variance | 16 | 10 | 11 | 9 |
| No. of Defining Variables | 7 | 5 | 4 | 2 |
| Average Reliability Coefficient | 0.8 | 0.8 | 0.8 | 0.8 |
| Composite Reliability | 0.966 | 0.952 | 0.941 | 0.889 |
| S.E. of Factor Z-scores | 0.184 | 0.219 | 0.243 | 0.333 |

Ultimately, we obtained four factors that constitute the four dominant perspectives on the discourse of sustainability in cold chain logistics and reefer transportation. These four factors together explained 16 + 10 + 11 + 9 = 46% of the total variance, sufficiently above the 35% to 40% threshold generally recommended (Watts & Stenner, 2012). In total, 18 respondents loaded significantly on one of these four perspectives (shown in the table as the No. of Defining variables), whereas the 10 others either loaded strongly on more than one perspective (hence lacking a significant loading on one of these) or none of them. The factors show high to very high reliability (average reliability coefficient = 0.8, composite reliability >0.9 for three factors and >0.8 for the fourth one). The reliability decreased slightly as the number of respondents loading significantly on a factor decreased, also evidenced by the slightly increasing standard errors of the factor Z-scores. This is understandable, as the amount of variation extracted with each subsequent factor decreased.

For every factor found, the Ken-Q application compiles an 'idealized' or 'typical' Q sort with a statement ranking that is representative of the factor extracted—for the purpose of discussing the differences between the perspectives, we treated these generated Q sorts (one for each factor) as the 'dominant' perspectives that clusters of respondents share to a strong degree. For interpretation, we took from these perspectives (i.e., the generated 'typical' Q sorts) the most salient statements (i.e., those rated with extreme agreement (scores of 4 and 5) or disagreement (scores of –4 and –5)) and those statements of which the rating differs significantly from the other perspectives, making them distinguishing of the perspective at hand as well. Furthermore, quotes from respondents' elaborations on these statements (translated from the original Dutch to English for reporting in this chapter) illustrate the considerations of the organizations that share a perspective. The interpretation of the generated 'typical' Q-sorts combined with information on respondents' considerations helps formulate a coherent narrative on the underlying rationale behind these four distinct perspectives (Webler, Danielson, & Tuler, 2009). The next section discusses these characteristics of the four dominant perspectives in more detail.

## 5.4 Results

The analysis resulted in four dominant perspectives on sustainability issues in cold chain logistics and reefer transportation. This means stakeholder viewpoints on this topic can be understood to a large extent by considering these four perspectives. The interpretation of the four 'typical' Q-sorts and respondents' elaborations allowed us to summarize these four perspectives under the following labels:

1. Sustainability as part of strategy.
2. Short term constraints.
3. Optimistic about technology, limited role for policy.
4. Long run willingness under risk avoidance.

These labels summarize stakeholders' overall views on the entire discourse on the topic of reefer transportation, emphasizing the aspects most salient to them and/or that distinguish their perspective the strongest from the others. They reflect how—within these perspectives—companies view themselves and their environment, their interests and position in the sector, their expectations from policymakers (notably the port authority), and their visions, expectations, and strategies with regard to the future. The four sections below discuss these perspectives in more depth.

**Perspective 1: Sustainability as Part of Strategy**

Perspective 1 is shared by relatively large and often internationally operating organizations, including carriers, shippers, LSPs, and the port authority. Also, several smaller, locally operating organizations loaded significantly on this perspective. In total, seven respondents loaded significantly on this perspective.

The most positively valued statements (7, 1, and 8, see Table 5.4) all concern the importance of sustainability at the organizational level in setting strategic and operational priorities.

Moreover, from this perspective, respondents tended to react most negatively to statements prioritizing cost reductions over sustainability improvements (statement 5) and the prospect of sustainability gains being impossible to achieve (statement 3). From this perspective, companies are already making a conscious effort to operate more sustainably, and consider themselves to be well equipped with the right means and capabilities to maintain this progress in the future. The quotes from the respondents' elaborations on these statements further illustrate this perspective. The focus tends to be on their own efforts to prioritize sustainability, including attaining certifications, experimenting on their own with modal shift initiatives, and regular internal reporting on everything related to sustainability—even including the use of coffee cups as one respondent stated (see quotes Table 5.4). Respondents that loaded significantly on this perspective also emphasized the independent nature of their sustainability efforts. They do not merely follow the example of other companies (statement 13, showing a significant difference with the other three perspectives), but see themselves as independent and capable forerunners, and tend to be dismissive of governmental support or subsidies for green initiatives (Table 5.4, quote Respondent 23). Also, when it comes to other companies in the sector, companies with this perspective emphasized the need for a culture or mindset change, as well as their opinion that companies should be able to invest in a more sustainable direction without external help.

**Table 5.4. Perspective 1: Distinguishing statements and illustrative quotes.**

| Statement | | Z-score | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|---|---|
| 7 | We are actively improving the sustainability of our services | 2.135 | 5 | 0 | 0 | 1 |
| 1 | For our company/organization, sustainability is important | 1.63 | 4 | −1 | 3 | 3 |
| 8 | Sustainability is an important strategic value of our company/organization | 1.572 | 4 | −2 | 2 | 3 |
| 5 | When facing a choice between cost reduction and sustainability improvements, we opt for cost reduction | −1.619 | −4 | 0 | 2 | 1 |
| 25 | There are better ways to transport conditioned cargoes than outmoded reefer containers | −1.656 | −4 | −3 | −5 | −4 |
| 3 | Making reefer chains more sustainable is an impossible task for our company | −1.824 | −5 | 0 | −1 | −1 |
| Other distinguishing statements | | | | | | |
| 13 | We address the sustainability of our operations because other companies in our sector do this as well | −1.482 | −3 | −1 | 0 | −1 |
| 37 | We find the costs of hinterland transportation by barge too high | −0.245 | 0 | 4 | −2 | −3 |

Quotes:

- We have been preoccupied with sustainability for years already, in order to preserve a healthy environment, and in 2004 we already received an ISO 14001 certification (Respondent 8, Carrier (deepsea))
- Within our organization, sustainability is always on the agenda, regardless of the type of work we do […] We report on a monthly basis on aspects ranging from the use of coffee cups to our various container movements (Respondent 9, LSP)
- There are always ways to improve the sustainability in the reefer chain; our customers also expect us to do so (Respondent 9, LSP)
- A modal shift first requires a mindshift, companies setting the right priorities […] we just started small with regular barge transport, now it's an attractive option […]. Parties are too hesitant, wait for others to make the first move (Respondent 23, Terminal operator)
- Companies should invest in sustainability on their own […] subsidies and the like would only distort the market, but laws and regulations could be used to punish polluting companies (Respondent 23, Terminal operator)
- Logistics concepts should change to address congestion and emissions, but the way of thinking, the culture in the sector is hard to change […] the port authority should have a role in bringing parties together, but should not get involved in the market […] they operate too bureaucratically and slow (Respondent 28, TSP)
- It might be easy for companies to let the port authority solve all their problems, but they should keep up their own trousers (Respondent 28, TSP)

**Perspective 2: Short Term Constraints**

The second perspective that emerges from the data is firmly juxtaposed to the first. Five respondents (a terminal, two forwarders, one short sea carrier, and inland transport organization) loaded significantly on this perspective. In terms of size and turnover, these organizations tended to be smaller than other organizations of the same type in the P-set.

From this perspective, a modal shift in hinterland transport is not feasible (yet). Statements regarding the high costs (37, see Table 5.5) and low performance (32, 29, and 33) of rail and barge werw rated with extreme scores, and in their elaboration on these ratings respondents cite high costs relative to truck, low reliability, congestion at terminals, and the lack of options to efficiently plug in a reefer on a train as main motivations behind this. Considering investment in more sustainable operations, organizations with this perspective emphasized the high costs (statement 6) and—accordingly—assigned this a lower priority than other perspectives (statements 1 and 8). A respondent's elaboration on this consideration highlights that firms operate on low margins, face strong external pressure on costs and lead-time, and lack the resources, capabilities, and long-term income stability to make investments or take risks (Table 5.4, quote Respondent 20). At the same time, this perspective also includes a stronger willingness to share (parts of) company data (statements 17 and 18)—under the right conditions. This ties in well with the relatively high expectations from the port authority in this perspective (statements 21 and 20) to take a leading role in such initiatives. For example, a logistics service provider (respondent 6) expressed his frustration with the port authority's focus on renting out land, rather than supporting value added activities. Elaboration from an inland transport organization representative highlights the facilitating role the port authority can take up regarding data platforms: Setting the boundary conditions and ensuring a fair and neutral treatment of participants. From this perspective, companies are facing short-term financial and operational constraints, but are willing to consider a modal shift to greener modes and participating in data sharing under the right conditions. However, these conditions have not yet been met, as trust in existing data platforms is lacking, and the performance of other modes than truck does not meet their expectations.

**Table 5.5. Perspective 2: Distinguishing statements and illustrative quotes.**

| Statement | | Z-score | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|---|---|
| 17 | We are willing to share parts of our data with other companies to further optimize the reefer chain | 1.512 | 0 | 5 | 1 | −2 |
| 37 | We find the costs of hinterland transportation by barge too high | 1.38 | 0 | 4 | −2 | −3 |
| 21 | We expect the port authority to push for sustainability | 1.301 | −1 | 4 | −2 | 1 |
| 32 | The infrastructure for hinterland transport of reefer containers by rail meets our expectations | −1.579 | −2 | −4 | −3 | 0 |
| 33 | The performance of hinterland transport by rail meets our expectations | −1.748 | −1 | −4 | −4 | 0 |
| 6 | Cost reduction and sustainability improvements go hand in hand | −2.144 | −2 | −5 | −1 | 1 |
| Other distinguishing statements | | | | | | |
| 18 | We are willing to share parts of our data with other companies involved in the reefer chain to improve the overall sustainability of the chain | 1.231 | 1 | 3 | 1 | −1 |
| 20 | The current business model of the port authority (renting out land and collecting port dues) is no longer suitable for the current economy | 1.165 | −3 | 2 | 1 | −3 |
| 1 | For our company/organization, sustainability is important | −0.582 | 4 | −1 | 3 | 3 |
| 8 | Sustainability is an important strategic value of our company/organization | −0.694 | 4 | −2 | 2 | 3 |
| 28 | In the future, we only want to work with newer, more sustainably operating reefer containers, instead of poorly isolated, inefficient, old reefers | −0.723 | 2 | −2 | 1 | 0 |
| 29 | Hinterland transport of reefer containers by barge is a good option | −0.756 | 1 | −2 | 3 | 4 |

Quotes:

- The handling of barges in the port is far below standards, price/quality balance is not there (Respondent 7, Terminal operator)
- Making operations more sustainable (still) costs a lot of money (Respondent 7, Terminal operator)
- Strive for value added activities that contribute to sustainable business, and accordingly jobs, cargo flows, and the right position in the world […] The port authority made a big mistake by [focusing on] renting out square meters (Respondent 6, LSP)
- The rail product for reefer containers is stuck in the 1980s, it should be possible to plug in a reefer on a train, instead of using diesel guzzling and leaking gensets (Respondent 6, LSP)
- Service providers are facing a strong pressure on costs and lead time, and work on short-term contracts, while investments require income security (Respondent 20, Inland barging and terminals association)
- Data sharing is a 'hot' topic, but in the sector still contentious: the willingness is there, but the right conditions are missing […] Data sharing platforms should be considered part of port infrastructure, including a role for government […] the port authority can take up a more facilitating role [and] ensure that solution platform is neutral (Respondent 20, Inland barging and terminals association)

**Perspective 3: Optimistic about Technology, Limited Role for Policy**

This perspective is shared by a diverse group of stakeholder organizations of various types and sizes, including shippers, a carrier, and logistics service providers. In total, four respondents loaded significantly on this perspective.

One important observation that emerged from this perspective is the optimism about the possibilities of energy saving (statement 11 see Table 5.6) and data sharing (statement 19). Respondents illustrated this by referring to monitoring technology at terminals (respondent 13), energy saving software in reefer units, and new track and trace technologies implemented by container carriers (e.g., respondent 21 referring to Maersk Remote Container Management). On the other hand, respondents tended to negatively view the contribution of port policy to efficiency and sustainability issues. They do not experience support from the port authority (statement 14), nor do they expect leadership in making reefer transportation more sustainable (statements 21 and 16). Moreover, from this perspective, the recent CoolPort initiative, in which the port authority took a leading role in stimulating the clustering of cold storage, intermodal container transport, cargo handling, and value added services, is valued considerably lower than in other perspectives. In his elaboration on these points, a shipper representative (respondent 2) stated that in his view, the port authority should first and foremost do a better job in setting the right boundary conditions for efficient port processes and information management. In sum, organizations that share this perspective have positive expectations from technology, but see a limited role for policy in improving the sustainability of reefer transportation.

**Table 5.6. Perspective 3: Distinguishing statements and illustrative quotes.**

| Statement | | Z-score | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|---|---|
| 23 | We prioritize reefers over dry containers | 2.187 | −2 | 0 | 5 | −1 |
| 11 | Energy saving is possible without compromising product quality | 1.649 | 1 | −1 | 4 | 0 |
| 19 | In the future, data sharing will play a larger role in improving punctuality, quality, and sustainability | 1.385 | 3 | 1 | 4 | 5 |
| 33 | The performance of hinterland transport by rail meets our expectations | −1.475 | −1 | −4 | −4 | 0 |
| 14 | The port authority is doing everything possible to help us operate more sustainably | −1.608 | −2 | −1 | −4 | 0 |
| 25 | There are better ways to transport conditioned cargoes than outmoded reefer containers | −1.816 | −4 | −3 | −5 | −4 |
| Other distinguishing statements | | | | | | |
| 20 | The current business model of the port authority (renting out land and collecting port dues) is no longer suitable for the current economy | 0.52 | −3 | 2 | 1 | −3 |
| 12 | We can expect an exponential growth in the use of reefer containers in the future | 0.294 | 3 | 3 | 0 | −5 |
| 31 | A lot of sustainability gains can be made in hinterland transport | 0.167 | 2 | 2 | 0 | 3 |
| 2 | In the near future, we want to be able to offer CO2-neutral services to our clients | −0.189 | 2 | 3 | −1 | −3 |
| 30 | Hinterland transport of reefers by rail is a good option | −1.043 | 0 | 1 | −2 | 0 |
| 21 | We expect the port authority to push for sustainability | −1.058 | −1 | 4 | −2 | 1 |
| 15 | Initiatives such as CoolPort have great added value for our company/organization | −1.154 | 0 | 2 | −1 | 1 |
| 16 | The port authority can play a major facilitating role in improving hinterland transportation | −1.429 | 1 | 1 | −3 | 2 |

Quotes:

- We can constantly monitor the reefers' temperature and alerts […] we know what the priorities are and the risks to technology and product quality if they malfunction (Respondent 13, Terminal operator)
- The port authority should first focus on the basics of excellent port processes and information management, as of now this is lacking. Lots of work to be done on that. In the hinterland there are plenty of specialists that can work on that part of the chain (Respondent 2, Shipper association)
- In this environment of price competition, cost control is necessary to survive. Therefore: operate more sustainably. (Respondent 2, Shipper association)
- Remote Container Management (Maersk line's real-time track and trace technology on reefer containers, red.) is a first step to make reefer transport more efficient and sustainable, software can help to improve the efficiency of the container itself (Respondent 21, Carrier/LSP)

**Perspective 4: Long Run Willingness under Risk Avoidance**

A fourth perspective also emerged, distinct from the other three. It should be noted that, although significant and explaining a fair amount (9%) of variation, only two respondents (respondent 3, a LSP, and respondent 24, an industry association of the inland shipping sector) loaded significantly on this perspective.

This perspective is relatively open to reefer transport by barge rather than truck—under the condition that demands on the logistics chain allow for a longer transit time, as voiced by one respondent (Table 5.7, quote respondent 24). An interesting observation is that although this perspective assigns the highest score to statement 19 ("In the future, data sharing will play a larger role in improving punctuality, quality, and sustainability”), statements reflecting a willingness to share data were rated more negatively than from the other perspectives. An elaboration from one respondent (respondent 24) highlights some reservations with regard to data sharing. He believes it will become important, but that at this moment, the willingness is not there, due to the uncertainty involved, the current lack of standards, and the commercially sensitive nature of information. The same timeframe considerations are reflected in a low rating of statement 2 (“In the near future, we want to be able to offer $CO_2$ neutral services to our clients”), in which respondents particularly objected to the “in the near future” phrase. From this perspective, investments in sustainability, as well as commitment to data sharing initiatives, take time and careful consideration. In the long run, organizations are willing to participate in data sharing and effectuating a modal shift to greener modes, but they are cautious of present risks and uncertainties, making them hesitant to act in the short term. More so than the others, this perspective envisages a considerable role of the port authority in facilitating a shift to sustainability.

**Table 5.7. Perspective 4: Distinguishing statements and illustrative quotes.**

| Statement | | Z-score | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|---|---|
| 19 | In the future, data sharing will play a larger role in improving punctuality, quality, and sustainability | 2.411 | 3 | 1 | 4 | 5 |
| 29 | Hinterland transport of reefer containers by barge is a good option | 1.639 | 1 | −2 | 3 | 4 |
| 9 | The port authority can play an important facilitating role when it comes to improving sustainability | 1.349 | 1 | 2 | 0 | 4 |
| 25 | There are better ways to transport conditioned cargoes than outmoded reefer containers | −1.544 | −4 | −3 | −5 | −4 |
| 24 | Reefers are an important component of our business model | −1.639 | 2 | −3 | 2 | −4 |
| 12 | We can expect an exponential growth in the use of reefer containers in the future | −1.834 | 3 | 3 | 0 | −5 |
| Other distinguishing statements | | | | | | |
| 32 | The infrastructure for hinterland transport of reefer containers by rail meets our expectations | 0.287 | −2 | −4 | −3 | 0 |
| 18 | We are willing to share parts of our data with other companies involved in the reefer chain to improve the overall sustainability of the chain | −0.482 | 1 | 3 | 1 | −1 |
| 17 | We are willing to share parts of our data with other companies to further optimize the reefer chain | −0.964 | 0 | 5 | 1 | −2 |
| 2 | In the near future, we want to be able to offer CO2-neutral services to our clients | −1.159 | 2 | 3 | 1 | −3 |

Quotes:

- Information provision about our activities is becoming increasingly important, because we can use it for analysis. Data is an important tool to pinpoint where we can improve punctuality, quality, and sustainability (Respondent 3, LSP)
- There is a focus on reducing emissions, but the question remains how. Which investments will work? […] It also depends on the timeframe whether we can make substantial sustainability improvements. 5 years, no. 20 years, yes (Respondent 24, inland barging association)
- Data sharing will play a more important role, but now the willingness to do so is low. Information can be commercially sensitive [so] if parties share, it will more likely be vertical rather than horizontal […] other parties in the market have to follow (Respondent 24, inland barging association)
- Barge transport is a good option technologically and on price, but only if there is enough slack in the logistics chain to make it possible […] the same goes for rail (Respondent 24, inland barging association)

### Similarities between Perspectives

Having so far highlighted the differences between the perspectives, there are also some parts of the discourse on which the four perspectives share similar views. One way to assess the compatibility of the perspectives identified is to check the correlation between the factors from which the perspectives were compiled (see Table 5.8). The correlations are weak at best (all <0.4), but most are positive, indicating that there are indeed some areas on which the four perspectives overlap. The close to zero correlation between factors 2 and 4 (−0.0398) may reflect the distinctly short term orientation of perspective 2, and the very long term orientation of factor 4, and the very different levels of willingness to share data.

**Table 5.8. Factor correlations.**

| | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|
| Factor 1 | 1 | 0.2565 | 0.3756 | 0.3776 |
| Factor 2 | 0.2565 | 1 | 0.1599 | −0.0398 |
| Factor 3 | 0.3756 | 0.1599 | 1 | 0.2771 |
| Factor 4 | 0.3776 | −0.0398 | 0.2771 | 1 |

The correlation between perspectives can be traced back to certain 'consensus' statements, on which the perspectives overlap to some degree. These statements and their scores per factor are shown in Table 5.9 below.

**Table 5.9. Consensus statements (* indicates significance ($p < 0.05$)).**

| Statement | | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|---|
| 9 | The port authority can play an important facilitating role when it comes to improving sustainability | 1 | 2 | 0 | 4 |
| 22 | We are very dependent on the port authority | −1 | −2 | −3 | −1 |
| 25* | There are better ways to transport conditioned cargoes than outmoded reefer containers | −4 | −3 | −5 | −4 |
| 26 | The development of technology for new (smart) reefers goes too slow | 0 | 0 | 2 | 0 |
| 27* | Smart reefers will contribute to our company operating more sustainably | 0 | 0 | 1 | 2 |
| 31 | A lot of sustainability gains can be made in hinterland transport | 2 | 2 | 0 | 3 |
| 34* | For us, good hinterland transportation performs well on cost, quality, and reliability criteria | 3 | 1 | 3 | 2 |
| 36 | We find the costs of hinterland transportation by truck too high | −1 | 0 | 0 | −2 |

An interesting observation concerns the relative neutrality with which all perspectives view statements related to the 'smart' reefer (26 and 27). Few of the respondents expect great efficiency and sustainability gains from reefer containers being integrated in the Internet of Things, and they—although some acknowledge in their elaboration the slow progress in the implementation of existing technologies in smart reefers—do not experience an urgent need to make use of this technology. Even perspective 3, characterized by optimistic expectations from technology, attaches relatively more importance to information sharing solutions and energy saving technology. Another shared view regards the attractiveness of the reefer container relative to other modes of transport for conditioned cargoes (statement 25): All perspectives prefered the reefer container over conventional reefer ships or air transport. Moreover, multiple respondents believed that major product categories that still predominantly rely on airfreight (notably flowers) will be containerized more in the future as well. There is also some consensus on statements regarding the role of the port authority (statements 9 and 22): All perspectives emphasized to a greater or lesser degree the potential role the port authority can play in improving sustainability, but in no perspective do stakeholders consider themselves particularly dependent on the port authority. Regarding hinterland transport, perspectives overlapped in their neutral evaluation of the costs of trucking (statement 37). For reefer containers, trucking is (still) the default mode of transport to and from the port area, so respondents may see its usage as a given. Interestingly, the costs of barge and rail (statements 35 and 37) were also rated rather neutrally or even negatively: Only perspective 2 strongly agreed (Z score > 1.0) with the costs of barge being too high. In their elaboration on these statements, multiple respondents concluded that costs alone did not incentivize the trucking decision, but more importantly, the flexibility, ease, and speed. Acknowledging that all perspectives agreed on statement 34 ("For us, good hinterland transportation performs well on cost, quality, and reliability criteria"), it can be surmised that all stakeholders value cost, quality, and reliability criteria, but in a mix that prioritizes speed and reliability as long as competition keeps costs at a reasonable level.

## 5.5 Discussion and Conclusions

In this study, the application of Q methodology identified four dominant perspectives that together account for 46% of the variation in viewpoints on sustainability issues in reefer transportation. Aside from the substantial variation explained by the four perspectives, several novel insights can be drawn from the results.

Before discussing the main findings and implications for policy, management, and research that can be drawn from the findings, some caveats with regard to the results are in order. The Q methodology applied is by nature inductive, taking the case information and the patterns that emerge from the data as a starting point to formulate propositions. The study was conducted in the context of the case of the Port of Rotterdam: A shared environment where stakeholders have a shared frame of reference and can thus be expected to show differing viewpoints on the same subject matter. The generalizability of findings is often a limitation of a Q methodology approach. Within a given context, there is a limited number of coherent patterns of viewpoints on a discourse that can be identified with a relatively small group of respondents (the assumption of 'finite diversity' (Barry & Proops, 1999)), but the case context may determine which aspects of the discourse become more salient to stakeholders. Hence, similar patterns may be observed in similar contexts (e.g., Western European ports), but the generalizability to very different contexts is limited.

The findings highlight the multidimensionality of stakeholder perspectives on sustainability issues, and the nuanced ways in which these differ from one another. Important differences between perspectives can stem from the way companies view themselves, their resources and capabilities (or lack thereof), their expectations of the future and technology development, and their (normative) evaluation of the proper role of formal government (e.g., a port authority) in relation to the market. All dominant perspectives that were identified are distinct from the others along several of these dimensions. Furthermore, the dominant perspectives found could not easily be reduced to one traditional categorization of stakeholders, as they cut across boundaries between stakeholder types. For example, one logistics service provider may be more comparable in attitudes to a terminal operator than to another LSP. It is valuable to highlight that while having brought stakeholder viewpoints on the topic back to no more than four dominant perspectives, we can still understand a large part of the variation in subjective attitudes among the broad and diverse fields of many different stakeholder organizations. This illustrates the usefulness of Q methodology to capture important patterns in viewpoints, while also dealing with the considerable heterogeneity among stakeholders in a given context.

The findings from this study also offer several considerations for supply chain actors, in managerial as well as policy-making roles, in three main areas.

First, the findings highlight the awareness of managers and policymakers of the growing importance of information sharing, but at the same time underscore barriers to the development of such initiatives and platforms. Across all four perspectives, respondents affirmed the importance of information sharing and improving inter-firm coordination, but due to the complexity and uncertainty involved, lacking capabilities, or fearing for their own competitive position, it is not attractive to be a first mover. Nor would other parties in the sector necessarily trust a first mover, especially if it concerns an already dominant party in the market—having the resources and capabilities necessary to take this first step. Leading firms in the market that consider starting data sharing initiatives should recognize the need to overcome this lack of trust among other supply chain actors for their initiative to be successful. In this aspect, there may be a potential role for policy. Port authorities, as well-connected organizations with considerable capabilities, and generally perceived and trusted as a neutral party, are well positioned to help overcome barriers to coordination and innovation by taking a leading role in data sharing initiatives. Especially with willing but smaller organizations with limited resources, there is a potential for sustainability gains that can be realized by supporting these organizations with knowledge and capabilities that allow them to act on their ambitions. In doing so, port authorities that pursue sustainability goals in a complex logistics context may consider expanding their scope beyond the traditional 'landlord' role and positioning themselves as more innovative and entrepreneurial cluster managers.

Secondly, the study findings also have several managerial implications for market actors wishing to develop their (sustainable) business models in cold chain logistics. The findings highlight the fact that a modal shift will not happen unless the right boundary conditions are met. Several respondents highlight the potential attractiveness of barge and rail transport as a cost-effective alternative to trucking, that can benefit from the bundling of flows of reefer and dry containers. However, in the studied case, while barge transport can (at a feasible route and distance) compete with truck transport on costs, it is used only to a limited extent. In addition, rail transport—still almost never used for operating reefers—needs better options to power reefers on board. If intermodal barge and rail are to be a competitive alternative to truck, the speed, ease of use, and particularly the reliability of these modalities have to improve. In this context, reducing holdup risk and increasing the reliability of barge and rail transport requires the coordination of activities of several actors, including terminal operators, LSPs, and transportation service providers to a degree that is still lacking (Van der Horst & De Langen, 2008). Additionally, aside from improving reliability, the attractiveness of these services for reefer transport can also benefit from new logistics concepts that allow for service differentiation through more flexible planning of intermodal shipments, such as the development of synchromodal transport services (Van Riessen et al., 2015). Considering the differing characteristics of reefer cargoes (in particular related to the time-sensitivity of different goods), a more differentiated service offer (i.e., combining different transport modes to meet a particular client's time and cost preferences) in combination with more reliable service will likely facilitate a modal shift of reefer cargoes to more sustainable modalities. For port authorities, stimulating the development of a differentiated service offered to users with different preferences in their port cluster can contribute to the creation of added value and enhancement of port competitiveness (Castelein, Geerlings, et al., 2019b).

Third, another interesting observation regards the development of the 'smart reefer.' While carriers are investing heavily in innovation and outfitting their reefers with sensors and other IoT devices, other reefer chain stakeholders do not seem to expect much from this technology in terms of improving their own processes. Therefore, it would serve container carriers and technology developers well to consider customer needs in their product development, and leverage their marketing to increase awareness of the possibilities of their smart containers.

For researchers, the findings highlight the usefulness of Q-methodology—a method used rarely so far in port and transportation research—to elucidate the most widely shared concerns in a complex and diverse network of stakeholders. Having now identified the perspectives on sustainability issues in reefer transportation and cold chain logistics that are dominant in the

Port of Rotterdam context, the study findings invite several interesting questions for future research to address. Most importantly, 1) can similar patterns be observed in similar port contexts? Additionally, 2) how exactly can convergence on issues that require broad cooperation and coalition building, such as a modal shift and data sharing, be stimulated? Furthermore, the depth of understanding of stakeholder attitudes achieved in this study is illustrative of the valuable contribution Q methodology can make to stakeholder analysis and management, and port policy. Although still scarcely used in the field of freight transport and ports, it may in the future be applied to problems of a similar nature where the identification and reconciliation of conflicting viewpoints, objectives, and interests is desirable. Examples of these problems include congestion issues around container terminals, enacting an energy transition in still fossil fuel-oriented seaports, eliciting stakeholder requirements for infrastructure planning, and conflicts at the port–city interface.

Finally, the study findings provide new insights about the barriers that need to be overcome to realize sustainability gains in multi-actor logistics contexts. While there is already an awareness of the need for improving the sustainability performance of (cold chain) logistics, change is slow to come about and the differences between the dominant perspectives discussed highlights several reasons why. A considerable group of actors lacks the capabilities or the flexibility to invest in sustainability improvements, due to their narrow margins and their customers putting a strong pressure on costs and lead-time. Another group may be reluctant to change their own behavior, either due to an expectation that technology will gradually improve sustainability performance, due to hesitation and uncertainty about which changes to make, or in a belief that their own efforts are futile unless other issues outside their control are addressed first. Also, expectations from policy are not unequivocal: Some parties prefer policymakers not to interfere in the market, whereas others expect a leading role in standard setting and platform development. These tensions lead to a present situation of deadlock in the Rotterdam-oriented cold chain logistics sector, and perhaps in other contexts as well. Changing locked-in perceptions and behavior and realizing a transition towards more sustainable transport remains a major challenge for chain actors across the board.

# 6 Cold chain strategies for seaports: Towards a worldwide policy classification and analysis

This chapter is based on Castelein, R.B., Geerlings, H., & R. Van Duin. (2019). Cold Chain Strategies for Seaports: Towards a Worldwide Policy Classification and Analysis. In: Witlox, F. (Ed.). *Moving towards more sustainable mobility and transport through smart systems. Proceedings of the BIVEC-GIBET Transport Research Days 2019*. Ghent, Belgium

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**Abstract**

The refrigerated ('reefer') container market and cold logistics chains create opportunities as well as challenges for seaports. This high-value market grows rapidly, but places stringent demands on seaports' logistics processes, infrastructure, and energy provision. This study addresses the question how port authorities can address the challenges and opportunities in this dynamic market environment. While previous research has outlined developments in port governance paradigms and the strategic scope of port authorities, the academic literature still lacks a comprehensive understanding of the policy options available to port authorities to respond to arising challenges and opportunities. To provide this missing understanding, this study presents a new dataset of policies, implemented by world's 50 largest container ports, addressing reefer transportation and cold chain logistics. Policy measures are classified according to content, goals, scope and port authority role. The findings from this worldwide comparative analysis illustrate that port authorities often pursue policies extending far beyond their traditional 'landlord' responsibility. Most commonly still, the scope of port policy is limited to the port cluster, where ports (co)-invest in or aim for cluster formation around cold stores. When a port extends its strategic scope towards its foreland or hinterland, this is usually aligned with policy goals formulated at higher levels of governance, such as modal shift goals or the development of domestic post-harvest distribution systems. There is however little evidence of coherent and comprehensive cold chain strategies, addressing the logistics, marketing, technology, and sustainability dimensions. The chapter outlines the general tenets such a strategy should contain as a consideration for policymakers.

## 6.1 Introduction

The focus of this chapter is on the policy measures that can be implemented by port authorities to better attract and facilitate transportation of refrigerated containers. Refrigerated or 'reefer' containers are a fast-growing segment in the container shipping market (Arduino et al., 2015). Whereas the container shipping market itself is in a phase of maturity, niches such as reefer transportation can still be exploited for further growth (Guerrero & Rodrigue, 2014). Over the past decade, the reefer market has been the only segment showing consistent year-on-year growth in a generally depressed container shipping market (Drewry Maritime Research, 2016b). The intermodal compatibility, increased reliability (in terms of delivery and quality control), flexibility, and traceability that these containers and associated technology provide, make it an attractive mode of transportation for temperature-sensitive cargoes. Facilitated by technical developments in the reefer market, the growing global demand for temperature-sensitive products, such as fresh and frozen agrifood products, flowers, chemicals, and pharmaceutical products, drives the further expansion of worldwide reefer trades.

Hence, these fast-growing, high-value cargo flows become increasingly relevant for port- and container logistics- related actors, including port managing bodies (commonly referred to as 'port authorities'). Although this chapter takes a policy-oriented perspective, it should be noted that a major part of the transportation and handling processes is conducted by specialized private companies, including carriers, terminal operators, and logistics service providers. While port authorities (in their role as 'landlord', focusing on regulation and infrastructure management in the port area (World Bank, 2007)) are not directly involved with these physical processes, they do have an important facilitating role towards this segment, in terms of their responsibilities for port infrastructure, regulation, coordination, land use, and marketing. These port-managing bodies generally have statutory responsibilities to maintain and enhance the port's competitiveness, quality of service, and infrastructure, as well as to ensure the port's societal license to operate in terms of mitigating externalities and ensuring a trend towards more sustainable port activities. Nearly all port authority responsibilities have specific implications in the reefer market. Reefer containers, with their built-in refrigeration and monitoring and control technology and sensitive cargo, place more stringent demands on port infrastructure, energy supply, and handling processes than standard containers (Behdani et al., 2018). Moreover, the perishables logistics chains of which they are an integral part is characterized by issues of growing energy consumption and food loss and waste (FAO, 2011). Considering these myriad issues and responsibilities, port authorities have an important role to play, also in the reefer market, as they are the only actor in a port area that is problem owner of all issues arising related to the reefer chain, including competitiveness, efficiency, infrastructure, and sustainability. Therefore this chapter focuses on the policy dimensions of accommodating reefer containers and cold chain logistics activities in port clusters.

Extending from this is the question what measures port authorities can take to better facilitate the transportation of reefer containers and improve their competitive position in this market. While the academic literature on port competitiveness has addressed the question how (container) ports can become more attractive to port users, so far containers have generally been considered 'black boxes' – a homogenous commodity without much regard for differentiation in their contents (Rodrigue & Notteboom, 2015). However, ports compete not only for cargo volume, but for cargo added value as well (De Martino et al., 2015). Therefore a more differentiated perspective on container flows – and how ports can deal with these – is desirable, with attention for containers' contents (Castelein, Geerlings, & Van Duin, 2019). For policymakers and managers this is particularly relevant, as it allows better tailoring of policy and processes to the demands of specific cargo markets where this is necessary – such as the reefer market. By focusing on port policy directed at a specific container market segment, this study contributes new knowledge on how ports position themselves in specific supply chains (Robinson, 2002).

Moreover, this approach contributes an in-depth perspective on the policy measures at the disposal of port authorities to respond to challenges and opportunities in their environment. Strictly speaking, these organizations function not only as 'port authorities' (in a strict regulatory sense), but also as 'port managing bodies' or 'port development companies', depending on their scope and governance structure. 'Port authority' is commonly used as the generic term for the entity that manages a port area (Verhoeven, 2010), and for brevity this study will use this term throughout. Studies in port governance generally focus on governance models, institutional reform, and their outcomes (Borges Vieira et al., 2014). Most attention has been paid to the predominant port governance model, i.e. the 'landlord' port authority: a corporatized entity, often with public ownership, with a role that is limited to infrastructure and real estate management and regulatory functions while balancing public and private interests (World Bank, 2007). This demarcation of port authority roles appears to be in constant flux however, as developments in the global logistics sector may place new demands on ports that forces a reconsideration of port authority roles and functions (Heaver, Meersman, Moglia, & Voorde, 2000; Notteboom, De Langen, & Jacobs, 2013; Robinson, 2002; Verhoeven, 2010). Earlier studies suggested ways in which changing contexts could impel port authorities to broaden their scope to the foreland and hinterland (Dooms, Van der Lugt, & De Langen, 2013; Notteboom & Rodrigue, 2005; Van der Lugt, Rodrigues, & Van den Berg, 2014; Zhang, Zheng, Geerlings, & El Makhloufi, 2019) and extend their role beyond that of the landlord to for example being a cluster manager, facilitator, or entrepreneur (Hollen et al., 2015; Verhoeven, 2010). A recent contribution (Parola et al., 2018) provided a novel conceptualization of marketing strategies for ports to engage actively with relevant stakeholders, but remained abstract as to the concrete policy instruments available.

At the heart of this literature is the recurring question 'what can a port authority do?' However, the question how developments in ports' strategic scope are translated into tangible policy measures has received little attention in this body of literature. This relates to the issue of how a port authority can insert itself in specific supply chains and help create more value for the port cluster (Jacobs & Hall, 2007), as well as how to meet new demands that require a change in strategic scope. Verhoeven (2010) has introduced a theoretical framework for the functions a port authority may fulfill, and how the governance context, power position, and resources and capabilities of a port authority determine the actions a port authority may take in fulfilling these functions. Accordingly, Verhoeven proposes a typology of port authority roles ranging from a 'conservator' to 'facilitator' to 'entrepreneur' – a spectrum along which a port authority takes on a more active role in the supply chains the port services, takes on more different responsibilities (and risks) and widens its strategic scope geographically (beyond the boundaries of the port cluster). This study presents a novel empirical application of this framework by applying it to a new dataset covering the policies implemented by major container ports worldwide, specifically for the reefer market. Applying this framework to the case of the reefer market, this study sets out to answer the research question: "how can port authorities respond to challenges and opportunities in the reefer market, and what roles do they need to develop to implement these actions?"

The authors present a newly compiled dataset of reefer- and cold chain-related policies implemented by the world's 50 largest container ports. To the best of the authors' knowledge, this is one of the first studies that is based on systematically collected information on port policy content for a worldwide set of major ports (see Gonzalez Aregall et al. (2018) for another recent example). The dataset covers policy measures implemented by the largest container ports worldwide, and describes their contents in great qualitative depth (including instruments, activities, goals, scope, and participation of stakeholders). Drawing on this new rich dataset, this study addresses the question how ports can respond to challenges and opportunities in this niche market. The study surveys the policy measures implemented by the largest container ports in the world to identify the spectrum of measures applied. Using the detailed information collected on port policies, the study provides a typology of measures, and discusses these by type, scope, goal, port authority role and stakeholder involvement. In addition to classifying policy instruments, the authors discuss the conditions under which ports' strategic scope tends to extend. Through the novelty of the dataset collected, the detail of information, and the insights in port policy and port authority strategy obtained through examination and analysis thereof, the study contributes to the further development of port policy research. Furthermore, based on these findings the authors offer considerations on how ports can formulate and implement a coherent and comprehensive strategy for cold chain facilitation.

Section 6.2 outlines the background to the study, including relevant considerations regarding reefers for ports, and a general discussion of port governance and the policy instruments available to port authorities. Section 6.3 outlines the process of data collection and coding of the policy instruments found, after which section 6.4 presents the results. Section 6.5 discusses the implications of the findings, and section 6.6 concludes and offers some recommendations.

## 6.2 Background

Research on what ports can do to respond to opportunities and challenges in a developing market – such as cold chains and reefer transportation – has been limited so far. From the existing academic literature two aspects should be highlighted that are relevant to understand ports' policy options in this context. First, the relevance of reefer transportation for ports, and second, insights into how port governance shapes the extent of policy instruments port authorities have at their disposal.

**Cold chain considerations for ports**

Three characteristics of reefer container transportation and cold chains make this sector particularly relevant for ports. First is the rapid growth in the market, creating opportunities for ports to attract high-value cargo. Second is the crucial role of ports in reefer chains as locations of (de)-consolidation, multiple transfers of custodianship, and the associated risks. Third, reefer containers account for a considerable share of ports' energy consumption, making them a relevant consideration for ports' energy policy.

Growth in reefer container transport has for long strongly outpaced growth in standard or 'dry' container markets (Drewry Maritime Research, 2016b), driven by three factors (Riccardo Accorsi et al., 2014; Arduino et al., 2015; Behdani et al., 2018): First, as incomes increase worldwide, people tend to increase their consumption of exotic, non-local food, and demand this regardless of seasonality. Secondly, due to improved preservation techniques and the cost-competitiveness of reefer container transport, there is a modal shift of temperature-sensitive goods away from air transport and conventional reeferships towards reefer containers, with 85% of the maritime perishables trade expected to be transported in reefer containers by 2021 (Drewry Maritime Research, 2017). Third, as reefer containers become more ubiquitous, the range of goods transported in them is expanded with cargoes that would not have been transported under refrigeration by plane or conventional reefership. These miscellaneous goods range from sensitive electronics to sneakers with temperature-sensitive

glue and even live lobsters. Due to these developments, the use of reefer containers worldwide increases, and their range of uses expands.
To consider the role of seaports in (containerized) cold supply chains, it is important to first outline what the typical cold chain looks like in terms of processes and actors involved. In their essence, cold supply chains are characterized by the need for the product to be kept continuously at a specific temperature at which its quality is preserved optimally, or at least within a tolerable range around this desired temperature (Behdani et al., 2019). Each product has its own temperature and atmosphere requirements, such as frozen fish that is to be stored around -30°C (or even -60°C in some cases) and bananas that need to be kept at a temperature within a narrow range around 13-14°C with the additional need for atmosphere control to prevent early ripening due to excreted ethylene. For long-distance, intercontinental transport of temperature-sensitive goods with a maritime leg, intermodal reefer containers have become the standard load unit. In a cold chain with reefer container transportation, the vast share of the transportation distance– from container stuffing in the region of origin to stripping at the destination – is covered with the cargo inside the container. Figure 6.1 shows the steps involved in a cold logistics chain with a containerized part.

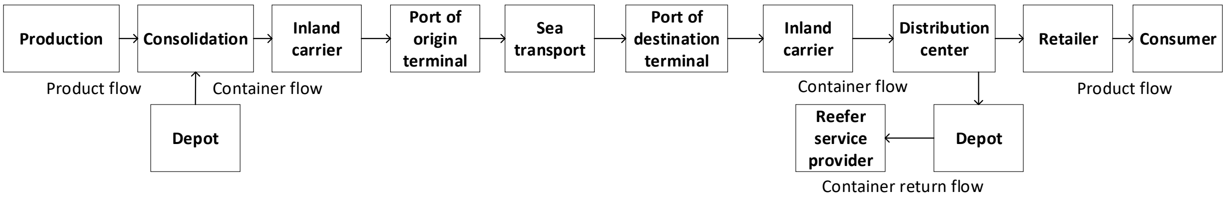


**Figure 6.1. Schematic overview of containerized cold chain processes.**

Source: elaborated from Castelein et al. (2020).

In this stylized example we assume intercontinental transportation of a perishable cargo (based on the outline sketched by Castelein et al. (2020)). The product is produced in the region of origin, stored temporarily (cold storage), and consolidated in a reefer container, coming from an empty depot. From this point onwards the cold chain cargo is containerized, i.e. a reefer chain. From the point where it is consolidated, the container is transported to a port, and loaded onto a deep-sea vessel at a container terminal. The vessel sails from the port of origin to the port of destination – usually a journey of several weeks – where the reefers are unloaded at a terminal and transferred to hinterland modalities (truck, barge, or rail) for transportation further inland. At a distribution center (either within the port cluster or further inland) the container is stripped, after which the cargo is distributed further, if necessary with further processing in between. Once stripped, the empty reefer container is returned to a depot, perhaps stored, and cleaned, maintained, and inspected (the so-called pre-trip inspection or PTI) before being allocated to another shipper. It should be emphasized that Figure 6.1 only outlines the physical processes and the actors involved (i.e. producer, shipper, consignee, transportation service provider, terminal operator, carrier, cold store operator). To facilitate this physical process, administrative, transaction, and governance processes are implemented by various stakeholders, many of which are not directly involved with the physical supply chain processes (Van Baalen et al., 2008). On the governance side, this includes customs and inspection authorities, and port managing bodies (port authorities), and on the transaction side shipping agents, forwarders, banks, and insurance companies that perform coordination and administrative functions. As far as these chains pass through seaports, the physical activities take place within the jurisdiction of port managing bodies. The extent to which these activities take place within port areas can differ however, in particular the consolidation and distribution. The transfer from inland carrier to the port terminal and from the terminal to the deep-sea container vessel (at the origin) and vice versa (at the destination), depot processes and reefer servicing usually take place inside the port cluster, but in many cases also consolidation and distribution centers are located in or near port areas. Considering the number of steps in the chain that are directly port-related, the port clusters are highly relevant for cold supply chains.

While a port is only a localized cluster in a global cold chain, they are a critical point where reefer containers are disconnected from their power supply, transferred, and re-connected at several points within the port, and possibly stripped or stuffed with new cargo in cold stores. These transfer points, where the container is disconnected from an energy supply while at the same time the custodianship shifts from one chain actor to another, are typically the points where the risk of the cold chain being broken is greatest (Fitzgerald et al., 2011).

Another consideration is the relevance of reefers for port's energy policy. Ports tend to be clusters of energy-intensive (industrial and logistics) activities, energy transport, and power generation ('energy hubs'), while sustainability considerations also place demands on ports to control their emissions and environmental impact. All these demands should be taken into account in port authorities' policymaking (Acciaro, Ghiara, et al., 2014). For cold chains overall, approximately 20% of all energy consumption is used for cargo refrigeration (Fitzgerald et al., 2011). At container terminals, energy consumption of reefer containers is responsible for 30-35% of total energy use, and the prime driver behind energy demand peaks (Van Duin et al., 2019, 2018). Considering recent developments such as the Paris agreement of 2015 stressing the importance of reducing $CO_2$ emissions, challenges arising from the energy footprint of refrigerated logistics deserve the attention of port authorities.

**Port governance and policy options for port authorities**

The reefer sector poses opportunities as well as challenges for port-related actors and port authorities. Notwithstanding that private sector companies (e.g. carriers, terminal operators, logistics service providers) undertake initiatives in the way of supply chain optimization and exploring new markets independently from policy, as outlined in the introduction this analysis focuses on the policy dimensions relevant for the role of reefer container supply chains in port areas. In addressing the policy dimension, one should consider the set of instruments available to port authorities to respond to these developments. This entails considerations regarding port governance, strategy-making, and policy options.

The World Bank (2007) distinguishes several governance models, with the 'landlord' port being the most commonly observed and generally recommended. There has been considerable discussion in the literature whether this is the best model for port authorities in a period of significant change in the logistics environment, and what their role relative to the supply chains they service should be. Major external factors include consolidation in the liner and terminal operator sector (Heaver et al., 2000; Notteboom, 2002; Panayides & Wiedmer, 2011) and the tendency of supply chains becoming more interconnected and footloose (Robinson, 2002). In different contexts and conceptualizations, authors have made arguments for ports to broaden their strategic scope, resulting in roles and concepts such as the 'entrepreneurial port developer,' 'facilitator', 'ambidextrous port', 'cluster manager,' and the 'extended landlord port model.'

Port authorities operate to meet a diverse spectrum of strategic goals, inspired by their hybrid nature, with characteristics of a public as well as a private organization (Van der Lugt et al., 2013; Verhoeven, 2010). These goals include straightforward financial performance criteria, ensuring the competitiveness of the port cluster, sustainability goals, and meeting responsibilities to a wide range of stakeholders. The latter include national and local government, the national logistics sector, port users, and regional inhabitants. Drawing on

Cochran and Malone's (2014) definition of policy actions as "decisions for implementing programs to achieve […] goals," in the seaport context the port authority can use a range of policy instruments to realize these various strategic goals (Hollen et al., 2015). These options are now discussed for the different roles a port authority can take.

In the traditional 'landlord' model, the port authority manages land concession agreements, has a regulatory role, and is responsible for port infrastructure (World Bank, 2007). Research so far has identified several ways in which port authorities extend their roles, either by using 'traditional' landlord policy instruments in innovative ways, broadening their strategic scope beyond the port boundaries, or by engaging in previously unexplored activities (Notteboom, De Langen, et al., 2013; Verhoeven, 2010). Concession agreements are not only used as a source of income for port authorities, but can also be used to incentivize port user behavior that is desirable from the perspective of the port authority's other goals (e.g. achieving a certain modal split to reduce emissions and congestion) (De Langen et al., 2012; Notteboom & Verhoeven, 2010). The role of regulator can also be extended into standard-setting to further the port's societal goals (Lam & Notteboom, 2014) or signal and address market failures. Another dimension of port policy development is a broader conception of what constitutes infrastructure. While physical infrastructure is traditionally within the scope of the landlord port authority, more entrepreneurial port authorities also invest in 'knowledge infrastructure' (Hollen et al., 2015), including information technology (Cepolina & Ghiara, 2013) inter-organizational relations, collaboration, and connectivity (De Martino & Morvillo, 2008; Hollen et al., 2015), and innovation (De Martino et al., 2013). When a port authority extends its role into that of a 'cluster manager' or 'community manager', other considerations play a role as well, such as the mix of activities (co-)located in a port, intra-port inter-organizational relations, and possible co-siting of activities that could benefit from one another's proximity (Hollen et al., 2015).

In a supply chain-oriented logistics environment, port authorities that are aware of their position in global supply chains want to undertake actions that help better integrate the port and port actors in these chains. These actions include data-sharing technologies, development of relationships with foreland and hinterland actors, pursuing value-added activities, and improving connectivity (Song & Panayides, 2008). Essentially any national or regional, public or private stakeholder – domestic or abroad – can be within the scope of targeted marketing efforts of port authorities (Parola et al., 2018). Specifically, cooperation between (semi-)public port authorities with private sector stakeholders (with varying degrees of commitment) are key instruments for port development (Dooms, Verbeke, & Haezendonck, 2013; Panayides, Parola, Siu, & Lam, 2015).

Geographically, an entrepreneurial port also considers areas outside the port cluster (i.e. its hinterland or foreland) to be within its strategic scope. This includes outreach to its own hinterland to improve connectivity – 'regionalization' of the port (Notteboom & Rodrigue, 2005) – or the development of the hinterland region itself (Cahoon, Pateman, & Chen, 2013). Also towards the foreland, research has shown evidence of internationalization of port authority strategies (Dooms, Van der Lugt, et al., 2013).

These aspects and respective evolutions of port authority functions and responsibilities have been incorporated in a conceptual framework by Verhoeven (2010). He distinguishes four port authority functions, namely the traditional landlord, regulator and operator functions and that of community manager, in which the port authority takes on more coordinative and stakeholder management responsibilities (e.g. addressing bottlenecks, implement ICT solutions, marketing, ensuring the port's societal 'license to operate'). Furthermore, he distinguishes the broadening of port authorities' strategic scope at three levels, ranging from the port cluster itself (local), regional and global. From this framework, labeled a 'renaissance matrix,' three hypothetical roles of port authorities arise: the conservator (strictly limited to traditional functions and responsibilities as a landlord, regulator and operator, local scope), the ‘facilitator’ (with a better-developed community manager function and a local and regional scope) and the ‘entrepreneur’ (with commercial aims and a local, regional, and global scope in all functions). Verhoeven labels these ‘types,’ but perhaps the term ‘role’ is more appropriate, as these features do not have to be constant across policy domains: a port authority may act as a conservator in one domain, and as an entrepreneur in another. The dimensions of this ‘matrix’ are shown in Table 6.1:

**Table 6.1. Port authority ‘renaissance matrix.’**

| Type / Function | Conservator | Facilitator | Entrepreneur |
|---|---|---|---|
| **Landlord** | | | |
| **Regulator** | | | |
| **Operator** | | | |
| **Community manager** | | | |
| **Geographical scope** | Local | Local, regional | Local, regional, global |

Source: Based on Verhoeven (2010).

Features and activities of port authorities in terms of scope, responsibilities, and aims can be placed in this matrix, corresponding to a certain type/function combination. Verhoeven goes on to hypothesize that four factors determine the type of features and activities a port authority will exhibit, namely its power position relative to government, the autonomy and responsibilities legally accorded to it, its financial capabilities, and its management culture. Furthermore, Verhoeven expects port authority features to change over time, due to changes in the market environment and in the governance context.

The question to be addressed with this framework in mind is how port policy is used to respond to growing opportunities and demands in the reefer market, and accordingly what roles port authorities need to develop to implement these policies. The next section outlines the data collection process for the new dataset on which this study will draw, and the analytical approach of the study.

## 6.3 Data and approach

### Case selection

To obtain an overview of what is done globally by ports to address the challenges and opportunities arising from a rapidly growing, high-value reefer market, the study draws on information from the world’s 50 largest container ports (Lloyd’s List, 2017) – as inspired by the ‘global review’ of hinterland-oriented green port strategies by Gonzalez Aregall et al. (2018). To the best of the authors’ knowledge, this type of study (a worldwide inventory of policies pursued by major port authorities) has been conducted only rarely so far. The motivation to scrutinize the largest container ports globally is twofold. First, they likely have the highest absolute numbers of reefer containers passing through the port, and hence the greatest incentive and possibility to implement (scalable) policy measures aimed at the reefer market. Second, the largest ports tend to have the greatest strategic scope, financial means and considerable national and regional political clout that allows them to implement a broad selection of policies that are generally not pursued by smaller ports, particularly towards the port’s foreland and hinterland. These multi-purpose gateway ports are also, according to Verhoeven (2010), most likely to expand their roles and extend their geographical scope. For each of the 50 ports, the authors collected information on the measures taken to facilitate reefer transportation and cold chain logistics.

**Data collection**

The starting points of data collection were ports' official (English) web pages, annual reports, and press releases. The authors did not impose a limit on the time period in which the identified measures were implemented or published, since the reefer container market has only fairly recently grown to significance. The measures found were generally not dating back further than 10-15 years. To omit the limitation of only consulting documents released directly by port authorities, the authors also consulted secondary sources for relevant policies, including academic research, professional publications, and news releases. These secondary sources were searched for through Google (Scholar), using the name of the port and variations of search terms related to reefer- and cold chain transportation (e.g. 'reefer', 'refrigerated', 'cold', 'cool', 'conditioned', 'temperature', 'fresh', 'frozen', and 'perishable'). For each port, these primary and secondary sources were searched until no new information was found, and all reefer-related policies were recorded and compiled. Only those policy initiatives were included of which it was clear that they were specifically aimed at facilitating the handling and transportation of reefer containers (e.g. policies targeting dry container transport or container transport in general without specific attention for reefer containers were not included.

It should be emphasized that this sampling approach does not guarantee that no relevant action has gone unnoticed. There may be relevant actions pursued by port authorities, but for one reason or another not publicized, hence remaining 'unknown unknowns.' For two reasons however, the authors consider this risk limited. First, ports that take action to improve their position in cold chains are likely keen to advertise this, either to catch the attention of potential users, or to advertise their efforts towards a broader goal (e.g. sustainability goals). Secondly, the study focuses on the world's largest ports: large organizations, with large amounts of reefer throughput, hence large-scale reefer-related policy actions, and considerable visibility to national and international industry, media, academia, or other parties that could – in one form or another – make mention of relevant developments. Despite these considerations, the sample may be biased towards including policy measures from those ports with the most accessible English-language information provision. This does not need to be a problem however. Since the goal of this study is to evaluate the full spectrum of policy measures available to ports, one overlooked action by one port authority– though not preferred – will likely enter the inventory through the use of a comparable action by another port due to benchmarking competition.

**Data recording**

All reefer- or cold chain-related actions by port authorities were compiled, each action constituting one observation in the sample dataset. Some actions were not coded as port policies, for example simple requirements to handle reefer containers such as constructing reefer racks and plugs, performing plugging and unplugging services, and the availability of reefer servicing and container inspections (PTIs, or pre-trip inspections). Moreover, actions by private sector companies or government agencies in which the port authority itself was not involved were not counted as port policy – even though public-private partnerships with port authority involvement were included. Third, multiple initiatives stemming from the same policy (e.g. subsidizing multiple barge connections, specifically for reefer transport, as part of the same program) were still counted as one policy.

For every policy identified, as much information as possible was recorded. First the policy instrument itself. Secondly the geographical scope of the policy, distinguishing between actions taken inside the port cluster, towards the hinterland or foreland (the so-called foreland-seaport-hinterland triptych (Ducruet et al. (2010) citing Vigarie (1968)) or impacting the cold chain in its entirety. Third, if mentioned in the information provided, the goal of the policy. Fourth, where applicable, the stakeholders with which the port authority partnered in implementing the policy. Furthermore, to classify the policies, they were coded for the dimensions included in Verhoevens' (2010) framework as outlined in Section 6.2, namely function (landlord, regulator, operator, community manager), role (conservator, facilitator, entrepreneur), and geographical dimension (local, regional, global – a spectrum with similarities to the geographical scope recorded in terms of the foreland-seaport-hinterland triptych, but not taking into account the direction of the cargo flow through the port from foreland to hinterland). Aside from these information categories, extensive notes were taken on all other information found regarding the policy in question.

**Analytical approach**

Even though the data collection process was aimed to be comprehensive, the risk of omissions and (availability) biases in the data precludes findings being proven with statistical significance or statements about causality being made. Also details about the performance of policy measures are generally not available, making quantification of costs and benefits of policies infeasible.

Instead, this study takes an inductive approach to the research question – how can port authorities respond to opportunities in the reefer market? – with the available information from a broad sample of ports. From a classification of the diverse policy measures encountered, we outline the instruments potentially available to port policymakers, while recognizing that institutional arrangements may limit port authorities' access to some of these instruments. Following a case study approach, we aim to identify patterns in the data, and formulate propositions on how port policy instruments, goals, and scope may be related (Yin, 1994).

The research question formulated in the beginning of this chapter is twofold: 1) "how can port authorities respond to challenges and opportunities in the reefer market, and 2) what roles do they need to develop to implement these actions?" The first question invites a predominantly descriptive answer, based on the policies recorded and their characteristics. In addition, based on the outline of the reefer market, typical containerized cold chains and the challenges for seaports formulated in section 6.2, a discussion will be possible of where the focus lies of policymakers, and possible blind spots of issues and/or stakeholders that are not (yet) within the scope of port policy. For the second part of the question, as a corollary to the first, the framework as introduced in Section 6.2 will be used to classify the port policies found. The policies included are coded for the dimensions included in Verhoeven's conceptual framework (port authority function, type (role), and geographical dimension) and placed in the framework. Based on the overall pattern, conclusions can be drawn about what roles port authorities are taking in implementing these measures. Moreover, this analytical approach facilitates discussion of what would be required from port authorities to pursue reefer chain issues that are so far not within the scope of port policy. Ultimately, this exercise will also yield insights into the extent to which the 'renaissance port authority' framework is suitable for analyzing port policy in a specific domain, and whether there are conceptual issues to be addressed in the further development of this framework for empirical applications.

## 6.4 Findings

This section details the findings from the new dataset, starting with some general descriptive information on the ports and policies found.

**Dataset summary**

Before discussing substantive findings, the general characteristics of the data deserve some attention. Of the 50 container ports surveyed, for 35 ports at least one reefer- or cold chain-related measure was recorded, obtaining a sample of 72 individual measures in total. Most individual policy measures (6) were recorded for the Port of Rotterdam (Netherlands). The other ports with the most distinct measures were the Port of Antwerp (Belgium) (5) and the Port of Dalian (China) (4).

Plotting the number of measures identified against the ports' rankings from Lloyd's List (Figure 6.2) shows that the ports that implement relatively most measures (3 and more) also tend to be the larger ports in terms of container throughput (the correlation between ports' Lloyd's List rank and the number of measures identified is -0.25, indicating a weak negative correlation, showing that as rank drops from 1 to 50, the number of measures tends to decrease). This skewness suggests that it makes sense to starts with the world's largest ports when compiling such a policy inventory. It should be noted here that the number of different policies is not necessarily indicative of the magnitude of resource commitment or impact, but rather of the diversity of the policies implemented.

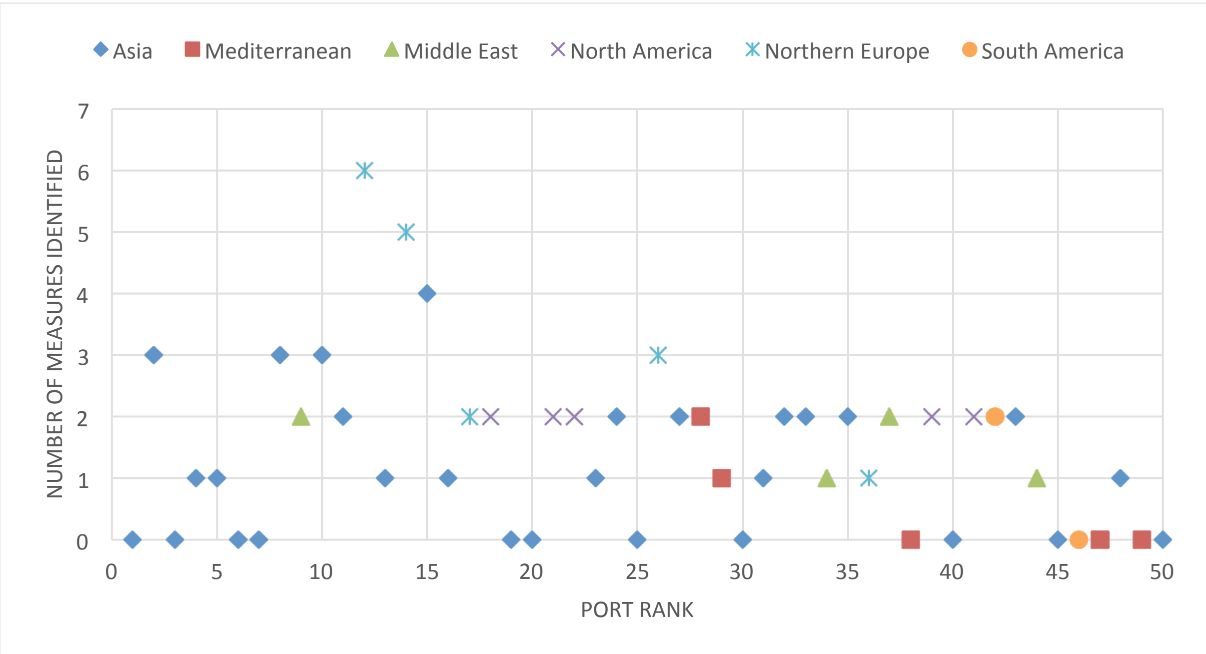


**Figure 6.2. Number of reefer-related measures by port ranking and region.**

Source: Own compilation, based on Lloyd's List (Lloyd's List, 2017)

Another important aspect is the geographical distribution of the investigated ports. Expanding the distinction in Figure 6.2 between ports in different regions, Table 6.2 below shows the number of ports per region and the average number of reefer or cold chain-related measures found per port. The regional categorization is adapted from the original source of the ranking (Lloyd's List, 2017), with Europe further divided into North-Western Europe (European Atlantic, North Sea, and Baltic) and the Mediterranean.

Most ports are located in Asia, which may lend a regional bias to the sample. It also deserves attention for which ports little or no policy measures could be found. This can be either due to their absence, or due to limitations in the port's information provision, in which case this is a blind spot in this investigation. Figure 6.2 shows that for 4 ports in the top 10, zero measures could be identified. These ports are Shanghai, Shenzhen, Hong Kong, and Guangzhou – all in China, suggesting that there may be a structural reason for lack of information – even though other top 10 Chinese ports, such as Ningbo, Qingdao, and Tianjin provide plenty information. Also for the Mediterranean ports relatively few relevant policy measures are recorded. This can be expected to be due to the transshipment focus of the larger container ports in the region (Piraeus, Marsaxlokk, Algeciras, and Port Said are considered to be transhipment hubs with transhipment incidences over 65% (Notteboom, Parola, & Satta, 2019)), which have a smaller market for hinterland-oriented policies or value adding activities. Furthermore, it may be that perishables exports from Mediterranean regions go predominantly to other destinations in Europe, for which land transport may be preferred. If this hypothesized explanation is true, reefer- and cold chain-related policy may not be as relevant for ports in these regions. Clearly, for North-Western European ports (notably Antwerp, Rotterdam, Bremerhaven, and Hamburg) most distinct measures were identified on average.

**Table 6.2. Regional breakdown of findings.**

| **Region** | **Number of ports** | **Number of ports recording zero measures** | **Average number of measures recorded per port** | **Minimum** | **Maximum** |
|---|---|---|---|---|---|
| Asia | 29 | 11 | 1.2 | 0 | 4 |
| Mediterranean | 5 | 3 | 0.6 | 0 | 1 |
| Middle East | 4 | 0 | 1,5 | 1 | 2 |
| N. America | 5 | 0 | 2 | 2 | 2 |
| NW. Europe | 5 | 0 | 3.4 | 1 | 6 |
| S. America | 2 | 1 | 1 | 0 | 2 |

Source: Based on Lloyd's List (2017).

Another potential limitation of the data also shows from this breakdown, namely that two major export regions for reefer cargoes (Latin America and Africa) are quite underrepresented. This is due to the fact that these regions have numerous smaller, specialized reefer ports, some only serving a few clients (see for example the report by Dynamar (Dynamar, 2017)). In this light, it is useful to verify the extent to which the top 50 overall container ports are important reefer ports, and compare them with major reefer-handling ports outside the top 50 (notably in Latin America and Africa, which are underrepresented in the sample). Unfortunately, worldwide data on the share of reefer containers in a ports' container throughput is not available. To give a rough indication of the absolute numbers and the relative importance of reefer containers in ports' throughput, we can compare the number of reefer plugs in top 50 ports and major reefer ports outside the top 50 (in this case being a major port in a country with major reefer exports, such as Chile, Ecuador, Argentina and South Africa – the closest approximation of what constitutes an important reefer port, given the availability of data) (Table 6.3). It should be noted that this breakdown is based on data availability (even for major container ports, information on the number of reefer plugs is scarce), and should serve as a rough indication of absolute and relative importance of reefer containers in ports' container throughput, all based on the assumption that a greater number of reefer plugs corresponds with a greater number of reefer containers.

**Table 6.3. Comparing the of reefer plugs for select top 50 and non-top 50 container ports.**

| Port | Country | Container throughput (TEU) | Reefer plugs | Reefer plugs per 100,000 TEU throughput |
|---|---|---|---|---|
| Included in top 50 | | | | |
| Singapore | Singapore | 36,600,000 | 12,000 | 33 |
| Qingdao | China | 18,010,000 | 5,976 | 33 |
| Rotterdam | Netherlands | 14,800,000 | 18,500 | 125 |
| Antwerp | Belgium | 10,400,000 | 8,000 | 77 |
| Colon | Panama | 3,900,000 | 4,100 | 105 |
| Santos | Brazil | 3,600,000 | 6,000 | 167 |
| Not included in top 50 | | | | |
| Guayaquil | Ecuador | 1,800,000 | 5,000 | 278 |
| Buenos Aires | Argentina | 1,500,000 | 3,000 | 200 |
| Valparaiso | Chile | 1,100,000 | 3,700 | 336 |
| Cape Town | South Africa | 888,976 | 4,000 | 450 |

Source: Various (Drewry Maritime Research, 2016b; Dynamar, 2017; Lloyd's List, 2017)

There are two main takeaways from this. First, the container ports in major food exporting countries have relatively more reefer plugs (as in, more reefer plugs per 100,000 TEU of throughput). This is especially true for the smaller, non-top 50 container ports in Latin American and Africa, that tend to have relatively larger numbers of reefer plugs compared to the ports included in the top 50. The same variation however is also present among the top 50 container ports: the comparison between Santos, Colon, and Rotterdam (all top 50 ports located in food exporting countries) and other ports in the top 50 (Singapore, Qingdao, Antwerp) shows that ports in food exporting regions have relatively more reefer plugs, and can be expected to have a larger share of reefer containers in overall container throughput. So overall, the top 50 container ports are not as specialized in reefer cargoes as smaller ports in major exporting regions. Secondly however, in absolute terms the top 50 container ports (especially the larger ones) tend to have greater total volumes of reefer containers than the non-top 50 ports considered – again assuming that a larger number of reefer plugs corresponds with a larger number of reefer containers passing through the port. The conjecture that the largest container ports have larger overall reefer throughputs than smaller container ports with a larger share of reefers, is supported by the observation that the largest container ports perform a hub function and serve as import gateways to major importing markets. For the purpose of this investigation with an explicit focus on port policy, the world's major container ports are the most interesting, not only because of the larger absolute numbers of reefer containers being handled there, but also because these multipurpose gateway ports tend to be governed by port authorities with greater resources, capabilities, and scope than the managing bodies of small, specialized ports.

The three sections below classify and discuss the cases of cold chain policies according to three dimensions: policy goal, scope, and stakeholder involvement.

### Policy goals

The sampled ports show a broad range of goals behind port policies, beyond commercial goals such as throughput, market share, or cargo added value. Not all measures recorded were accompanied by a statement explaining the goal. Some ports report a generic or instrumental goal (e.g. 'improve efficiency,' 'serve customers better'), without mentioning the final goal (e.g. sustainability goals, market share, trade facilitation, export development etc.). Where such a specific final goal was reported, this was recorded in the dataset, along with other relevant notes. Roughly, the stated goals can be labeled as relating to sustainability, food safety, trade facilitation, efficiency improvements, and increasing competitiveness. Table 6.4 below shows these goals with a few specific examples (not exhaustive) of port policies implemented with that goal.

**Table 6.4. Possible goals of reefer-related policies and examples of ports reporting a certain goal (not exhaustive).**

| Goal | Example policies | Example ports |
|---|---|---|
| Food quality/safety | Cooperation with national customs and inspection agencies for quality monitoring and pest control | → United States, Indonesia, China. |
| | Aim of establishing a 'halal hub' with quality control and certification | → Port Klang |
| Sustainability | Energy use of cold stores: shift to renewable energy | → Bremerhaven (Ger.) |
| | Modal shift away from trucks, stimulate use of barge and rail for reefer transport | → Antwerp, Rotterdam, Long Beach, Valencia, Dalian |
| | Reduce congestion: expedited treatment of trucks with reefers, exemptions from restrictions, modal shift | → Long Beach, New York/New Jersey, Seattle/Tacoma, Manila |
| | Reduce food waste (various monitoring and control initiatives) | → Hamburg, Singapore |
| Trade facilitation (national) / support domestic perishables-producing sectors | Cold chain policies as part of nationwide plan to improve post-harvest distribution system | → Indonesia, Japan, India, Taiwan, China |
| | Improve connectivity of exporting regions | → Rotterdam, Los Angeles, Santos |
| More efficient service to customer | Expedited clearance by customs and inspection agencies; prioritization of trucks picking up reefers at terminal gate | → Long Beach, New York/New Jersey, Seattle/Tacoma, Manila, Tanjung Perak |
| | Container tracking within the port or worldwide | → Hamburg, Singapore |
| Increase competitiveness (market share, value added) | Marketing: Host trade shows for perishables traders | → Hamburg, Algeciras |
| | Marketing: outreach to shippers | → Multiple |
| | Co-invest in cold stores with value added logistics activities | → Multiple |

Some specified policy goals (as stated by the port authorities themselves) can be considered instrumental goals, the achievement of which contributes to achieving a higher strategic goal. For example, some port authorities (e.g. the port of Jeddah) aim to reduce the dwell-times of reefer containers (specified policy goal), but remain unclear whether this is to reduce energy use, make better use of existing infrastructure, to prevent product spoilage, or several of these (final) strategic goals. A similar example is the reduction of congestion (stated policy goal), which can be aimed for with sustainability or efficiency goals in mind, or to circumvent the need for additional infrastructure investments.

The following general observations can be made based on these goals. First, many ports are aware of the myriad sustainability considerations related to reefer containers, and various ports take multiple measures addressing one or more of these aspects. Second, some goals may conflict, while others may produce attractive synergies. An example of conflicting goals is intensified customs and quality controls, which typically entail longer time in transit for larger amounts of cargo – as is the case in Indonesia. Nevertheless, in this case ensuring the quality and safety of imported goods trumps the transit time benefits of less intensive inspections. Conversely, ports can achieve synergies between policies addressing efficiency and sustainability goals, as smoother handling and shorter time in transit generally reduces overall energy consumption and reduces the risk of product waste. A frequently observed example of a policy aimed at such synergies is the establishment of cold logistics clusters: the co-siting of cold storage, value added logistics, customs and quality inspections, and reefer servicing at a location with good intermodal connectivity. The clustering of these related functions reduces intra-port transportation distances (improving efficiency as well as reducing transportation emissions) and reduces the risk of cold chain breaks. Third, a considerable number of ports pursue policies aimed at trade facilitation, and often more specifically export stimulation. Particularly in Asia (India, Malaysia, Taiwan), these port policies are often tied in with a nationwide plan to improve post-harvest distribution systems, addressing both export competitiveness and domestic food security. In Europe and North America ports are also improving connectivity with main agrifood export regions, but in these regions there is less evidence of a nationwide government-led plan, and the focus seems to be predominantly on export competitiveness.

**Categorizing reefer policies by geographical scope**

The policy measures can be differentiated by their scope: some of the most broad-scope measures impact on the cold chain overall, whereas others are limited in scope to the port cluster itself, the port's foreland, or the port's hinterland. A port authority can extend its role beyond the landlord to a greater (e.g. being more entrepreneurial by taking on financial risk) or lesser degree (e.g. limited to infrastructure provision, regulation, and basic port services), and also geographically by pursuing policies beyond the boundaries of the port authority's jurisdiction. Figure 6.3 below classifies the reefer-related measures observed by their scope, and lists the (number of) ports that implement the type of measure. Where a similar policy was observed in multiple ports (e.g. 20 different port authorities (co)-investing in cold store capacity), a generic description of the policy is shown. It should be noted that this visualization of the geographical scope of port policy is not based on any assumptions about ports' governance models or strategic scope, but only shows the type of policies that the examined real-world port authorities pursue in different geographical dimensions relative to their ports. These dimensions can be conceptualized as the 'foreland-seaport-hinterland triptych' (Ducruet et al. (2010), citing Vigarie (Vigarie, 1968)) – a geographical representation of a seaport's position as a node in logistics networks extending further towards its foreland and hinterland. The extent to which an individual port authority's strategic scope extends beyond their port cluster boundaries depends on that port's governance model, and the port authority's scope, goals, resources, and capabilities. Due to these differences, policies shown in Figure 6.3 to be implemented by one port authority may not be feasible to pursue by another.

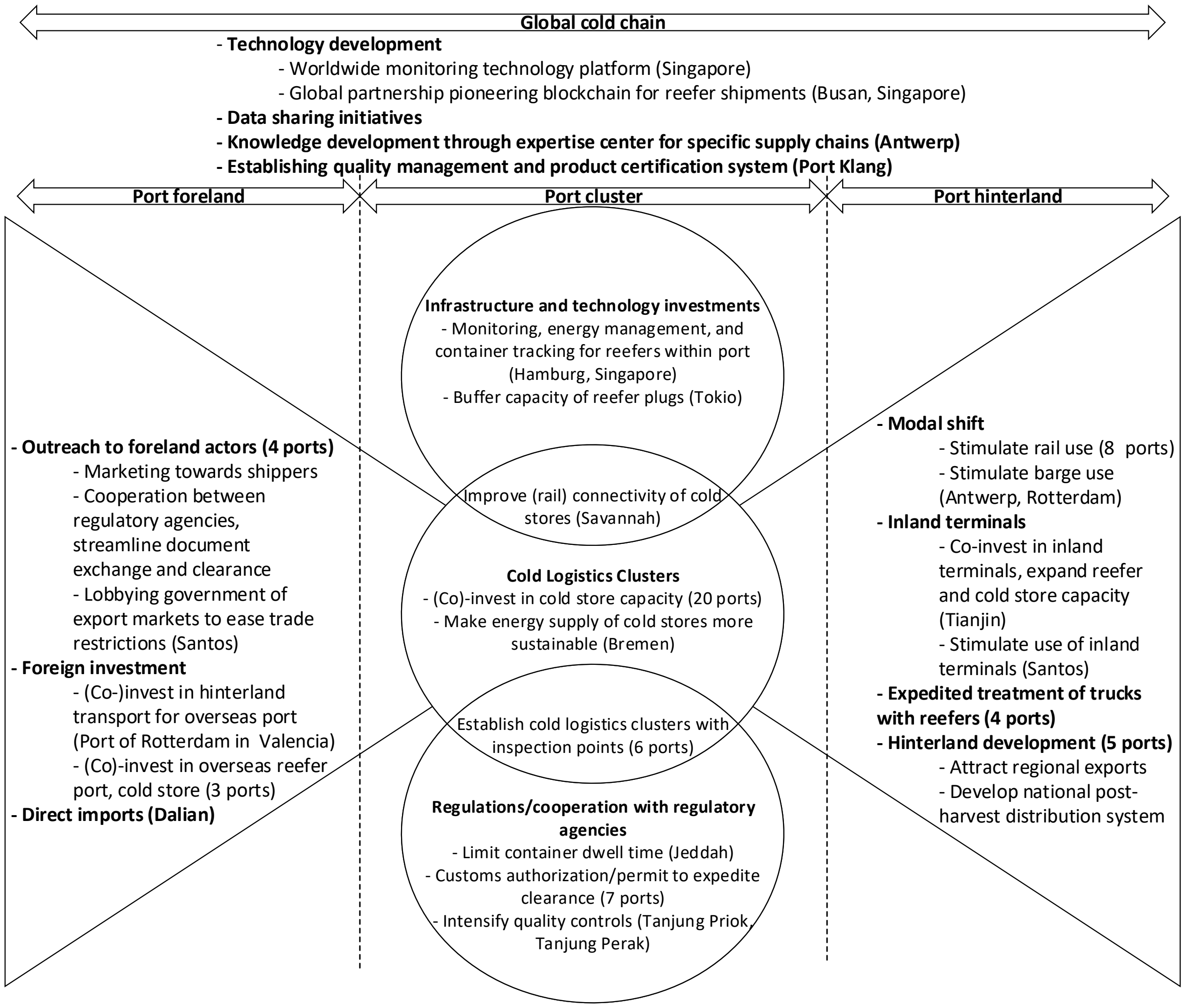


**Figure 6.3. Schematic overview of the full spectrum of port policies for cold chains.**

*Policies for the port cluster*

The greatest diversity of observed policy measures is within the port cluster itself – within the scope of the most limited 'landlord' port governance model. The most frequently observed measure is port authority involvement in the construction of cold storage capacity through their landlord and/or operator roles. Although in some cases the port authority plans, constructs and operates the cold store by itself, in most cases this takes the form of public-private partnerships with various degrees and types of port authority involvement. Some port authorities (e.g. Ningbo-Zhoushan, Qingdao, Jeddah) (co-)invest in cold store facilities in a joint venture with one or more private sector counterparties, whereas others participate in these projects by tailoring land concession policies towards a clustering of cold chain activities (e.g. Rotterdam, Tianjin). This type of cluster policy includes customs and inspection facilities and reefer servicing being co-located with cold stores, streamlining cargo clearance and container servicing. Frequently, these clusters are set well-connected intermodally. For example, in the Port of Rotterdam cold logistics facilities in the 'coolport' cluster are located in the proximity of barge and rail terminals, or even have their own quayside to handle barges. Furthermore, this cluster was set up in the proximity of container depots, ensuring reefer storage and servicing facilities nearby. Whereas the Rotterdam 'coolport' cluster is an example of a location decision being based on pre-existing functions in the area, other ports (for example Long Beach and New York/New Jersey) extend the port rail network with newly constructed sidings to cold storage facilities and reefer quays. There is

little evidence of ports being actively involved in the energy management of port-based cold chain functions, with the exception of Bremerhaven undertaking a project to power cold stores with newly constructed wind turbines.
In their regulatory function, port authorities can also impact upon the reefer flows through the port. Some observed measures include the expedition of customs clearance – in cooperation with customs and inspection agencies and select shippers. This can take several forms, ranging from co-locating regulatory inspection points with cold logistics facilities (e.g. Tianjin) to assisting port-based companies to obtain import authorization from regulatory agencies (e.g. Dalian, Tanjun Priok, Savannah, Taican). In these cases the port authority acts as a facilitator towards other agencies and port-based companies, but in other cases the port authority itself acts as an enforcer of regulation. One example of this is a crackdown by the port authority of Ho Chi Minh City on dangerous counterfeit refrigerants being used for reefer maintenance. As regulators, port authorities can also facilitate quicker handling and transport of reefer containers specifically, either by actively enforcing existing regulation or establishing new regulation. One port authority (Jeddah) regulates the dwell times of reefer containers at the port’s terminals to stimulate quick pick-up. Other ports allow off-hours pickup of reefer containers at terminals (Long Beach, New York/New Jersey, Seattle/Tacoma) or establish dedicated express lanes for trucks carrying reefers (Manila)
Port authorities can also gear infrastructure policies towards reefer and cold chain facilitation. For example, the Port of Tokyo provides government subsidies to increase the number of reefer plugs within the port, and the Port of Savannah has a strategic plan to keep the port’s reefer plug capacity always at 20% above regular demand. More sophisticated infrastructure policies also affect the energy mix with which reefers and cold stores are provided (e.g. cold stores in Bremerhaven being supplied with wind power). In this case the port authority acts more as a facilitating community manager, mediating between port users, energy companies, and grid operators, rather than a direct infrastructure developer. In a similar role, port policies are observed that actively facilitate knowledge exchange and coordination by acting as a matchmaker and mediator between firms. For example, the Port of Antwerp has set up an expertise center for cold supply chains through the port, bringing together a network of regional producers, shippers, and service providers.

*Foreland policies*
The simplest policies directed towards the foreland come in the form of outreach or marketing to overseas shippers. This can be general marketing efforts (e.g. by organizing conferences for the international perishables sector, as Bremen and Algeciras actively advertise), or directed efforts towards shippers in specific regions and sectors (e.g. the port of Salalah actively engaging with African horticulture companies to attract transhipment traffic). More entrepreneurial ports also direct their investment policies towards the foreland parts of their reefer chains. It is observed that some ports invest in other ports with a notable predominance of reefer flows (e.g. the port of Qingdao taking a stake in the Mediterranean reefer hub of Vado). In one case, the Port of Rotterdam participates in a hinterland rail connection from another port (Valencia). Another port – Dalian – takes on the role of shipper itself (through a joint venture) to arrange a container vessel loaded with reefers exclusively destined for Dalian.
Port authorities also engage in policies aimed at trade facilitation, sometimes unilaterally, but in most observed cases in cooperation with higher-level government agencies that also seek to lower barriers to (perishables) trade. National governments as well as port authorities can exert lobbying efforts, such as the Port of Santos that lobbies with foreign governments to ease restrictions on Brazilian beef – an important category of export cargo for Santos. Another example of trade facilitation efforts by port authorities is the spearheading of regulatory

agency cooperation to streamline administrative procedures, such as the Port of Antwerp working with Belgian and Peruvian customs agencies to streamline reefer clearance with digital certification.

*Hinterland policies*

In the hinterland dimension of reefer transport, port policies frequently address modal split. Seven policies have been identified that aim to facilitate rail transportation of reefers or temperature-controlled goods, with port authority involvement ranging from coordination and facilitation (e.g. Rotterdam and Valencia in the CoolRail project) to providing regulation for priority status for reefer containers on trains (Tanjung Perak) or port authorities being active as investor and operator (Qingdao, Tianjin, Dalian, Yingkou). Two ports (Rotterdam and Antwerp) have taken steps to increase the modal share of inland waterways transport of reefers through pilot projects and subsidies. Multiple port authorities stimulate the use of inland terminals, and some even invest in inland terminals or cold storage facilities (e.g. Tianjin) citing improving hinterland connectivity for reefers as a main goal. Interestingly, the ports that extend their scope the most towards the hinterland, often do so in the pursuit of goals that tie in with policy goals specified at higher levels of governance (e.g. national, regional, or European). In Europe in particular, the aim of a modal shift from road transport to rail or inland waterways was specified in an EU whitepaper, adopted by national governments, and subsequently integrated in port policy (European Commission, 2011). In Asia, more ambitious initiatives extending ports' strategic scope towards their hinterland are often linked with goals formulated by higher-level government pertaining to the improvement of food safety, the development of national or regional postharvest distribution systems, or the ambition to stimulate domestic agricultural exports. Examples of countries where port policy explicitly contributes to these national policies include China, India, and Indonesia.

*Cold chain policies*

At the top of Figure 6.3, examples are shown of port policies impacting the cold chain in its entirety, which in most cases relates to end-to-end monitoring of reefer containers or conditioned shipments, or data sharing and coordination between stakeholders along the cold chain. An exception to this type of policies is the quality certification program for Halal products being set up by Port Klang, with the specific intention of improving transparency regarding product characteristics along the chain. Despite this example, most policies spanning the full chain are ICT-related. For example, the Port of Rotterdam has several data-sharing initiatives and projects that aim to connect data from various sources to allow for container tracking and prediction. Whereas one ports (Hamburg) invest in container tracking in and around the port with sensor networks, several more port authorities are involved in initiatives that revolve around new technologies and data exchange – notably experiments with blockchain applications – along the entire reefer chain (e.g. Singapore, Busan, Antwerp). While these technologies will in the future likely have an impact on transportation of standard containers as well, port authorities and their partners in these projects (broad coalitions of shippers, carriers, insurers, government agencies, technology companies, and financial institutions) use the reefer chain to pioneer these technologies. The motivation is probably twofold. First, reefer containers already have the embedded technology that make remote monitoring possible. Second, the perishable and time-sensitive nature of reefer cargoes make that these flows will benefit the most from improved monitoring (allowing real time adjustments) and streamlining of administrative actions. In the long run, one can expect technological advances in the reefer sector to diffuse to the standard container market as well.

**Stakeholder involvement**

From the sample, we can distinguish a variety of policy instruments employed by port authorities, including investment, regulation, infrastructure provision, networking, pricing, incentives, subsidies, coordination, mediation, and marketing. Almost all policy actions identified entail a port authority engaging in a partnership with one or more public and/or private stakeholders, and instances where a port authority acts entirely unilaterally are limited. There is a considerable diversity in stakeholder configurations and partnership compositions that port authorities engage in to co-create reefer chain measures. The dataset shows partnerships with shippers, terminals, carriers, other port authorities, logistics and transportation service providers, customs and other government agencies, knowledge institutes, technology companies, and financial institutions - domestic as well as foreign. The role of the port authority in these multi-stakeholder initiatives differs, even between initiatives that at face value seem very similar. Take for example cold logistics clusters, where numerous stakeholders and functions are clustered in close proximity. Some port authorities (e.g. Rotterdam) make active use of concession policy and take on a mediating, facilitating role towards the other stakeholders that ultimately have to operate in or through the cluster (e.g. cold storage, depots, inspection authorities, terminals), but are not involved in the operations themselves. Another example of active involvement without significant resource commitment is a strategic partnership between a port authority and a service provider, as for example in Los Angeles. On the other hand, there are port authorities that become a shareholder in service providers (either as a wholly owned subsidiary (e.g. Dubai) or as a joint venture with a specialized private-sector counterpart (as for example in Jeddah, Dalian, and Bremerhaven)). In doing so, they take on a more entrepreneurial role as operator. In both cases, partnering with other stakeholders is necessary, because these organizations have capabilities that the port authority lacks and is not likely to develop itself (for example in warehouse operations or customs inspections), but the role of port authorities in these initiatives determines the resource commitment, risks, and degree to which the port authority has to be involved in the management of the organizations involved.

Port policies that aim to impact the cold chain in its entirety are characterized by broad and diverse coalitions of port authorities and other stakeholders, often even internationally. Examples include container tracking, data sharing initiatives and blockchain experiments that typically involve shippers and port users, as well as technology companies and organizations involved in the administrative dimension of the transport chain. As with the case of cold clusters discussed above, the role of the port authority in these initiatives depends on its strategic scope and its capabilities. Considering the example of blockchain experiments, the Port of Singapore, managed by PSA, an organization that operates terminals worldwide, makes use of PSAs global network and capabilities in managing container handling operations to experiment with blockchain for the purpose of expediting administrative processes. However, they still needed the expertise and capabilities of for example a shipping line (PIL) and an ICT company (IBM) to effectively address all relevant aspects of this project. The Port of Busan has undertaken an experiment with similar scope, but in a larger consortium, involving not only a carrier (HMM) and a technology company (Samsung), but also various government ministries to facilitate coordination with foreign counterparties, and a knowledge institute to add to the knowledge and capabilities of the port authority. Recently, Samsung has also entered in a similar project with the Port of Rotterdam, this time involving also a financial services company (ABN AMRO) to help address the trade finance and insurance dimensions – specifically for reefer transportation of flowers. Between these examples, the role and commitment of the port authority differs, as does their intention to remain involved once the experiment can be extended into a commercial product, marking the difference between ‘facilitator’ and ‘entrepreneur’ ports in this domain.

As ports' scopes broaden towards the foreland or hinterland, also the stakeholder coalitions in which policies are implemented change. Towards the foreland examples include marketing initiatives in which the port authority seeks out foreign shippers (e.g. the Port of Dalian acting as direct importer), carriers (e.g. the Port of Salalah attracting shippers and carriers to use it as a transhipment port), or even foreign governments (e.g. the Port of Santos lobbying foreign governments to lift trade restrictions on Brazilian beef). In addition to these one-on-one marketing efforts, there are also examples of more long-term strategic partnerships, either between a port authority and foreign customs and inspection authorities (e.g. the Port of Antwerp working with Belgian and Peruvian customs to expedite reefer clearance with a digital certification) or foreign ports and government (the Port of Rotterdam in Brazil). In these cases, port authorities commit more resources to a long-term relationship, and contribute their expertise to the joint project. Furthermore, these examples of 'facilitator' roles towards the foreland – even without equity investments – are emphasized as initiatives in which the port authority can learn from the project and its partners and further develop its own capabilities. Also in foreland-oriented policies, port authority roles differ from 'facilitator' (acting as a matchmaker, mediator, or representative or engaging in long-term strategic partnerships – as illustrated above) to 'entrepreneur' (directly investing in foreign reefer ports, such as the Ports of Qingdao and Dubai are doing in Portugal and India respectively).

Towards their hinterland port authorities partner with inland terminals, transportation service providers, regional government, and logistics and production clusters. Also these partnerships show differing degrees of commitment and different port authority roles. The majority of hinterland-oriented policies involve the stimulation of a modal shift of reefer containers from truck transport to barge or rail. In these initiatives, port authorities either operate hinterland transport services themselves (as for example Dalian, Qingdao, and Tianjin), or work together with a transportation service provider (e.g. Valencia, Rotterdam, Antwerp, Tanjung Perak). In the latter case, these port authorities limit their financial stake in the project but take on a predominantly coordinating role, using their own network and expertise to assist the service provider and increase the chance of the initiative being successful. Inland terminals and logistics and industry clusters are also important partners of port authorities in their hinterland strategies. Here as well, 'entrepreneur' ports invest in inland terminals or cold logistics facilities and extend their landlord and operator functions beyond the port perimeter (e.g. Tianjin), while 'facilitator' ports limit their financial commitment, but instead focus on using their expertise and network to achieve their policy goals. In Asia in particular, port authorities contribute their expertise and capabilities as a facilitator to policies pursued by national governments aimed at increasing the export competitiveness of the domestic perishables sector.

Two types of partnerships and policies are surprisingly *not* encountered or only to a very limited degree. First, the link between port policy and the processing of reefer cargoes within the port cluster is observed only rarely in the sample – notable exceptions include food processing in Bremerhaven and juice processing in Rotterdam, even though there is no evidence of port policy directed at better facilitating these activities. This is surprising, considering that this is a logical next step in creating opportunities to generate more value added from reefer cargoes shipped through the port. Second, the policies in the sample are rarely related to energy management for reefer and cold chain facilities. One port (Bremerhaven) does mention shifting the energy mix provided to cold stores towards renewable energy sources, but given the relevance of energy strategies for ports, it is striking that these considerations seem to be few and far between.

**Port authority roles**

Section 6.2 introduced the ‘renaissance port authority’ framework (‘matrix’) of port authority functions (landlord, regulator, operator, community manager) and roles (called ‘types’ by Verhoeven (2010): Conservator, Facilitator, Entrepreneur). To explore the roles port authorities may need to develop to pursue certain cold chain or reefer-related policy measures, this section classifies the measures observed along the dimensions of the framework. As the measures themselves have already been extensively described in the sections above, this section focuses on the application of the framework and the findings from this exercise. Table 6.5 shows the framework outlined earlier, with the port authority actions matched to the appropriate function and port authority role.

**Table 6.5. Port authority ‘renaissance matrix’.**

| Type<br>Function | Conservator | Facilitator | Entrepreneur |
|---|---|---|---|
| **Landlord** | | - Cluster cold chain activities<br>- Strategic partnership with overseas reefer port<br>- Partnerships with cold clusters in hinterland<br>- Assist development of hinterland post-harvest distribution system (in combination with community manager role) | - Co-invest in cold chain logistics cluster<br>- Direct investment in overseas reefer port (port itself or port service providers)<br>- Investment in cold stores in hinterland<br>- Connect docks and cold stores with rail sidings<br>- Invest in reefer infrastructure capacity |
| **Regulator** | - Quality control on reefer servicing<br>- Intensifying cargo quality control | - Co-site customs and inspection authorities with cold chain activities<br>- Coordination with overseas (foreland) customers<br>- Cooperation with businesses and regulatory agencies for authorizations and expedited clearance<br>- Expedite reefer pick-up<br>- Penalize long reefer dwell times | - Establish quality certification system<br>- Establish security seal system for reefers |
| **Operator** | | - Cluster cold chain activities (in combination with landlord function) | - Energy management for reefer racks<br>- Co-invest in cold store (possibly in cold cluster)<br>- Invest in and operate refrigerated train connection<br>- Invest in cold stores in hinterland (regional) or overseas (global)<br>- Reefer imports by port authority |
| **Community manager** | | - Make connections with hinterland producers (regional exporters)<br>- Coordinate and subsidize hinterland barging projects<br>- Promotion of port towards foreland (global)<br>- Setting up stakeholder network and expertise center for perishable cargoes<br>- Stimulate green energy use<br>- Lobby government of export destinations to ease trade restrictions | - Worldwide reefer monitoring<br>- Blockchain consortia for reefer shipments<br>- Setting up data sharing platform<br>- Sensor networks in port |
| **Geographical scope** | Local | Local, regional | Local, regional, global |

Source: Based on Verhoeven (2010)

It is immediately apparent that nearly all policies actively geared towards the reefer market imply port authority roles beyond the traditional landlord functions. Only the specific attention to quality control and enforcement of standards could be subsumed under this 'conservator' role, as it implies enforcement of existing regulation – but still this requires awareness of the unique challenges of this segment. Apart from these examples, among these global multi-purpose gateway ports facilitating and entrepreneurial roles are the norm rather than the exception.

For some policies, it shows to be necessary to combine multiple functions and roles simultaneously, such as the creation of, and investment in cold logistics clusters. For port authorities that go furthest in this, this entails dynamic use of concession policy to co-locate related activities (Landlord – Facilitator) with investment in facilities and port service providers (Landlord/Operator – Entrepreneur) as well as coordination with regulatory agencies to co-locate and coordinate activities (Regulator – Facilitator). Along the functions of 'regulator' and 'community manager', there is a greater diversity of policy measures implemented from a 'facilitator' role, rather than 'entrepreneur.' This may be because regulation and community-related issues tend to be complex, port- or country-specific and difficult to commercialize for use in other settings. Examples of entrepreneurial actions in the community manager function involve the (commercial) scaling of ICT, such as monitoring solutions, data-driven tools, and experiments with blockchain networks. Similarly for regulatory functions, the actions for which the port authority can take on a more entrepreneurial role are not context-specific and scalable (e.g. product certification and container security seals). In the landlord and operator functions, there is greater diversity in entrepreneurial actions, but these tend to have a predominantly local scope, focusing on investments in cold logistics facilities within the port cluster – also consider Figure 6.3, showing that overall most observed measure is investment in cold stores within the port cluster. Interestingly, some policies that emphasize the 'facilitator' role are in fact implemented with a global scope (e.g. promotion and lobbying). These lack the entrepreneurial element of direct commercial involvement, but still have the global scope that the framework associates only with the 'entrepreneur' role.

## 6.5 Discussion

The study has mapped and analyzed the policy options for port authorities to respond to challenges and opportunities arising from the rapidly growing reefer container market and cold chain logistics sector. The sections above discussed the characteristics of 72 individual policy measures sampled from the world's 50 largest container ports, focusing on the policy instruments, goals, scope, port authority role, and stakeholder involvement. The findings support and further illustrate Robinson's (2002) conjecture that ports indeed position themselves in specific supply chains – in this case a relatively small sub-segment of the container market. It is also in the course of this positioning that port authorities extend their scope beyond the classic 'landlord' model, including actively facilitating, coordinating or even entrepreneurial roles and an extension of their strategic scope geographically towards their hinterland and foreland. To the academic literature on port governance and port policy, this study contributes a worldwide overview of the concrete policy measures port authorities employ to pursue their goals within the strategic scope defined by the prevailing governance arrangements.

The policies were placed in Verhoeven's (2010) framework of port authority roles as a combination of port authority functions and strategic scope (geographically, and in terms of autonomy, resources, and risk-taking). This application of the framework shows that 'renaissance port authorities' are indeed to be found among the world's major container ports: the major container ports worldwide commonly take on facilitating and even entrepreneurial roles to respond to challenges and opportunities in the reefer market. This implies that making the deliberate decision to focus policy towards one particular segment where the port authority identifies challenges and/or opportunity is an act of strategic orientation that puts the port authority beyond the more passive, mechanistic 'conservator' role. The fact that this shows to be the case for 35 of the 50 surveyed container ports, despite vast differences in governance models and institutional contexts, shows that Verhoeven's model of port authority roles is generalizable to port authorities worldwide. In its application to the case of reefer transportation and cold chain logistics, the framework proved to be of added value in terms of showing how port authorities leverage different roles in the pursuit of policy goals, and what roles port authorities need to develop to be able to effectively pursue different types of policy goals. An interesting finding from applying the framework to the dataset is that in many cases, policies require a combination of functions and roles, such as cold logistics clusters being commonly set up with a port authority acting as an entrepreneurial landlord/operator as well as a facilitating community manager. It also highlighted some nuances in that port authority roles can be different (facilitator versus entrepreneur) in pursuing the same type of policy, depending on the resources committed, risks taken, roles of other stakeholders involved, and the ultimate aim of the port authority. From the data analyzed, it appears that the difference between a facilitator and entrepreneur is the commercial orientation, which boils down to the question whether a port authority would be directly financially and commercially involved in port infrastructure and services, or if it would deliberately leave this to the market. With this point, also the main limitation of the framework that has shown in the analysis should be discussed. In the 'renaissance matrix' the geographical orientation progresses from local for a conservator role to regional and global for facilitator and entrepreneur roles, respectively. While the step from facilitator to entrepreneur is made by adding direct financial and commercial involvement, the expansion of geographical scope does not appear to be synchronous with this role progression. The data show that port authorities can take on a facilitator role in policies with a global scope, such as international partnerships. So while the model is valid to classify port policies in functions and roles, and it can be applied in a generalized way across institutional contexts, its simultaneous incorporation of expanding geographical scope runs into limitations when applied empirically.

The limitations of the study itself should also be addressed. One limitation is the constitution of the sample. By reviewing actions taken by the world's 50 largest ports, the cases of policies entering the sample were highly dependent on the ports' information provision, which may have introduced a bias in the sample. Hence the patterns identified should be seen in the context of this sample. Secondly, the policies included in the sample did not include performance evaluations of the policies studied, either because the information was not publically available or because it concerns relatively recent initiatives of which some are still being developed. Therefore it has unfortunately not been possible to judge the success of the policy measures studied. Third, while the authors showed that ports expand their role and scope, differences between ports in terms of governance and operating environment should be recognized. For example, observations regarding European ports cannot easily be generalized to Chinese ports. In the discussion of the results, we have acknowledged regional variation where appropriate. In Verhoeven's framework, four governance factors (the port authority's power, autonomy, resources, and management culture) determine the roles it is able to fulfill. While the data allowed classification of port authority roles for different policies, linking governance factors to port authority behavior was unfortunately not possible given the data available.

Regarding port policy in its governance context, other observations can be made based on the study findings. Although public port authorities have been commercialized and corporatized, in their most ambitious endeavors (extending the geographical scope of their strategies towards their foreland and hinterland) we still see strong intertwining of the policy goals and efforts of port authorities and higher-level government. Interestingly, this trend varies between regions, with distinctly different underpinnings in Europe and the United States (e.g. modal shift) compared to Asia (agricultural development and food quality). Although in these cases port authorities emphasize public goals this does not preclude an underlying strategic agenda with commercial goals. Interestingly, the most commonly observed policy of cold storage facilitation seems to be the most fundamental type of cold chain policy, since the port authorities that broaden their strategic scope towards their fore- or hinterland do so *in addition* to cold chain policies within the port cluster. The same logic applies to measures that target the cold chain overall (such as data sharing and trade facilitation initiatives), which are generally undertaken by port authorities that already pursue cold chain facilitation policies within the port area.

Two important port-based facets of cold chain logistics activities – processing and energy management – were surprisingly not encountered in the sample, which deserves some further discussion. This can be the case for several reasons. It may be because responsibility for this has not been devolved to port authorities, but in case it is within the scope of port authority responsibility, it may be due to a lack of perceived importance (i.e. the port authority has other priorities) or lack of capabilities (i.e. the port authority does not have the expertise to play a facilitating or coordinating role regarding these functions). Furthermore, energy use in ports is typically a transaction between a user (e.g. container terminal) and a provider, the information of which is usually kept private, due to the commercial sensitivity of this information – the energy use of a container terminal is closely related to its degree of activity (Van Duin & Geerlings, 2011). So also information asymmetries can prevent port authorities from becoming actively involved with energy management in their port cluster.

It may make sense that processing activities are outside of the scope of port authority responsibility, either because of the location (inside or outside of the port cluster) of these activities or their nature (operational). Before the mass containerization of reefer cargoes, conventional reeferships would unload at the quayside in ports, with the cargo being stored straight away in warehouses at or near the quayside. The introduction of the reefer container has reduced this necessity, and may have shifted the location of value added logistics activities (stuffing and stripping containers) to outside of the port cluster. However, other research (Castelein, Duin, & Geerlings, 2019) also shows that importers prefer to strip their reefer containers in or close to the port cluster, due to the limited free time the carrier (the owner of the container) allows them to return the empty container before charges for late delivery apply. For this reason, one would expect facilities of perishables-shipping firms to be located near the port, or at least well connected to the port. This includes the potential for functional linkages with firms and processes in the port cluster, which can be explored by a port authority with a sufficiently broad strategic scope. Regarding the nature of processing activities, it may be that private-sector parties perform these operational activities without any need for tailored policy – much in the same way that other types of industry in port areas (though subject to regulation) are not a regular policy focus of port authorities. In two ways port policy may address these activities in a strategic manner. First, in line with the frequently observed formation of cold logistics clusters (see section 6.4), they can tailor land allocation policy to co-locate processing activities with associated logistics activities, reducing transportation and creating more value – leaving the operational aspects of these activities to the firms involved. This ties in with the second point, namely that considering literature regarding active involvement of port authorities in other industrial sectors (see for example Herder & Stikkelman (2004) on methanol-based clusters), policy can support the reduction and higher-value utilization of waste flows. As product loss and waste is a highly relevant sustainability issue in the food chain, this deserves more attention. Examples could include, as mentioned, co-location of complementary activities to reduce transportation distances and the risk of cold chain breaks, but also connecting waste flows from cold chain activities (product loss in logistics and processing waste) to bio-based industry in the port cluster where these waste flows can be used as an input in higher-value-generating processes, including the production of biofuels and bioplastics. In both cases (co-location and connecting waste flows) the port authority can play a facilitating role, while the operational activities are managed by private sector firms.

While energy management is becoming more of a focus area for port authorities (Acciaro, Ghiara, et al., 2014; Parise et al., 2016), this is not yet reflected in cold chain logistics activities, despite reefer containers and cold storage facilities exhibiting a large and growing energy demand with associated negative externalities. Important aspects addressed in port policy are greening of the energy mix (including renewables such as wind and solar power), stimulating energy efficiency in operations, and supporting energy-saving innovations, including smart grids. In these aspects, port authorities are involved through their role of infrastructure manager, and as process facilitator building cooperative arrangements between utility companies, grid operators, and energy-consuming port users. Organizational challenges lie in adequately matching demand and supply of energy, with more variable supply coming from renewables, and demand from port activities still growing, including energy demand peaks from reefer containers. Interestingly, blockchain technology can play an important role in matching demand and supply in smart power grids, but for the cold chain it is specifically explored (in stakeholder coalitions often led by port authorities) in administrative and monitoring and control applications. Moreover, reefer containers and cold stores can play an important role in smart grids due to the nature of their energy demands. While cooling down to their setpoint temperature, they require power, but when cooled down to their setpoint temperature or slightly below (a so-called cold buffer function), they can remain off-power for a while before needing to actively start cooling again. These fluctuations (and potential flexibility) in demand can be used in smart grids to better match power consumption to more volatile production from (energy- and wind-dependent) renewables. So while we did not see evidence of port authorities incorporating cold chain activities specifically in their energy management strategies, it is clear that they are developing capabilities and playing an active facilitating role in a transition to more sustainable energy use. This trend in combination with the still growing importance of the cold chain logistics sector makes this a likely development for the future.

## 6.6 Conclusions and recommendations

This study presents several considerations for academic research as well as port policy. To research on port policy, this study has produced three main contributions. The first is the collection of a new dataset of tangible policy measures implemented by the world's leading container ports, in a systematic way that is relatively novel to the field. Secondly, examination of this data has provided insight in the full spectrum of policy measures port managing bodies can potentially pursue to better facilitate the growing cold chain logistics and reefer transportation sectors. Third, analysis of the data using the 'renaissance port authority' framework shows what roles and capabilities port authorities should develop to effectively pursue these policies, as well as the strengths and limitations of this framework in an empirical application.

Nevertheless, based on the findings, implications and limitations of this study, the authors can also formulate several recommendations for future research. Most importantly, as the dataset used in this study did not include data on the performance of specific policies, future research should focus on which type of policies achieve the desired outcomes, and which factors impede or enhance the effectiveness of policies. The qualitative findings from this study may serve as the starting point for more in-depth research into the performance of specific types of cold chain policies, ideally quantifying costs and benefits. More generally, similar exercises to the one conducted in this study can be done into the tailoring of port policies for specific (niche) markets – ideally extended with information on policy outcomes in more mature markets. Furthermore, the study warrants several recommendations for future research using the same theoretical framework: while the ‘renaissance port authority’ model is generalizable and yields insightful findings, the way geographical dimension of port authority scope is incorporated in the model deserves further consideration.

As discussed above, this study based on a sample from the world’s 50 largest container ports likely lends a bias to the types and extents of the measures observed. The ports observed are major, global multi-purpose gateway ports, with important regional hub functions. Even though some port authorities show to have a clear focus on the reefer market, for the ports themselves reefer containers are likely only a small part of total throughput (see section 6.4). Specialized reefer ports may show a different approach in policy focusing on this market. The measures surveyed did show one aspect of reefer-related policy that is probably unique to major multi-purpose gateway ports, namely the goal of mitigating the risk that time-sensitive reefer cargoes are not held up in congested port areas and at or around terminals (e.g. off-peak reefer pickup, clustering related activities, expedited clearance, more sophisticated container tracking and prediction). These efforts to efficiently accommodate reefer container flows amid other (perhaps less time-sensitive) port activities makes up a large share of policies observed in this study, but may not be as relevant for specialized reefer ports. Also, the containerization of reefer cargoes has introduced a tension between standardization and economies of scale in container shipping on the one hand, and the time-sensitivity of reefer cargoes on the other that warrants policy focus to mitigate the downsides of this trade-off. As the larger container ports are more likely to handle the largest container carriers and the largest absolute numbers of containers, this issue of differentiation will be more relevant to them than to smaller, specialized ports, that typically receive smaller vessels (or perhaps have a focus on conventional reeferships, that do not require investments in container handling equipment) and do not have this need for differentiation of cargo flows. Moreover, as discussed in section 6.3, managing bodies of larger ports will likely have a greater strategic scope, and more resources and capabilities at their disposal than managing bodies of smaller ports. Nevertheless, it would be relevant for future research to consider specialized ports and their efforts to better accommodate reefer logistics and cold chain activities, and compare and contrast the efforts and roles of port authorities in ports of different sizes and scopes.

For managers and policymakers, this study provides a comprehensive overview of what major ports worldwide are doing to facilitate cold chains and reefer transport. The typology of policy actions presented can serve as a palette of possible actions from which policymakers and managers can draw, and adapt generic concepts to their local context. Currently, there is little evidence of ports establishing comprehensive strategies for cold chains. The policy measures identified are generally separate measures, each with their individual goals, with no indication of being part of an overarching strategy. While some port policies in developing regions are connected to national government policies aimed at establishing post-harvest distribution systems, for developed regions (North America, Europe), there is no higher-level governance framework observed addressing cold chain logistics in ports and informing port policy. However, in the light of rapidly growing markets, technological developments, and sustainability concerns, a more thorough and comprehensive approach is desirable. From the findings of this study, at least the most important tenets of such an overarching strategy can be identified. Within the port, port authorities should take an integrated perspective of different cold chain activities, including stripping and stuffing of reefer containers, storage, inspection, processing, and container servicing. A smart port can strive to better connect its cold chain activities with intermodal container networks and co-site relevant activities together to improve handling efficiency with a central role for well-connected cold stores. Considering sustainability concerns, the energy mix of these cold clusters can be made more sustainable, and smarter energy management techniques can be implemented (such as the use of cold stores or reefers as accumulators for energy storage). Towards the hinterland, many ports strive to reduce road congestion while also ensuring fast transit for time-sensitive reefer cargoes. Some do this by prioritizing trucks with reefers, others by stimulating the use of rail and/or barge transport for reefers. To achieve this modal shift, we observed a range of possible measures: infrastructure investments in intermodal connectivity for cold stores, start-up subsidies for barge connections, and investments in inland terminals to improve connectivity. Foreland-oriented policies may consist of marketing and lobbying, but port authorities can also stimulate cooperation between different national customs and inspection agencies to expedite clearance of goods. As seen for example with data sharing initiatives and blockchain experiments, smart ports can take a role as networking organizations, forming coalitions with diverse sets of stakeholders, and using the network and expertise of each to address pervasive issues in the reefer chain. This conception of cold chains as complex, multi-stakeholder systems in an uncertain global environment can serve as the rationale behind more comprehensive cold chain strategies for ports and ports' conception of their own role in these chains. On an even more ambitious note, the same type of integrated policy-making can be extended to port positioning in other supply chains. Lastly, the application of Verhoeven's framework to real-world instances of port policy has shown that worldwide ports are taking on facilitating and entrepreneurial roles to respond to challenges and opportunities in the reefer market. This does not mean that this behavior comes naturally to port authorities, but depends on the presence of conducive governance factors. If port authorities do not manage to make progress towards their strategic goals (e.g. competitiveness, sustainability), it is vital to consider whether they have the power, autonomy, resources, and management culture that allow them to take on the roles necessary to pursue their goals effectively.

The reefer market will likely keep growing in the near future, and ports would serve themselves well by considering all relevant aspects of this niche market for their own policymaking. In particular two global developments emphasize the relevance of cold chains for ports. First, there is a growing tension between rapidly growing, energy-intensive cold chain markets, and the need to curtail greenhouse gas emissions, as specified in the Paris Agreement. Considering the overall energy-intensity of ports, and their central role as nodes in global cold chains, there is a growing relevance for ports to address the environmental footprint of reefer transport, and perhaps even take a leading role in broader coalitions of stakeholders whose cooperation is required. Secondly, reefer containers are becoming more technology-intensive, allowing for better monitoring and control, and smarter handling – technology that is likely to diffuse to dry containers in the future as well. It is also in this segment in the container that the use of blockchain technology is first being pioneered. Developments such as these suggest that reefer containers are the first sector where new technologies for container transport are tested and implemented. Ports and other service providers that want to have a strong position in the container market when these technologies diffuse are therefore served well by being at the forefront of these new developments in the reefer market. In addition to these trends, considerations regarding sustainability, logistics processes, technology, and competitiveness are top priorities for ports, and the reefer segment poses several challenges in these domains that may require port authorities to develop new activities and capabilities to address. The findings from this study serve to help practitioners and researchers get a firmer grip on what ports can do to respond to these challenges and opportunities.

# 7 A modal shift in reefer transportation: Investigating user perspectives and technological prospects

This chapter is part based on:
Castelein, R.B., Geerlings, H., & J.H.R. Van Duin. (2020). Reefers on Rails: Investigating User Perceptions and Technological Prospects. Presented at Transportation Research Board Annual Meeting, January 11-16, Washington D.C., United States of America.

**Abstract**

The global market for conditioned transport – predominantly conducted in refrigerated containers ('reefers') – grows rapidly. Due to the energy usage for continuous cargo cooling, the climate impact of cold logistics chains is substantial and still increasing.

In addressing climate concerns, governments have committed themselves to a 'modal shift' of freight transport from road to more sustainable modes such as rail or barge transport. Concerns including road congestion and shortages in the trucking sector provide an additional impetus for a modal shift. The perishables sector, however, is almost entirely reliant on trucking. The authors address the question what is necessary for a modal shift of reefer containers to become a viable option to stakeholders in the cold chain.

This study surveys the existing options for a modal shift of perishables transport to rail or barge. A major finding is that there is no established option yet to connect reefers on trains to an energy supply from the catenary: most existing options rely on some form of diesel-electric generator to power the reefers. Furthermore, the authors conducted interviews with a wide range of cold chain stakeholders on their considerations regarding modal shift. Disadvantages of rail transport include the absence of a 'plug and play' option to power reefer containers, and the perception the current rail and barge services do not offer the desired speed, reliability, and flexibility. While the authors also observed that new intermodal reefer logistics concepts are viewed favorably, options besides trucking are simply not considered in current decision-making. Hence, a modal shift also requires a 'mental shift' within the sector.

## 7.1 Introduction

Much of the world's welfare today is produced, or is facilitated, by freight transport. Over the last decades, freight transport worldwide has experienced an unprecedented growth, driven by the increase in global trade. For many products, production and consumption are scattered worldwide, and logistics clusters and intermodal networks (including seaports and their hinterland networks) play an important role in connecting these points of production and consumption.

The success of freight transport is reflected in the rise of container transportation; initially introduced in the 1950s as a box useful for groupage, nowadays the container is a dominant factor in logistics chains (UNCTAD, 2017). Presently, the global container market, after decades of strong growth, is characterized by stagnation, with the exception of the fast-growing market for temperature-controlled 'reefer' containers. Reefer transportation is the dominant transport mode of global cold supply chains for temperature-sensitive and high-value products, such as fresh and frozen agrifood products, flowers, and pharmaceutical products (Arduino et al., 2013; Rodrigue & Notteboom, 2015). A reefer container is an intermodal shipping container (usually 40ft) with insulated walls, fitted with an integrated refrigeration unit that circulates cold air through the container, cooling the cargo down to its required temperature.

Nowadays there is increasing attention for intermodal transport by rail and/or barge as an attractive option for long-distance perishables transport, a market traditionally dominated by road transport. Motivated by the need to shift toward greener transportation and reduce road congestion, many new intermodal initiatives are introduced such as the 'Silk Road Initiative' with an important rail component, and numerous initiatives to stimulate the use of barge transport in countries with well-developed inland waterways systems. This chapter focuses on the technological and logistics characteristics of the options for intermodal transport by rail or barge of refrigerated containers, and their acceptance by key stakeholders.

The structure of the chapter is as follows. Section 7.2 addresses the position of the reefer container and the logistical context. Section 7.3 presents the approach applied in this study. In Section 7.4, the authors discuss the technological and logistical opportunities, limitations and barriers for intermodal reefer transportation. Section 7.5 discusses user perceptions of the available options for intermodal alternatives to road transport. Section 7.6 concludes.

## 7.2 Background

**The reefer market**

Over the past decade, the container shipping market itself has entered a phase of maturity, but niches such as reefer transportation can still be exploited for further growth (Guerrero & Rodrigue, 2014). The reefer market has been the only segment showing consistent growth in a generally depressed container shipping market (Drewry, 2017). Growing global demand for temperature-sensitive products, such as fresh and frozen agrifood products, flowers, chemicals, and pharmaceutical products, drives the further expansion of worldwide reefer trades. The reefer container has become the dominant option for long-distance transportation of temperature sensitive goods. An important factor for a well-functioning cold chain for temperature-sensitive cargoes is the reliability (in terms of delivery and quality control), flexibility, and traceability that these containers and associated technology provide, making it an attractive mode of transportation (Castelein, Geerlings, et al., 2019).

Reefer containers, with built-in refrigeration technology and sensitive cargo, place more stringent demands on the transport model. Road transport is the most-used transport mode for food and perishables transport in Europe as well as North America (Reis et al., 2013; Boyer, 2014). This is mainly because of its flexibility and the fact that it is able to directly reach all final destinations. At the same time however, road transport is hindered by increasing congestion in port areas and on roads, undesirable negative external effects (emissions such as $CO_2$ and particulate matter (PM), noise, impact on the quality-of-life of people, and infrastructure claims on scarce spaces), and shortages of drivers in the trucking sector. Geographically, most containerized supply chains of conditioned food and flower products are intercontinental (often from tropical regions to developed markets) with a major maritime component, making seaports important nodes in these chains. Currently, almost all import reefer containers in ports are transported directly by truck to the hinterland. In 60 percent of these cases, this speed of delivery appears to be unnecessary (FruitDelta Rivierenland, 2018). Intermodal transportation by barge and/or rail may offer a good alternative, as it is cheaper than road transport, and leads to less congestion on the motorways and a reduction in $CO_2$ emissions – albeit with a longer transit time and less flexbility.

**Sustainable transport and modal shift**

It is for this reason that governments introduced modal shift policies. A major example is found in the EU White Paper on Transport (European Commission, 2011), specifying modal shift goals (by 2050, 50% of road freight over 300km should shift to rail or inland waterways) on the European level, to be implemented via the process of subsidiarity by all EU member states. These policies are implemented in for example urban areas, mainly dealing with passenger transport, and in ports and logistics clusters with a focus on shifting freight transport from trucking to more sustainable modes such as rail or barge. As an illustration, in the latest port extension Maasvlakte-2 in the Port of Rotterdam, new container terminals had to commit to a modal split goal of only 35% of the imported containers being transported by road, 20% by rail and 45% by barge (De Langen et al., 2012). In this context intermodal compatibility is also a crucial element for reefer transportation. Castelein et al. (2019a) find that multiple port authorities stimulate the use of intermodal transport and inland intermodal terminals, and some even invest in inland terminals or cold storage facilities, citing improving hinterland connectivity for reefers as a main goal.

In most European Union countries, the modal split of overland freight transport remains heavily skewed towards road transport. Figure 7.1 shows that on average, close to 80% of tonne-kilometers is road-based, with rail transport making up 17.3% and inland waterways transport 6% - as of 2017. In the United States, domestic freight transport (excluding air and pipeline transport) is split between 48% by truck, 40% by rail, and 12% over water, of which approximately 4.2% is coastal shipping and 7.4% is inland waterways shipping (including lakewise) and the remainder being intraport barge transport (Bureau of Transportation Statistics, 2020). Inland waterways transport is only used heavily in those few regions with naturally well-developed inland waterways networks: The Netherlands, Belgium, Romania, Bulgaria, and to a somewhat lesser extent Germany, Croatia, and Luxembourg. In the United States this is predominantly in the Mississippi River System region. In the absence of natural rivers and canals of sufficient capacity, a well-developed rail network can carry a major share of freight transport, as has already been the case in some countries and regions. Therefore rail transport can be a promising possibility for a modal shift where currently road transport dominates and there are limited options for inland waterways transportation.

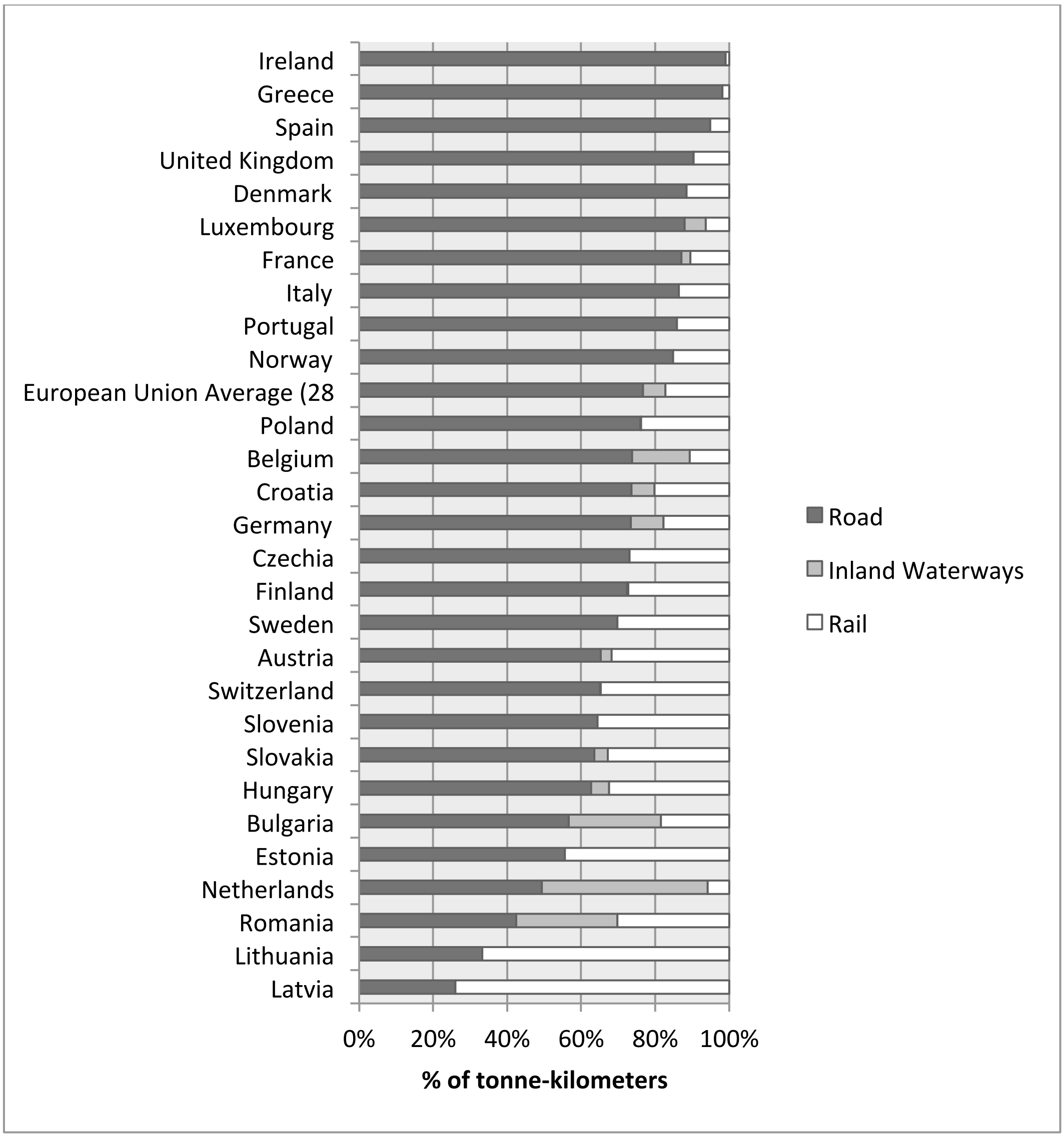


**Figure 7.1. Modal split of freight transport for EU countries, 2017.**

Source: Eurostat (2019b).

When considering the modal split of containerized freight, there is also considerable potential for a modal shift. Figure 7.2 shows (for EU countries) the road-based percentage of tonne-kilometers of long-distance container transport (over 300km – distances where rail transport would be viable). On average, still 41.2% of long-distance container transport is road-based, with some countries having a road share far above 60%. The relative dominance of trucking in long-distance container transport further underscores the transition that remains to be made regarding modal shift.

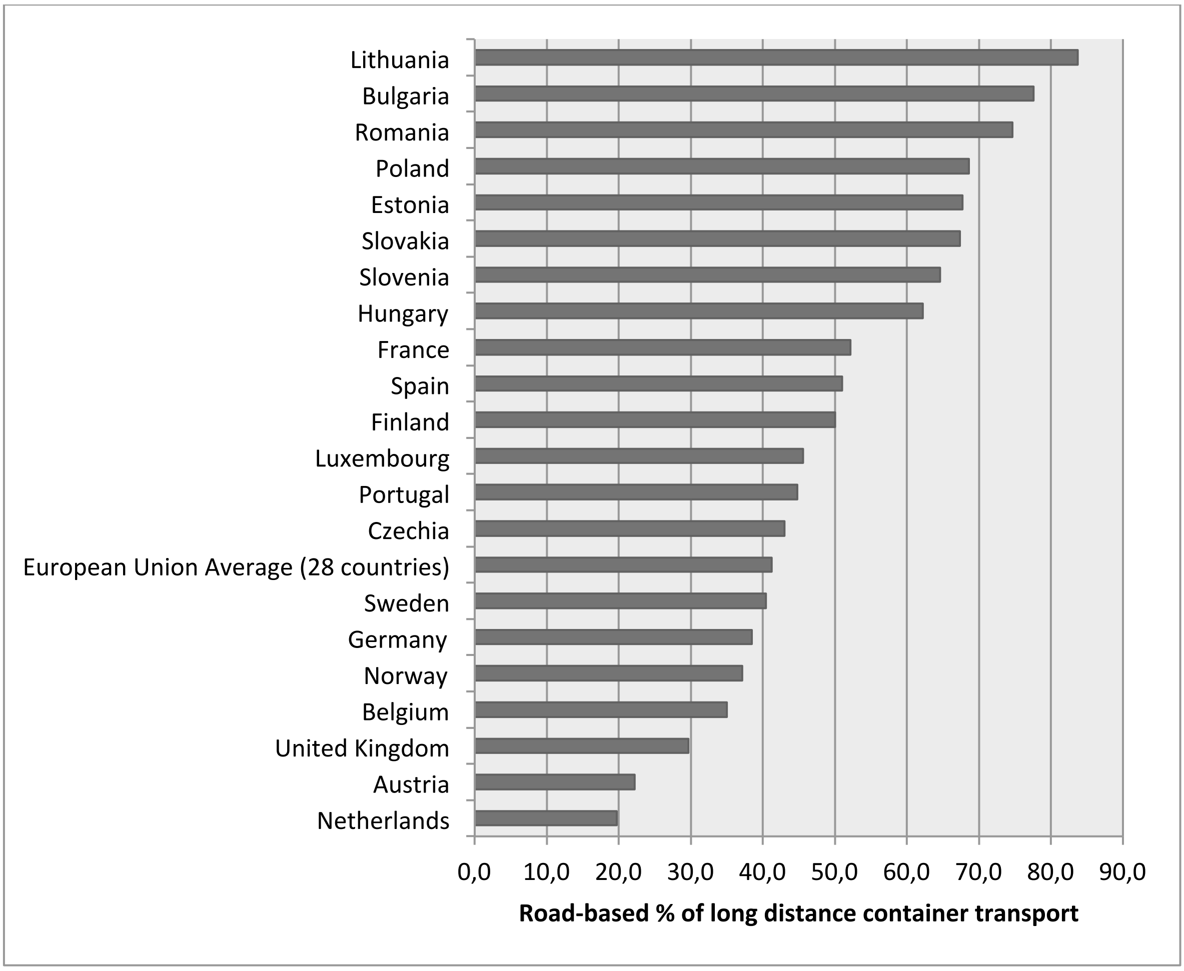


**Figure 7.2. Modal shift potential of containers for EU countries (non-exhaustive).**

Source: Eurostat (2019a).

The increasing sense of urgency to address climate change might work as a catalyst globally, and draws increasing attention to the potentials of rail transportation. Globally, this is reflected in the Paris Agreement, dealing with the reduction of greenhouse gas emissions, which was accepted in 2015 by consensus of 196 nations. The agreement formulates the long-term goal to keep the increase in global average temperature well below 2°C above pre-industrial levels; and to limit the increase to 1.5°C, since this would substantially reduce the risks and effects of climate change (United Nations, 2015). Each individual country should make a contribution to achieve the worldwide goal. The Paris Agreement has to be translated into concrete actions for the transport sector as well, requiring the sector to respond to the challenge. There is increasing criticism of the fact that air- and maritime transport are excluded from the Agreement when it comes to concrete actions. Despite the traditionally strong cost focus in the logistics sector, the $CO_2$ footprint of transport has be taken into account in the future.

## Growing attention for a modal shift

A wide range of policy levers is needed to reduce transport emissions and therefore understanding of their effectiveness is crucial. Transport emissions will become the main obstacle in delivering the EU's climate objectives when concrete measures are lacking. Several measures are suggested, including clean vehicle technologies (engine technology and alternative fuels), optimizing networks, and a modal shift of freigt transport from road transport to other, less polluting modes such as rail or inland waterways transport. This chapter focuses on the options for such a a shift. Rail can be considered the most promising mode for emissions reduction and de-carbonization of the transport sector: for road transport the $CO_2$ emissions are 90.3 grams per ton-km, while rail transport emits 11.3 grams of $CO_2$ per ton-km (assuming 80% of the trains are powered electrically, which for the European case is a reasonable assumption) and inland waterways transport 38.6 grams (Jonkeren et al., 2019). As discussed above, inland waterways transport is only a viable option in those regions with well-developed inland waterways networks. A modal shift represents a promising option where the environmental and the economic added value are demonstrated, but user acceptance still depends on the attractiveness of new logistics concepts based on the traditional criteria of costs, speed, reliability, and flexibility.

## 7.3 Methodology

Considering the developments sketched above, this chapter addresses the following questions: *1) What options are available to transport operating reefer containers by rail or barge?* And *2) What are the stakeholder requirements that intermodal logistics concepts for reefers should meet?*

By synthesizing these findings, the authors outline the viability of a larger-scale modal shift of reefers from road to rail or barge transport, and identify what challenges should be addressed in technology and logistics concept development.

The analysis follows a two-pronged approach: mapping the current options for rail and barge transportation of reefers in terms of technology and logistics concepts, and elucidating through interviews the stakeholder requirements and perceptions of the current options.

The first research question is answered by mapping and evaluating the existing technological options to transport operating reefer containers on a train or barge. Apart from asking respondents about the options they use, offer, and/or are aware of, the authors conducted a web-based search of available technologies, drawing on information from industry publications, corporate websites, and presentations. Technologies were found using different search terms on search engines and in the archives of industry publications, until information saturation was reached and new searches only produced already known information. The following characteristics of the technologies were recorded:

- How power is supplied to reefer containers,
- What equipment is necessary,
- What additional handling requirements there are,
- Capacity of the service (i.e. how many operating reefers can be powered and transported at the same time),
- Other options (e.g. real-time temperature monitoring),
- Examples of cases where it is implemented.

For the interviews, the authors approached stakeholders active in cold chain logistics and reefer container transportation in the Netherlands, most of which operate in or through the Port of Rotterdam – the largest container port in Europe – for the maritime leg of their perishables transport. The Netherlands is a relevant research setting for this topic, considering its strong position in the agrifood market as an importer as well as exporter of food products, as well as its central role in (Western) European logistics networks. Moreover, it is one of the few European regions where the inland waterways network plays a major role in freight transport (see Figure 7.1). Therefore, the most relevant findings for inland waterways

transport are likely to be found in this part of Europe. For rail transport, findings are easier to translate to other regions, even those without well-developed inland waterways networks.
The authors aim to include a wide variety of cold chain actors, considering various types of organizations (shippers, container carriers, logistics and transportation service providers (LSPs and TSPs), terminal operators, and government actors), with different positions in the market (i.e. direct service provider, service user, government actors, and those who directly of indirectly cooperate with barge and rail transport users and/or providers), as well as actors focusing on different types of cargo (fruit, flowers, meat, pharma etc.). Within these organizations, respondents were recruited that fulfilled a decision-making role, with direct experience with, and knowledge of intermodal transport of reefer containers. The authors presented respondents with discussion statements on sustainability concerns and modal shift in reefer transportation (Castelein, Van Duin, et al., 2019), asked them about the extent to which they (dis)agreed with the statements, and to elaborate on their considerations. To identify stakeholders' evaluation of the service offer of reefer transportation by rail or barge, these statements (or discussion questions of equal wording) were used:

- Hinterland transport of reefer containers by rail/barge is a good option
- A lot of sustainability gains can be made in hinterland transport
- The infrastructure for hinterland transport of reefer containers by rail/barge meets our expectations
- The performance of hinterland transport of reefer containers by rail/barge meets our expectations
- For us, good hinterland transportation performs well on cost, quality, and reliability criteria
- We find the costs of hinterland transportation by truck too high
- We find the costs of hinterland transportation by rail too high
- We find the costs of hinterland transportation by barge too high

The statements were introduced as discussion points in semi-structured interviews, aiming to elicit the extent of agreement with the statement, but more importantly stakeholders' elaborations on their considerations regarding the statements. Furthermore, the semi-structured format allowed the respondents to comment on other issues they found relevant in relation to the discussion statements. Using the responses to these statements and follow-up questions during the interviews, the authors strived to obtain an as complete as possible evaluation of stakeholders' perspectives on the topic. Table 7.1 lists the respondents by their function title and the type of company they represent. Company names are omitted to preserve respondents' anonymity.

**Table 7.1. Interview respondents.**

| Type of organization | Role respondent |
|---|---|
| Association of inland terminals and barge operators | Junior policy advisor |
| Business association (road transport) | Secretary |
| Carrier/LSP | General manager logistics services |
| Carrier/LSP | Business development reefers |
| LSP | Manager import/export |
| LSP | Manager container department |
| LSP | Director |
| LSP (rail) | Managing director |
| LSP/TSP (multimodal) | Manager |
| Port authority | Business manager logistics |
| Port authority | Business manager agrofood |
| Port authority | Advisor sustainability |
| Shipper association (fruit/vegetables) | Project director |
| Shipper (flowers) | Supply chain consultant |
| Shipper/LSP association | Policy advisor |
| Terminal | Commercial manager |
| Terminal | Consultant business development |
| TSP | Managing director |
| TSP | Director |
| TSP (barge) | Manager |

## 7.4 Technology and logistics: opportunities and limitations

As discussed, the reefer container market is rapidly growing due to growing global demand for temperature-sensitive products. Reefer containers require a continuous supply of electricity to keep the refrigeration unit running and preserve the cargo at the desired temperature. Therefore, reliable power supply and temperature control are crucial elements for the success of reefer transportation by rail or barge. On deepsea container ships, reefers are plugged in and powered through the ship's engine. On the larger deepsea container ships, reefer plugs are available for 10-20% of the ships' capacity, and on specific trade lanes (e.g. Latin America – Europe) this extends to over 30% (Rodrigue, 2014). For these ships, the ship's engine configuration and the on-board electrical system are sized to the entire ship's energy needs, including reefers carried on board. At terminals reefer containers are usually plugged in in dedicated reefer racks and can draw power from the grid. On trains and barges, there is no standard technology (yet) to provide the necessary power, with several alternatives in the market. In the rail and barge sector, technological and logistical innovations are still under way. Technological innovations evolve regularly from R&D processes, but their implementation in transportation markets encounters considerable difficulty. This especially applies to the intermodal transport sector for long distance transportation of temperature-sensitive goods.

**Reefers on rails**

There are several systems in the market and potential entrants are working hard to introduce new systems. To provide an overview of the possibilities and their characteristics, the authors identified 7 different techniques for cooling reefers during rail transportation (information from corporate websites and presentations, unless otherwise indicated).

- Conventional (or clip-on) gensets are diesel generators that are attached to a reefer container, that can provide energy independent from a power connection. While frequently used in truck transport, it is possible to also apply this method on trains. The actual usability for rail transport must be questioned however. First, a genset must be attached to a container and thus occupies space on the train carriage. In addition, the tank of a typical genset is rather small, which means that it can supply the reefer with power for a few days at most, which makes this a less suitable alternative for transport over long distances. Furthermore, the scale of rail transport makes the assembly (and after transport return) of dozens of gensets per train a cumbersome way to regulate the power supply.
- Several companies worldwide operate so-called Refrigerated Block Trains (including Sungate (Baltic), Canadian Pacific (North America), RZD (Russia), MacAndrews (Spain), and Transnet (South Africa)) a system in which a larger diesel generator or ‘power pack’ (fixed on a wagon) is used to supply power to a train of reefer containers (numbers quoted range between 8-18 plugs, with Transnet indicating capacity for 38 reefers, with a separate fuel tank). Depending on the capacity of the fuel tank and the energy needs of the reefer containers, these solutions can provide power for up to 10 days. These generators and their fuel tanks are placed in ISO containers (20ft or 40ft) and loaded onto railcars much like conventional ISO freight containers. In the concept operated by Sungate, the wagon with the generator is equipped with living space for 2 mechanics, who perform maintenance on the generator and monitor the temperature of the reefers. Other systems include options to remotely monitor the reefers’ functioning and temperature.
- The Rail Reefer Generator set (RRG) is a 10ft container equipped with a diesel generator. This RRG is ideally placed together with a 45ft reefer on a 60ft wagon, or with a 45ft and a 20ft reefer on a 90ft wagon. The RRG is equipped with a system to check position, power supply and tank capacity. In principle, the RRG can provide 2 reefers with power for a week. It has not been possible to find information about current operations.
- An integrated diesel-electric reefer is a reefer with a built-in fuel tank and generator, making the reefer self-sufficient in its energy while on the train, given that there is enough fuel in the tank. In Europe, these containers are commonly 45ft. Also reefer containers transported on the new Silk Road are of this integrated type. In North America, similar integrated solutions exist, some in continental containers or (less common) refrigerated boxcars. A similar model is ‘trailer-on-flatcar’, where a refrigerated trailer with its own power supply is loaded from a truck onto a rail flatcar.
- The four options described above (genset, integrated generator, or an separate generator powering multiple containers) are used worldwide. These are established technologies in rail markets and are all based on power from a (diesel) generator. The authors also found three examples of new technologies that are not reliant on fossil fuel:
- The Siros Sustainable Power System (SSPS) converts the kinetic energy of a train carriage into electricity, which is stored in a battery. The SSPS is placed on the reefer like a genset. Apart from storing and providing power, the unit transmits information about the reefer’s functioning and temperature. The battery is charged when the train slows down by absorbing energy that is normally lost as heat. SSPS is currently still under development and a patent has been applied for. It is an environmentally friendly solution, but little is known about the distance it can travel with one charged SSPS, how much the SSPS is charged as soon as braking occurs, and how a reefer can be powered when the SSPS’ battery is empty. The authors contacted the company behind

SSPS with further questions, but received no response. Furthermore, no information about its use in the market could be found.

- Similar to the SSPS, the rCE Powerpack is a set of rechargable batteries (Harder, 2019). Individual railcars are fitted with a frame with battery modules that can power the reefers (up to 4 20ft boxes per railcar). In addition, the system includes an axle generator (connected to the railcar wheel) that charges the batteries while the train is driving. This solution with batteries that are recharged en route allows long travel times, and a stable power supply to the containers while the train is not moving. Each individual railcar has to be fitted with the frame, generator, and batteries, but the advantage is that railcars are entirely self-contained, without the need for additional equipment on the train. This is currently in use in Switzerland by railCare AG and elsewhere in Europe by VTG (VTG, 2019).
- The Reewa wagon is developed by the Croatian company Transagent (International Transport Journal, 2018). This system provides power to reefers by using the energy drawn by the locomotive from the catenary, and a wagon-based power converter. Information about the reefer's temperature and position are communicated in real-time. A prototype of this system was presented in 2017, no information could be found about current operation. Reewa is only being developed in certain standard sizes, 50ft, where the wagons are on the long side (16.4m) in relation to the containers themselves (45ft = 13.7m), 80ft, and 90ft.
- The Swiss company Wascosa also developed a railcar designed to power a reefer container with electricity from the grid through the catenary and the locomotive. The system connects the reefers to an electricity supply from the locomotive using standard equipment already in use in (international) passenger trains. Trains using this system operate from the Port of Koper (Slovenia) since 2018, currently on a small scale.

To the best of the authors' knowledge, electrification of the power supply of reefer containers on trains is still in an experimental phase, with several technologies proposed, but not used on a large scale yet, and no evidence of standardization. The established options in the market are still usually based on diesel generators. Table 7.2 below summarizes the most important characteristics of these technologies.

**Table 7.2. Summary of power supply options for reefers on trains.**

| Technology | Power source | Capacity | Use cases |
|---|---|---|---|
| Conventional 'clip-on' genset | Diesel-powered genset | One genset per reefer, power supply for several days | Worldwide |
| Refrigerated block train | Diesel generator on wagon powers train with reefers | Numbers quoted range from 8-38 reefers per generator | Worldwide |
| Rail Reefer Generator Set | 10ft container with diesel generator | Generator can power 2 reefers for 1 week | Test in the Netherlands, no information on current operations |
| Integrated diesel-electric reefer | Diesel-electric generator and fuel tank integrated in reefer | Self-sufficient for at least 3 weeks (full tank) | Unit45-produced containers for the New Eurasian Landbridge, CoolRail Spain-Netherlands |
| Siros Sustainable Power System | Clip-on battery solution, charged when train is braking | One system per reefer, duration of one charge unknown | Market offer unknown |
| Reewa Wagon | Power supply from catenary via locomotive, wagon-based converter | Unknown | Market offer unknown, prototype announced in Croatia (Transagent) |
| Wascosa wagon | Power supply from catenary via locomotive (UIC552 standard), wagon-based converter | 2 reefers per wagon | Operations from the Port of Koper |
| rCE Powerpack | Rechargable batteries with axle generator fitted on railcar | Up to 4 20ft reefers per railcar | In use in Switzerland by railCare AG, elsewhere in Europe by VTG |

Source: Corporate websites, news releases, and presentations.

The information is summarized quite roughly and is a simplification in the sense that other important factors such as traffic management, fleet management, demand management, and modal transfer technologies are left beyond the scope of this study. Nevertheless, the overview illustrates that the technological potential and assessment is a complex issue. In the inventory above, the technical advantages of each system differ substantially by the type of technology when it comes to engine design, vehicle design and fuel technology. As an illustration of the complexity related to fuel technology, for the Silk Route climate-neutral (synthetic), fossil-free fuels are in development, so that equipment can still be used under the most extreme temperatures and temperature fluctuations. It is essential that reefer containers can perform under extreme weather conditions (ranging from –30°C to 50°C). This also requires that reefers need to be equipped with internal heating systems. For one trip from China to Western Europe it is calculated that this requires 800 liters of fuel (Unit45, 2014). Furthermore, they pass through remote areas where energy supply is difficult and monitoring and maintenance are impossible.

Apart from surveying the available technological options for reefer transport by rail, it is also relevant to consider cases where new rail logistics concepts for reefer transport by rail have been (or are being) introduced. The growing attention for a modal shift of perishable cargoes is illustrated by examples of new types of services from Europe, North America, and Asia, as discussed below.

Most of the European railway network is electrified (Jonkeren et al., 2019), but new rail-based reefer transport services that are introduced rely on diesel generators as well as batteries and/or catenary power. The section above mentioned the use of refrigerated block trains in the Baltics and Spain, use of catenary power by Reewa in Croatia and Wascosa in Switzerland,

and two concepts with rechargeable batteries (SSPS and rCE). One other case of a new service for reefer transport by rail, also often referred to by the study's respondents, is CoolRail. On May 6th, 2019, this new direct train shuttle for fresh products was introduced between Valencia (Spain) and Rotterdam (the Netherlands). The train runs three times a week with fruit and vegetables, replacing 41 truckloads per journey, and saving up to 90 percent in $CO_2$ emissions (RailFreight, 2018). The CoolRail concept uses Unit45 integrated diesel-electric reefers containers with built-in fuel tanks. Transport to the Netherlands on this train is just as fast as road transport, but more sustainable. The train carriers reefer containers on the leg from Spain to the Netherlands, and the backhaul is filled with empty, re-usable crates – a durable solution for transport and storage of fruit and vegetables, for which the company Europool operates a European network of transport and cleaning facilities, supplying growers with clean, empty crates, and organizing the return and cleaning of crates from retailers.
Parallel to Europe, in the US interest in reefer transport by rail is growing as truck capacity is tightening. Since the 1970s railroads were dropping LCL (less-than-carload) and short-haul business allowing the trucking industry to pick up most perishables traffic. However, now that truck capacity is tightening on the long-haul routes, rail operators argue they can grab reefer market share from other transport modes (Sowinski, 2018). In the absence of catenary wires on most tracks, American operators use clip-on gensets or railcar-mounted power packs (with diesel generators). In the ports sector, the ports of Long Beach and New York/New Jersey are actively improving the rail connectivity of their cold chain logistics facilities by installing extra rail sidings (Castelein, Geerlings, et al., 2019).
Third, there is growing attention for intercontinental rail connections in Asia, in particular the Belt and Road Initiative (BRI), a global strategy deployed by Chinese government involving worldwide investments in existing and newly developed infrastructure. This initiative includes a new train connection taken into operation in 2018 from China to The Netherlands. For eastbound cargo, the rail connection is aimed at temperature-controlled cargo in 45ft reefer containers with integrated diesel-electric reefer units with a high-capacity tank containing fuel for up to two weeks, whereby electronics is the main focus for Westbound cargo in the winter period. To guarantee the quality of conditioned transport, operators have invested in their own equipment. Block trains on this route have a travel time of twelve days, while a container ship takes about 28 days for a single trip.

**Reefer transport by barge**

For reefer transport by barge, as an alternative to trucking, there are also several technological options.

- Similar to deep-sea container ships, barges allow the option to power reefers through plugs connected to the on-board electrical system, powered by the main or auxiliary (often diesel) engines. On inland waterways barges there is often a limited number of reefer plugs available, but due to their long lifespan, many older barges are not fitted with enough plugs to accommodate the reefers in quantities that today's volumes require. One study respondent (representative of barge operator) explained that the on-board electrical system of barges can be used to power reefer containers, but will have very limited capacity (a handful of reefers at the same time), unless the engine configuration is sized with larger numbers of reefers in mind. The fact that the reefer segment is becoming more important for the barge transport sector is illustrated by two developments. First, that newly delivered barges are generally equipped with a larger number of reefer plugs than before (some with to 70 plugs on a 420TEU barge) and correspondingly higher capacity of the main and auxiliary engines (Hoek, 2016).

Secondly, older barges are retrofitted with more plugs and additional power generation capacity (either by installing a higher-capacity engine configuration or installing an additional diesel generator), creating quoted capacity of 14 to 40 reefer containers (Doepgen, 2016; GreenPort, 2018). Two barge operators interviewed – both of which have undertaken comprehensive expansion of the reefer capacity of their fleets – explained that as a part of the overhaul of their vessels they also had reefer monitoring systems installed using power line communications technology through the reefer plugs.

- A more improvised solution is to provide power to a larger number of reefers at intervals, allowing the engine and/or generator capacity to remain unchanged (Doepgen, 2016). All interviewees representing barge operators stated this is one of the practices they use. A reefer container should be able to maintain an internal temperature well within the tolerable bandwidth for approximately a day without being plugged in. Therefore, powering a reefer for one hour every few hours should not be a problem. However, shippers – in particular pharmaceutical companies with high-value cargoes and stringent requirements – increasingly demand uninterrupted power supply to their containers, also under pressure by their insurance companies. These developments make more barge operators consider retrofitting their fleets with greater reefer capacity.
- In case of too few reefer plugs being available for the number of reefers to be transported, clip-on gensets can also be used during barge transportation. For more details, see above.
- A solution that is similar to the refrigerated block train discussed above is power packs for barges. A power pack is a diesel generator with a large fuel tank placed in a 20ft or 40ft ISO container. A 20ft power pack with a 1000 gallon (3784 liters) tank can, depending on the reefers' energy needs, power up to 50 reefers for 1 to 3 days (Power Pool Plus, 2020). In practice however, rarely more than 25 reefers are connected to the same power pack, as operators prefer to keep the power lines as short as possible to prevent line losses (Pratt & Chan, 2017). Depending on user needs, power packs can come with a variety of add-ons, including auxiliary fuel tanks for extended run time, and dual engines to provide redundancy in case of generator failure. The generator can be handled in the same way as regular containers, and is placed in one of the container slots on the barge. The big difference with railcar-mounted generators is that power packs at barges are exposed to (salt) water, protection for which has to be incorporated in the design.
- In the examples above, the power supplied to the reefer containers is coming from the ship's engine or from a mobile generator (power pack). To the author's best knowledge, there is currently one other solution in the market, namely power packs with hydrogen fuel cells.
- Hydrogen fuel cell power packs are similar to power packs with diesel generators, in that the power source is placed in a standard ISO intermodal container body. The experimental setup operated in Hawaii starting 2015 entailed a 20ft ISO container with hydrogen fuel cells and associated equipment that could power 10 reefers for up to 28 hours (Pratt & Chan, 2017). The pilot project report includes the caveat that for operators this is relatively limited capacity, and that they would rather have the option to power up to 25 reefer containers with one power pack. Also the operating time is considered limited, but for short haul trips (such as between Hawaiian islands, taking a half day at most) the solution is adequate. There is no evidence yet of this concept being used elsewhere, and researchers note that the implementation depends on the

availability of refuelling facilities, and the training of maintenance staff to work with hydrogen power packs.

Table 7.3 below presents an overview of the technologies discussed.

**Table 7.3. Summary of power supply options for reefers on barges.**

| Technology | Power source | Capacity | Use cases |
|---|---|---|---|
| On-board electrical system | Ship (auxiliary) engine, option for retrofitting with greater capacity | Depends on engine, option to power reefers at intervals | Worldwide |
| Clip-on gensets | Diesel-powered genset | One genset per reefer, power supply for several days | Worldwide |
| Power packs | Diesel generator fitted in ISO container | Commonly up to 25 reefers, power for several days | Worldwide |
| Hydrogen fuel cells power pack | Hydrogen fuel cells in ISO container | Can power 10 reefers for a little over a day | Experiment in Hawaii |

Source: Corporate websites, press releases, and presentations.

Case studies of new logistics services for reefer transportation by barge are geographically limited to regions where barge transportation is an established sector, facilitated by well-developed inland waterways networks. Accordingly, well-publicized cases come mostly Europe (the Rhine basin) and United States.

As discussed above, American regions frequently experience road congestion and truck driver shortages, especially in port cities and their long-range connections to hinterland destinations. Accordingly, ports in California including LA/Long Beach, Oakland and Stockton are stimulating a modal shift to rail and barge transport by investing in additional infrastructure and subsidizing the creation of new transport services (Castelein, Geerlings, et al., 2019a; Nall, 2014). Between the inland port of Stockton and the deep-sea port of Oakland, barge operators use existing barges with power packs in ISO intermodal containers to provide power to the reefers with meat and produce for export (Nall, 2014). Simultaneously, participating cold store operators invest in additional barge-handling equipment on the quayside. Transport by barge takes considerably longer due to the waiting time and lower speed, meaning that containers take 1-2 days to be delivered instead of a few hours by truck. Apart from avoiding congestion and reducing emissions, transport by barge is considerably cheaper at approximately $350 per container as opposed to $630 by truck – not taking into account repositioning fees.

Similarly, in the Rhine basin in Western Europe, there is increasing attention for a modal shift from road transport to the region's well-developed inland waterways network. The major seaports of Antwerp and Rotterdam also take a leading role in stimulating the use of barge transport and the creation of new services. An example in Rotterdam is a pilot project for a newly created barge service for intra-port transport. The Port Authority here facilitated cooperation between a deep-sea container terminal, a deep-sea carrier, and a barge terminal operator, which led to the creation of a regularly scheduled barge service from the deep-sea terminal to the barge terminal (some 40km one-way), where containers can be picked up relatively quickly by truck through a fast-lane system (Dijkhuizen, 2019). This initiative aims to reduce transport emissions and make reefer container shippers suffer less from road congestion, while not significantly impacting the transit time. Moreover, bundling of reefer and dry container flows allows for a higher service frequency and reduced waiting times. In a similar initiative from the Port of Rotterdam, called Lean & Green Barge, shippers with large volumes (including major breweries and potatoe- and dairy-processing firms) are stimulated to set up barge connections, allowing smaller shippers to use additional capacity on these lanes once they are created with a minimally guaranteed volume from the big shippers (Port of Rotterdam, 2014). Also the private sector has taken on a leading role in shifting cargo from road transport to barging. One of the study respondents (a barge operator executive) outlined how their company already had a high-frequency service between Switzerland and the ports of Antwerp and Rotterdam, and actively sought reefer cargoes for the backhaul to create a better trade balance against the Swiss reefer imports. With the pharmaceutical sector being a major exporter of reefer cargoes in Switzerland, the operator convinced several of these companies to participate in pilot shipments, in which the operator would make upfront investments in power supplies and monitoring systems on selected vessels. As this experiment proved successful with barge transport performing well on cost, efficiency, and quality criteria, several pharmaceutical producers have made the shift from truck to barge transport for their export containers. Similarly, a multimodal operator is also investing in reefer infrastructure in inland terminals, allowing them to handle and store growing numbers of reefer containers, and providing an expanded range of reefer services, including inspections and maintenance (Contargo, 2019).

These examples together with the examples of technology listed above illustrate the trend currently underway in the Rhine basin, with equipment and infrastructure being gradually upgraded to facilitate growing reefer flows on inland waterways, and shippers, transport service providers and public sector bodies cooperating in experiments with reefer transport by barge. A key factor in these initiatives appears to be the bundling of cargoes (reefer as well as dry containers) to guarantee a sufficiently high service frequency to meet the demands of time-sensitive shippers. Moreover, the use of barge transport is a rather new concept to the truck-dependent reefer sector, and new logistics models are started as tentative experiments, with further expansion of services and equipment fleets depending on the success of these pilot projects.

Wiegmans et al. (2010) formulated that the potential for large-scale diffusion of transport technology is dependent on two elements. First there are technological innovation system characteristics that are relevant. This section shows that there is not one dominant technology for reefer transport by rail or barge yet. Electrified alternatives to fossil fuel-based generators are in the early phase of development and not yet taken up in the market for long-distance transport on a large scale. Even in cases where electrified traction is available (as in most major European corridors), power supply to reefers on the train is still a stand-alone system based on diesel generators. In case of barge transport, reefers can be powered by the barges' main or auxiliary engines, but with the fleet still predominantly running on fossil fuels (only a handful of electrified barges are in operation), this also affects the energy mix used to power reefers. Secondly, there are user requirements and perceptions regarding the relative advantage of a technology, compatibility with existing systems and processes, complexity, opportunities to observe and evaluate performance, the possibility to try-out (Rogers, 2003), uncertainty, user-friendliness, and risk (Nooteboom, 1989). In addition to this, Wiegmans et al. (2010) address the growing concern for sustainability as a criterion in users' decision-making. All these factors are visible in the new logistics services (and associated technologies) described above: many new initiatives start with pilot projects with a few participants, exploring what is needed to meet user requirements to a sufficient degree (e.g. bundling dry and reefer cargoes to increase service frequency), and improving the compatibility of intermodal equipment and infrastructure with the requirements of the reefer and cold chain logistics sector. These user requirements and considerations are addressed in further depth in the following section.

## 7.5 User perspectives

The focus of the stakeholder interviews was on two types of corridors on which reefer containers could be transported by train or barge: the hinterland link of a maritime reefer chain (hence having the overland leg starting or ending in a seaport), and the continental intermodal transport of reefer containers from origin to destination. A third option, namely intercontinental reefer transportation by train – as is the case on the new Silk Road rail connection – was also addressed, but due to it being a somewhat atypical example of a modal shift to rail (in this case, rail being the faster, more expensive option relative to sea freight), the main focus was on corridors where a modal shift from road to rail or barge is in question. Due to barge transport being limited to regions with well-developed inland waterways networks, long-distance intercontinental barge transportation is not relevant.

**General requirements**

Before discussing their considerations regarding a modal shift from road transport to rail or barge specifically, the respondents elaborated on their general requirements of reefer container transport. While the transportation costs by rail or barge are lower than the costs of trucking, most respondents (especially shippers, and service providers working on behalf of shipper clients) emphasized the importance of speed – especially when the product quality needs to be assessed and/or the products need to be delivered at an auction (as can be the case for fruit, vegetables, and flowers) before a certain cutoff time. A second criterion is flexibility: shippers want to determine their own pick-up and delivery times, with the option to make adjustments on short notice. This includes the option to decide between trucking or other modalities on the spot. This is juxtaposed with terminals' expressed preference to be able to plan on a container leaving or arriving on a predetermined modality. Third, respondents emphasize the importance of reliability, which is jeopardized by failing coordination of barge and rail transport around container terminals in seaports.

Most shippers or service providers work directly or indirectly for large retail chains, often under stringent performance agreements, with the retailer demanding reliable and frequent service to keep their inventory limited, while also requiring flexibility to adjust delivery times and quantities as needed. Retailers' market power allows them to put pressure on costs as well as flexibility and lead-time, limiting the discretion of shippers and service providers to consider alternatives to truck transport.

**Evaluation of rail and barge reefer transport technology**

The main technical barrier to the attractiveness of rail transport for reefers – as expressed by respondents – is the lack of a 'plug and play' option to power the reefers on board the train with power drawn from the catenary. Gensets can be used, but this is generally not an attractive alternative for users: gensets are expensive to rent for long trips, have to be redelivered after the trip (for which there is seldomly a suitable reefer cargo available for the backhaul due to trade imbalances in food products), and require additional care to install, set up, maintain and refuel. An often-used alternative is a 45ft continental reefer container with an integrated generator and fuel tank. This integrated solution eliminates the need for an additional genset, but still requires refueling and is fossil fuel-based. While there is awareness among shippers that rail transport is a more sustainable option compared to trucking, the fossil fuel reliance of the existing power sources (clip-on gensets or (integrated) generators) creates the perception (described by one LSP as a dislike towards 'often leaky, diesel-guzzling generators') that the potential for sustainability gains of reefer transportation by rail is limited.

A similar consideration applies to barge transport. One respondent describes the barge fleet in the Rhine basin as ‘old junk,’ and others affirm this shared perception that barge transport is not much more sustainable compared to trucking. Also the considerations regarding gensets sketched above apply to users’ perspectives on barge transport – gensets have to be rented and repositioned after transport, which can be expensive. With investments in new barges and the retrofitting of existing barges still being limited, the European barge fleet still has limited reefer plugs per ship available, and the practice of alternating power supply to a larger number of reefer containers poses a risk to cold chain integrity and cargo quality from the perspective of the user.

**Evaluation of current intermodal logistics concepts – Operators and users**

Rail logistics concepts fall within three categories: block trains, shuttle services, or single wagonload services. While many shippers ship limited volumes at one time, single wagon load services are often not considered because of the greater lead-time caused by frequent shunting operations to combine or split up trains en route. When respondents mention successful cases of rail-based logistics concepts for reefers, they refer to block train or direct shuttle service concepts. Examples are the GreenRail concept for flower exports from the Netherlands to Italy (BestFact, 2013), and CoolRail, a direct service for fruit shipments from Valencia (Spain) to Rotterdam (the Netherlands) (RailFreight, 2018). Both concepts entail direct shuttle trains between two regions where – despite the considerable distance – there is a large enough perishables trade for the operator to consolidate volumes on a frequent (multiple times per week) direct train connection. Representatives of a shipper organization and a transporters association sketched the necessary conditions for a viable rail concept for reefers (assuming that the nature and time-sensitivity of the goods allow for rail transport): long distance, bundling of large volumes from committed shippers, high frequency, direct trains (i.e. no shunting operations, in either a block chain or direct shuttle connection), and a two-way flow of perishables trade to ensure sufficient equipment utilization in both directions. In the same vein, reefer transport by barge should also offer a high service frequency (frequent enough to offset the relative inflexibility relative to truck), a baseline demand of committed shippers, and a two-way flow of reefer containers to justify capacity investments. There are several examples of barge services that meet these requirements, and that respondents viewed considerably positive. First, in California a barge shuttle runs between Stockton and Oakland, with a direct service guaranteeing a relatively fast transit (Nall, 2014). In this case, the region imports as well as exports perishables, which allows the operator to utilize the expanded capacity of power packs and reefer plugs on both legs of the connection. Moreover, ports in the region have a broad cargo mix with imports and exports of other goods (in dry containers) to easily fill up excess capacity. Secondly, Danser – a barge operator based in the Netherlands operating in the Rhine basin – has invested considerably in the reefer capacity of its barges including an on-board monitoring system, and convinced Swiss pharmaceutical companies to commit fixed amounts of export reefer containers on a weekly basis. Their fleet size allows a high service frequency, and the pharmaceutical exports provide valuable cargo for the back haul, after transporting import reefers. By strategically seeking backhaul cargo from the hinterland, Danser has managed to use their reefer capacity both ways. The large amount of dry cargo being transported in this corridor helped to guarantee a high service frequency, which in turn facilitated the modal shift of shipments of reefer containers. Multiple shippers interviewed indicated that this is a good example of a modal shift done well, and if it proves to be successful in the long run, they would much sooner consider using barge transport as well. A third example also underscores the importance of proven concepts to convince hesitant users. In the Port of Rotterdam, a deepsea container terminal cooperates with a deepsea carrier and a barge terminal operator to use the barge terminal (further inland) as a designated pickup and drop-off point for reefer containers (Dijkhuizen, 2019). Imported reefer containers are transported directly by barge to the barge terminal, and barges receive fixed windows to load and unload at the quay at the deep-sea terminal. Also here, a steady flow of dry containers in the corridor facilitates a high service frequency and allows the operator to mitigate seasonal fluctuations in the flow of reefer containers. Several respondents have been involved in this pilot project, and are positive about the reliability and speed, as well as the reduced trucking distance and avoidance of congestion around deep-sea terminals.

These examples for rail as well as barge highlight the importance of food trade imbalances (i.e. major importing regions are rarely major exporting regions) and fluctuating reefer volumes for the supply side of intermodal reefer transportation. One respondent estimated an occupancy rate of approximately 80% being necessary to break even on a rail shuttle service with dedicated reefer equipment. In case of major trade imbalances, a large share of the backhaul trade would be repositioning of empty or non-operating reefers. This may explain the current absence of dedicated rolling stock that offers the option to directly plug in operating reefers, as this would require dedicated investments that serve their purpose to the full degree on only one leg of a trip, in a fairly small niche market. Moreover, the seasonal fluctuations of most reefer trades do not match well with the long-term equipment commitments (i.e. one year or more) that are common to the rail sector. To overcome these barriers, an operator has to work with a diverse portfolio of clients and cargoes that allows to hedge for seasonality and trade imbalances in corridors where this is possible. Another solution that was frequently mentioned in the context of reefer transportation by barge is the combination of dry and reefer containers to be able to increase the service frequency and mitigate seasonal fluctuations in the reefer segment. Interestingly, for rail transportation this was not mentioned by any of the study respondents.

Concerning intermodal connections from seaports towards their hinterland, two operating models can be distinguished: one where the intercontinental (usually 40ft) reefer container is loaded straight onto the train or barge, and another where the intercontinental container is stripped and the cargo is re-stuffed into a continental container (usually 45ft). Considering hinterland transportation, the first model may be faster, but is also more expensive to the shipper as the length and duration of the trip increase. The intercontinental container is owned by the deep-sea container carrier, which prefers to have it back quickly for use by another client. Therefore, after a few days of 'free time' (usually 2-3 days), the shipper starts paying 'detention' charges for late delivery of the container. For this reason, shippers typically opt to strip the 40ft deep-sea container in or close to the port area. When cross docking, they can opt for a 45ft continental reefer container or to stuff the cargo into a truck (of similar capacity) directly. Even for long-haul hinterland transport, shippers often opt for a truck, since it entails fast and direct delivery, and does not have the additional handling (including last-mile trucking) that a rail or barge shipment would.

Also users' evaluation of hinterland networks illustrates some barriers to the adoption of intermodal transport for reefer containers. Inland terminals usually have limited availability of reefer plugs for storage of reefer containers, and considering their sometimes-limited connectivity, they involve considerable risks of delays, even for last-mile trucking. Moreover, after every trip, a reefer container requires cleaning, maintenance, and inspection (pre-trip inspection, or PTI) before being used again. These PTIs are offered in different locations in port areas, but only in a few inland terminals. Recent examples exist of container depots and PTI facilities being placed at inland terminals (Contargo, 2019), but in practice most reefers still have to be transported back to a port empty before being reuse – as affirmed by multiple study respondents from intermodal operators, as well as their clients.

Lastly, respondents mention administrative barriers and interoperability concerns they expect to cause delays in international rail freight transport. Different European countries require a train driver to speak the country's language, and the locomotive to be compatible with the country's signaling systems. Also pointing out different catenary voltages and gauge changes, respondents fear that international rail transport is too prone to hold-up risk and too cumbersome compared to trucking. When it concerns intercontinental reefer transport by rail – the major example of which is the New Silk Road railway – another hold-up risk is introduced by mandatory veterinary inspections of animal products at the EU border. In the regions where this is relevant, international barge transport is more effectively governed. The Mannheimer Akte and the Central Commission for Navigation on the Rhine guarantee free traffic, standardized regulations, and maintenance of navigability of the river Rhine, whereas the Danube Commission fulfills similar functions in the Danube basin.

**Competition between modes**

The common frame of reference when evaluating intermodal options for reefer transportation is the alternative of truck transport. For the great majority of shippers, trucking remains the default option, and intermodal alternatives are rarely considered. The reliance on truck is tied in with shippers' and retailers' internal processes all being designed based on trucking of their cargo. From a modal shift perspective however, it is desirable to reduce truck transport in favor of intermodal alternatives, to address externalities and capacity constraints of road transport.

The attractiveness of truck transport stems – as described – from its flexibility, speed and reliability. Truck transport is more expensive than barge or rail transport, although in lower-wage regions (e.g. Eastern Europe), it can compete on costs as well. Regarding sustainability concerns, a shipper representative – while still acknowledging other problems like road congestion and driver shortages – expects the environmental footprint of road transport to decrease due to the introduction of truck platooning and electric vehicles. This they compared to 'old junk' barges operating in inland waterways transport, and inflexible, cumbersome rail transport that does not offer a good option to power reefers on-board.

For longer distances (over 300km), rail and barge can compete effectively with trucking on costs, albeit at a lower speed – barge compared to rail offers a lower speed at a lower cost, and has a number of reliability issues stemming from barge handling at terminals (usually on a first-come first-serve basis, with unpredictable waiting times) and load restrictions due to low water levels in dry summers. However, inland waterways transport only holds a significant position in specific regions. The respondents identify several factors that make them prefer barge transport over rail on routes when possible: lower costs, more flexible, more options to power reefers on board and no (perceived) barriers to cross-border transport due to the Mannheimer Akte. In this consideration, speed differences between rail and barge are not considered problematic, arguing that if speed were a pressing issue, users would opt for trucking.

Figure 7.3 below shows respondents' average evaluation of statements related to intermodal transport of reefer containers, with -5 indicating strong disagreement and 5 indicating strong agreement (as well as the standard deviation of the responses) (see Castelein et al. for the full survey study (Castelein, Van Duin, et al., 2019)). While the absolute scores are only meaningful in the context of the full survey, the relative scores of the statements related to intermodal transportation, and the overall trend of agreement and disagreement are insightful. Overall, respondents see the potential benefits of a modal shift. Between barge and rail, they are – within a European frame of reference – considerably more positive about barge transportation than rail. Between these two intermodal alternatives, the advantages over trucking are not great enough to incite a more rapid modal shift, despite positive perceptions of experiments with new service concepts.

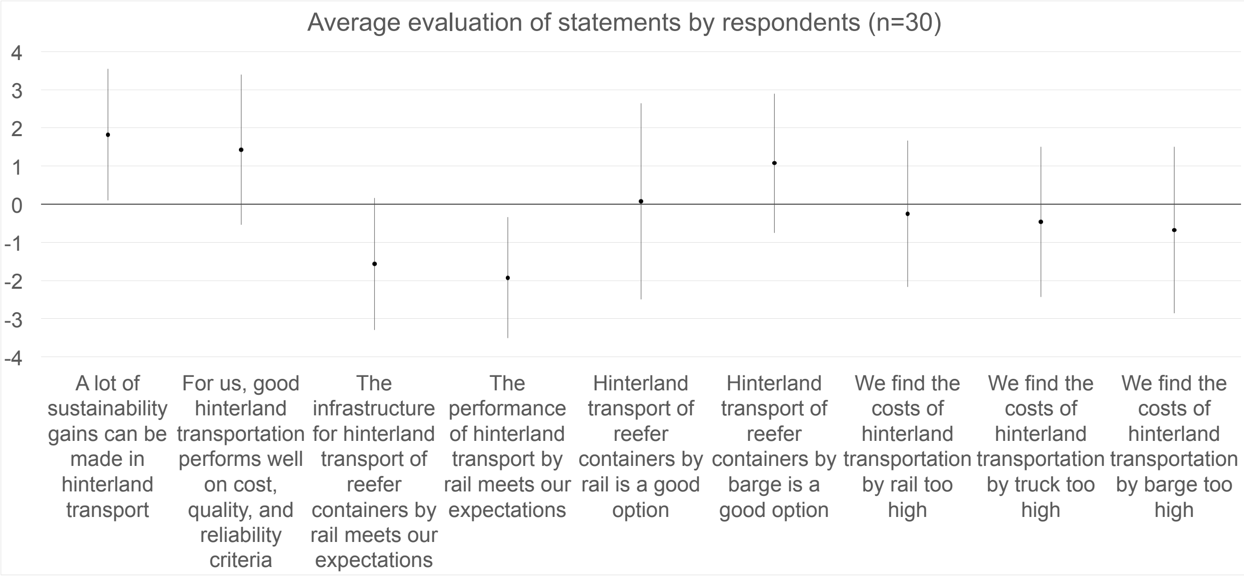


**Figure 7.3. Respondents' average evaluation of Q-method study statements related to modal shift of reefers (standard deviation in bars).**

Source: Castelein et al. (2019).

## The need for a 'mental shift'

Multiple respondents, including carriers, logistics and transportation service providers, terminal operators and port authority representatives, stress the need for new ways of thinking to realize a modal shift. As one LSP voices, rail and barge are simply not considered as options, because trucking is the default choice. This seems to be partly inspired by what respondents call a 'false sense of urgency' – the idea that every container should be delivered as soon as possible, while several logistics service providers describe how their clients rather receive shipments gradually over a period of time to keep their inventory low. The prevailing idea with perishables seems to be that every container is urgent, while practice illustrates that this is not by far the case for all containers. In one of the cases discussed (the barge shuttle between Stockton and Oakland in California) a venturing operator also emphasized that changing routine behavior in the sector is a major challenge, and that there is broad reluctance to be the first party to try something different (Nall, 2014).

One terminal operator supports the idea that dominant ways of thinking and organizing processes work as barriers to change in the sector. They point out how the way the market is organized and the ways actors operate contribute to this (false) sense of urgency. Deep-sea carriers have reduced the 'free time' for their containers (i.e. the period within which a container has to be delivered back before the shipper starts paying a detention fee), putting more pressure on shippers to quickly strip the container. On the other end of the chain, retailers demand a high delivery frequency and a high degree of flexibility that are most easily met by resorting to trucking. Accordingly, constraints imposed by dominant actors up and down the chain limit the extent to which alternatives to truck transport are a viable option.

To sum up, these stakeholder considerations illustrate two barriers to the development of reefer transportation by rail and barge. One is the current absence of a logistics concept that sufficiently satisfies user needs – although the fact that potential users view recently developed concepts favorably indicates a trend towards greater acceptance of barge and rail transport. The other barrier is an ingrained dependence on truck transportation and an associated perception that trucking is the only way to meet user needs in terms of speed, ease of use, flexibility, and reliability. Thus, to achieve a modal shift in this sector, a 'mental shift' is needed first, including a reconsideration of existing convictions, structures, and processes.

## 7.6 Conclusion

In freight transportation, the concept of a modal shift from road transport by truck to intermodal alternatives such as rail or barge transport receives increasing attention due to externalities and capacity constraints associated with road transport. In the fast-growing perishables transport market however, truck transportation is dominant, and the modal shares of rail and barge transport are negligible. In this exploratory study, the authors surveyed existing technologies to transport refrigerated containers by rail and barge, and mapped user requirements and evaluations of existing service models to evaluate the potential for a modal shift.

Technically, rail transport of reefers can be zero-emission, if reefers can be powered by energy from the catenary, and depending on the grid's energy mix. Among current technical options available to power reefers however, fossil fuel-based diesel-electric generators seem to dominate. For perishables market stakeholders this has two implications. First, they doubt the sustainability gains to be had from a modal shift due to the association with fossil fuels. Secondly, they doubt the ease of use of rail transportation for them, citing the hassles of working with gensets or re-stuffing cargo into containers with an integrated generator. An option where the reefer can be plugged in is deemed desirable, but none of the proposed innovations has shown large-scale adoption yet. In absence of a new standard of electrification of the power supply to reefers, and considering the small market and the dedicated investments this requires, diesel-electric solutions remain the standard. Similar issues are relevant for the barge transport sector, in which it is relatively easy (compared to the rail sector) to accommodate larger numbers of reefer containers, but with a barge fleet with fossil fuel engines and considerable life span. The existing fleet has limited capacity for reefer containers due to the absence of a large enough number of reefer plugs per barge. By retrofitting barges with higher capacity engines and by taking on board mobile generators (power packs) the capacity to connect reefer containers can be expanded. However – especially compared to the rail sector in Europe – electrification in the barge sector is nearly non-existent – leading to potential users discounting the sustainability gains to be had from a modal shift.

Several examples were discussed of corridors where reefer logistics concepts by rail or barge are explored. The most prominent example of perishables transport by rail is currently the new Silk Road connection between China and Europe. However, this intercontinental service is a quite a-typical example of a modal shift to rail. In this case, rail transport is actually the faster option (a transport time reduction of 50% or more compared to deep-sea shipping) at a higher price (reportedly approximately 5 times as expensive as sea freight). Nevertheless, if perishables transport along this corridor grows, there may be two implications for a modal shift from road to rail in other markets/corridors. First, it may stimulate the development of new logistics concepts for reefer transportation by rail, which can be implemented in other markets to enhance the attractiveness of a modal shift in contexts where truck transport dominates. Secondly, the same applies for technology development. If the scale of intercontinental perishables transport by rail grows, this serves as an impetus to further develop technologies to power reefer containers on board and enhance the environmental performance. Barge transport is a more regional phenomenon, with only a relevant market position in regions with well-developed inland waterways networks. However, examples from Europe and North America show increased attention for barge transport as an alternative to reefer transportation by truck. Two European examples of an initiative entailing a modal shift to rail were discussed as well. Interestingly, both rail-based initiatives involve direct dedicated shuttle trains (i.e. terminal to terminal, no shunting en route) with reefer containers, while the barge concepts examined were explicitly based on combining reefer and dry container flows to increase service frequency and mitigate seasonal fluctuations. For both modalities, potential users view these new services as promising user cases where intermodal alternatives to trucking still meet their demand for rapid enough service at a high frequency. These examples also illustrate the conditions under which a modal shift from road to rail or barge is feasible and acceptable to stakeholders. For rail this entails corridors with sufficient volume in two directions, high frequency service with block trains or direct shuttle service, organized by a service provider who can effectively manage an efficient rail service through multiple countries. For barge, this also entails a high service frequency, with reliability enhanced through coordination with other organizations (e.g. ensuring fixed windows at container terminals). In the future, the flexibility of rail- and barge-based logistics concepts can be further enhanced by combining different modalities to meet customers' specific preferences in terms of price and speed. These observations underscores the importance of proven concepts – even at a small, experimental scale – to show hesitant potential users what is possible, and alleviate their doubts towards alternatives to trucking.

Ultimately, the research findings show that a successful modal shift first requires a change in mindset regarding existing practices by all stakeholders involved in the cold chain.

# 8 Discussion and conclusions

## 8.1 Introduction

This dissertation investigates how maritime refrigerated container chains can be effectively accommodated in seaport clusters. In the introduction, the research question was posed *how seaport-related actors can effectively accommodate reefer container supply chains in a seaport cluster, meeting demands for efficiency and competitiveness, as well as sustainability.* The articles in this dissertation have addressed various facets of this question. This chapter summarizes the main findings from the six articles constituting the chapters of this dissertation and sketches an answer to the main research question. Furthermore, this chapter reflects on the approach taken in this dissertation, and outlines the main implications and recommendations for research, policy, and practice.

As the chapters of this dissertation were previously published as self-contained academic articles, each chapter contains a unique exposition of (and reflection on) the conceptual and methodological approach – meeting the academic standards for publication – as well as a complete discussion of implications and recommendations derived from the individual study. The discussion and reflection in this concluding chapter extend from the total body of research contained in this dissertation, focusing on those insights that only become apparent when considering the individual chapters in relation to one another. In addition to the introduction (Ch. 1), this concluding chapter is where the article-based dissertation gets a real holistic character and becomes more than the sum of its parts. For specific reflection and discussion on one of the constituent studies, the reader can find back the information in the relevant chapter.

## 8.2 Summary of findings

This dissertation started from the question how seaports can better accommodate specific supply chains, taking the reefer container and cold chain logistics segment as a relevant case study, with increasing relevance for seaports due to its growth, high value, stringent demands, and implications for seaports' energy management. The introduction conceptualizes reefer container chains as complex multi-stakeholder systems, with seaport clusters as functional and geographical clusters of cold chain stakeholders, processes, as well as challenges and risks. The latter relate to physical hold-up risks in the port cluster, and the myriad sustainability concerns relevant for cold chain logistics. Due to the important role of seaport clusters in these chains, and the fact that port authorities are the only stakeholder organization that is explicitly the primary problem owner – in terms of legal and statutory responsibilities – of all relevant issues (related to efficiency, competitiveness, and sustainability), the approach of this dissertation includes an explicitly policy-oriented component, as well as a comprehensive focus on the characteristics of the reefer container and cold chain logistics sector as a complex multi-stakeholder socio-technical system and the associated governance challenges.

The general structure of the dissertation is as follows. Chapter 1 introduces the topic and its relevance for practice and the research field as summarized briefly above. Before zooming in on the reefer and cold chain logistics segment, chapters 2 and 3 address two relevant topics pertaining to container ports in general, namely port pricing and inter-port competition (Ch. 2) and intra-port competition and coordination (Ch. 3). Chapters 4-7 subsequently focus on the reefer container and cold chain logistics, with chapter 4 setting the scene with a detailed investigation of the maritime reefer market itself, establishing the relevance of seaports, and a systematic literature review of the topic. Chapters 5 and 6 investigate stakeholder perspectives on coordination and sustainability issues in the reefer chain (Ch. 5) and the policy options for seaports to facilitate reefer container transport and cold chain logistics activities in port clusters. Based on the findings from chapters 5 and 6, chapter 7 investigates the feasibility of a modal shift of reefer containers as one of the more promising directions of change from both a chain actor and a policy perspective.

**Chapter 2 – Port choice and port competition**

Chapter 2 investigates new linkages in an overarching conceptual framework involving port characteristics, port choice by supply chain stakeholders, port policy, and port competitiveness, for the container market specifically. In particular, the chapter highlights interdependencies in actors' decision-making, and how actors' strategies and decision making together with port policy determine the ultimate value proposition a port competes with in the regional or global freight market. The findings from stakeholder interviews, triangulated with port throughput data and information from the professional literature, show that port pricing in combination with port characteristics and the strategic positioning of port users (importantly container terminals) matter for strategic market positioning of ports. A too strong focus on cost competitiveness and throughput growth undercuts port performance on other indicators such as service level and value added. Furthermore, a port's attractiveness to carriers' does not always translate to attractiveness to shippers. The most important finding is that port's physical characteristics and port policy (notably pricing) alone do not determine a port's value proposition. Rather, a port's value proposition is also dependent on how port users (shippers, terminals, and carriers) strategically position themselves, and how they use the port. The congruency between port policy and other driving factors of ports' value proposition is a key driver of port performance and competitiveness.

**Chapter 3 – Intra-port competition and coordination**

Chapter 3 considers intra-port competition and coordination in container ports. Most major container ports have multiple container terminals, operated by several terminal operating companies. Within the same port, they compete for carriers' business, but also face the need to coordinate activities such as the loading and unloading of barges and trains that need to call at multiple terminals, and the exchange of containers between terminals for transfer to deep-sea and/or feeder ships. Interviews with a representative selection of key supply chain actors reveal the problems that can occur in the physical flow of containers within a port when cooperation between terminals is under pressure. These problems stem from deficiencies in inter-organizational relations, which do not tend to arise or improve spontaneously in a competitive context. By placing information from the interviews and professional literature in a theoretical framework on balancing pressures for competition and cooperation (a so-called 'coopetitive' relationship), the chapter identifies root causes and makes suggestions for (technical and organizational) solutions aimed at specific bottlenecks in physical goods and information flows. The chapter emphasizes that effective implementation depends on various tacit factors that determine actors' willingness to commit and cooperate. Most importantly, this chapter shows that when organizations in a (port) cluster face strong competitive pressure from each other, even necessary coordination and cooperation may not come about, which hurts the overall competitiveness of the (port) cluster.

**Chapter 4 – The reefer market, characteristics, trends, and the academic state of knowledge**

In chapter 4 the maritime reefer container market is introduced, as well as an overview of the present knowledge from academic research on this market. Given that this segment of the container market is fairly 'new' – first being introduced in the 1970's and 1980s, but starting an explosive growth in the mid-1990's that continues to this day – the questions how this segment is embedded in seaports and how seaports should position themselves in this market are still very much open ended. Data of the worldwide reefer market show growth, modal shift from conventional reeferships to reefer containers, and increasing differentiation in the form of niche technologies and services. A closer examination of reefer container supply chains and data on insurance claims related to damaged or lost cargoes shows that that cold chain failure and cargo loss can occur due to technical failures at any point in the chain, but just as often due to organizational errors, in particular due to hold-up risk at container transfer points in seaports. A bibliometric analysis of the key concepts of this body of research shows that it mostly consists of highly specialized, technical studies on product characteristics and quality preservation, monitoring and control, refrigeration technology, and temperature management. Most importantly, this chapter shows that technological advances in these fields have largely enabled the containerization of cold logistics chains, many current pressing issues in reefer transportation are of an organizational or logistics nature. This finding informs the remainder of the substantive chapters of this dissertation.

**Chapter 5 – Stakeholder perceptions of sustainability issues in reefer transport**

In the introduction, the reefer container and cold chain logistics market was conceptualized as a complex, multi-stakeholder socio-technical system with an important relevance for (port) policy to address persistent issues related to efficiency and sustainability. As a solution to these issues critically depends on stakeholders' willingness to commit to a solution, it is important to understand the subjective perceptions of these problems by stakeholders, and their acceptance of new concepts, initiatives and policies. In chapter 5, to obtain an informative overview of a wide variety of stakeholder perceptions that is still parsimonious enough to effectively inform negotiation, coalition building and policymaking, Q-methodology is used – a survey-based method to study subjective viewpoints to identify a limited number of broadly shared perspectives. So far, Q-methodology has been used only rarely in the freight transportation field, but has produced interesting findings in other complex multi-stakeholder environments. The Q-method survey, augmented with respondents' elaboration on their responses, shows that stakeholder perspectives on this domain can be summarized in four 'dominant' perspectives that together explain a large share of variation in survey responses. The perspectives were described as:

- Sustainability as part of strategy
- Short term constraints
- Optimistic about technology, limited role for policy
- Long run willingness under risk avoidance

The organizations surveyed varied in their sense of urgency regarding issues and risks in the chain, their own resources and capabilities to propose or contribute to solutions, and in what they see as the appropriate role for policy. Interestingly, for the second group listed in particular, firms' reluctance to invest in sustainability or addressing inefficiencies in the chain stems from financial and operational constraints imposed by other (more powerful) actors in the chain, such as retail firms and carriers. Most importantly, there was a broader consensus among most firms in the four groups on the potential for sustainability gains in hinterland transportation (e.g. modal shift to rail or barge, upgrading inland terminals), and numerous respondents indicated openness towards a modal shift to more sustainable modes, if it can meet their requirements in terms of cost, speed, flexibility, and reliability.

**Chapter 6 – Cold chain strategies for seaports**

In addition to the multi-stakeholder perspective taken in chapter 5, chapter 6 focuses specifically on port policy for reefer transportation and cold chain logistics. An investigation on policies implemented by the world's 50 largest container ports yielded over 70 policies that were subsequently classified by their goal, geographical scope, instrument, stakeholder involvement, and the role taken by the port authority in question (ranging from conservator, to facilitator to entrepreneur. Most commonly, the scope of these policies targeting reefer and cold chain activities is limited to the port cluster, where port authorities (co-)invest in or aim for cold logistics cluster formation around cold stores. Where port authorities extend their scope towards their hinterland, this is usually aligned with policy goals formulated at higher levels of governance, such as modal shift goals or the development of domestic postharvest distribution systems – the latter in particular in developing economies. More ambitious port authorities with a broader scope contribute to initiatives impacting on the entire cold chain or reefer sector, often related to technical innovations for monitoring and control of reefer containers, most of which are fairly recent experiments with blockchain technology. Interestingly, no evidence of port policy nor a port strategy is encountered dealing with the energy management of cold chain logistics activities, or the further processing of conditioned (food) reefer cargoes in port clusters.

On the whole, there is very little evidence of port authorities pursuing targeted comprehensive cold chain strategies, addressing the logistics, marketing, technology, and sustainability dimensions related to this sector. Based on the spectrum of policies identified, this chapter sketches the general tenets such a strategy should contain. Most importantly, this chapter shows that port authorities very often pursue policies extending far beyond their traditional 'landlord' responsibility, developing facilitating and entrepreneurial roles that require active investment decisions under considerable uncertainty, and the development of new capabilities. The majority of the managing bodies of the world's major container ports develop these new roles and capabilities to expand their port's value proposition in the reefer container and cold chain logistics segment, suggesting that the 'landlord' port authority governance model does not suffice to understand the current behavior of port managing bodies.

**Chapter 7 – Exploration of reefer transportation by rail and barge**

As chapters 5 and 6 identified a possible modal shift of reefer containers as a direction of change that is both broadly supported by sector stakeholders and within the scope of most port authorities, chapter 7 considers the feasibility of a modal shift of reefer containers from road transport to more sustainable modes such as train or barge, drawing on two main sources of information. First are interviews to elucidate stakeholder requirements and perspectives. Second is the development of a detailed exposition of the technical and logistics options of transporting operating refrigerated containers on barge or train. A major finding is that for rail transport, there is no established option yet to connect reefer containers to an energy supply from the catenary as most existing options rely on some form of diesel-electric generator to power the reefers. For barge transport a limiting factor is the limited number of reefer plugs available on barges. For both, reliability of the service is cited as a major drawback.

Another, perhaps more interesting observation is that respondents consider trucking as the default option for their overland reefer transport, often without considering any alternatives. So the current dominance of road transport in the reefer sector is not just a result of the limits of physical transportation and power equipment, but also a locked-in pattern of truck-dependency more based on habit than regular conscious consideration of different options. This suggests that a modal shift requires a 'mental shift' among decision-makers first. Such a shift can be brought about by experimental pilot projects. Decision-makers who were reluctant about modal shift were considerably more positive about examples of current intermodal reefer services in specific corridors. Through these examples, and expansion of similar logistics concepts to other corridors, may reduce the trepidation of supply chain actors, and make barge or train transport options part of their consideration.

## 8.3 Answering the research question

The research question formulated in the introduction, namely *how seaport-related actors can effectively accommodate reefer container supply chains in a seaport cluster, meeting demands for efficiency and competitiveness, as well as sustainability*, is of an explorative nature, asking for a multi-dimensional 'how'. A key assumption here is that these actors in a seaport cluster may compete, cooperate, or otherwise interact to differing degrees, but are interdependent in that they have a shared interest in the performance of the cluster (either through their geographical location, or through their logistics chains). This requires them to align and coordinate processes and activities where necessary for an efficient flow of goods and information – even between competitors (Ch. 3). In the same vein from a policy perspective, port policy should support these initiatives and complement the value proposition developed by chain actors in the port cluster with the appropriate pricing and concession policies, in order to enhance port competitiveness (Ch. 2). This requires strategic decision-making on part of actors that have a role in multiple supply chains – including port managing bodies that more actively than before need to detect and respond to challenges and opportunities in the market environment. The reefer container market is growing fast and is potentially interesting for actors in the port and logistics communities (Ch. 4). However, a conscious choice to target competitiveness in one segment has an opportunity cost of foregone specialization in other niches – even though capabilities developed in one type of supply chain activities (e.g. the reefer segment) may translate to other (sensitive and high-value) supply chains. The majority of the world's major container ports are implementing port policies directed specifically at accommodating reefer container transport and cold chain logistics activities (Ch. 6). In addition, most policies observed involve some form of investment to be made under uncertainty. These elements of the behavior of port managing bodies indicate that the 'landlord' port authority is not an insightful model to understand decision-making, but that facilitating and entrepreneurial port authority roles have become ubiquitous worldwide. To adequately respond to challenges and opportunities in relevant markets, port managing bodies actually need to develop additional roles and capabilities, and become actively involved in port-oriented supply chains (either financially or otherwise). Expectations from policy differ between supply chain actors (Ch. 5), but a large share of actors see a (potential) role for policy in overcoming collective action problems, and acting as a trusted third party in initiatives where trust and (data) confidentiality are relevant. This mirrors the growing worldwide involvement of port managing bodies in data sharing initiatives and coalitions experimenting with blockchain technology for maritime supply chains. The roles of port managing bodies in experimental initiatives is also seen in other domains (Ch. 6), such as energy management, innovation and modal shift. A closer look into modal shift (as a type of change that is both broadly supported by stakeholders (Ch. 5) and within the scope of (port) policy (Ch. 6)) shows the relevance of stimulating pilot projects and experiments (Ch. 7). In case of reefer transportation, truck transport is by far the most dominant mode of overland transportation, but is associated with congestion and emissions. The research in this dissertation shows that a modal shift from road transport to barge or train transport first requires a 'mental shift' within the sector: a deviation from locked-in routines and a singular focus on truck transport without considering alternatives (Ch. 7). Despite the current dominance of trucking, numerous small-scale, experimental logistics services by barge or train are set up in specific corridors – all of which are evaluated positively by stakeholders. This shows that small-scale examples and small policy steps can help bring about the necessary 'mental shift' and bring intermodal alternatives into the consideration of supply chain decision-makers. To overcome inertia in the sector, policymakers can stimulate these projects through a wide range of instruments they have at their disposal, including direct investment, subsidies, coalition-building, and contributing knowledge and capabilities. This does however – as described – require the development of new facilitating and entrepreneurial roles. These observations are derived from a study of the port-oriented reefer container transport and cold chain logistics sector, but may also serve as a modal of a strategic reorientation of port managing bodies becoming more full-fledged supply chain partners with specific objectives and well-developed capabilities. Especially in cases of locked-in routines in the sector, appropriate port policy is crucial in stimulating a transition to more sustainable freight transport.

## 8.4 Contributions and limitations of the study

**Contributions**

Apart from the separate contributions of the individual studies in this dissertation, the overarching narrative and approach provide two main contributions to research – one conceptual and substantive, another methodological.

The introduction started with two main conceptual developments in the field of port studies with which this dissertation tied in. The first is the paradigm proposed by Robinson (2002) to view ports as being embedded in specific supply networks, with port and competitiveness depending on the effectiveness with which ports manage to accommodate these chains. The second is the change in perspective proposed by Rodrigue and Notteboom (2015) to view containers not as homogeneous load units, but to consider diversity in container contents to better understand market developments and operational challenges. By exploring the case of reefer containers and cold logistics chains, this dissertation has created significant substantive insight into what it looks like to have one specific container supply chain embedded in port clusters. By mapping the relevant flows, processes, issues, stakeholders and their perspectives, policies, and ongoing trends, this dissertation contributes to a new understanding of the position of the reefer container in seaport clusters. Beyond in-depth understanding of the reefer case itself, the findings illustrate how embedding supply chains in seaports, with specific attention for differentiated cargo characteristics and requirements, works in terms of supply chain governance and port policy. Most importantly, seaport actors' processes, strategies and policies need to be aligned for the seaport cluster to offer a coherent and robust value proposition in a specific type of supply chain. This requires strategic and commercial decisions from private parties, but also from port managing bodies that are – in a traditional 'landlord port authority' role – perhaps less used to this type of decision-making. For this, port managing bodies need to develop new roles and capabilities to strategically target specific supply chains, and coordinate with port-based actors to develop the seaport's value proposition in these chains. The research in this dissertation shows that this re-orientation of port managing bodies is already underway, and highlights the areas where it may come to

play a bigger role in the future, including intermodal transportation, coordination efforts, and digitization.
The second main contribution of this dissertation to the field is in its methodological approach. The overall research strategy of the study can be described as predominantly qualitative, mixed-methods social science approaches that deviate from the predominantly quantitative approaches taken in research on ports and freight transportation (Woo et al., 2011). This has resulted in a rich insight in supply chain actors' considerations and behavior that not only helps to address the research questions informed by the existing academic literature, but also identifies various issues and dynamics that are completely new to the academic literature. Examples include the complex interdependencies between container port actors' strategies and decision-making, and nuanced differences in stakeholders' perceptions of issues relevant to the reefer chain. By taking relatively little-used methodological (predominantly qualitative mixed methods (Woo et al., 2011)) and conceptual (considering the reefer chain as a complex, multi-stakeholder socio-technical system (De Bruijn & Herder, 2009)) approaches this study has broadened the scope of the field and identified interesting new venues for future research.

**Limitations**

Every individual chapter contains a reflection on the method and the possible limitations on the approach taken. However, some critical reflection on the overall approach of this dissertation is also in order.

This dissertation relies on a mixed-methods approach of a mostly qualitative nature to answer the research question, using mainly interviews, surveys, and document research, augmented with the use of secondary (quantitative) data and a systematic literature review of the present state of research on the topic (Ch. 4).

First, as evidenced by the approaches taken, the work included focused on subjectivity (understanding perspectives and behavior) rather than quantification. Findings regarding decisions and tradeoffs were often voiced in relative terms (X costs more than Y) or as judgments (X costs too much), which may be appropriate given the fact that cost levels differ between settings in which case quantifications may be hard to generalize (N. S. Kim & Van Wee, 2011). Nevertheless, due to the chosen focus, as well as the availability of data, many quantitatively oriented questions that the studies undoubtedly invite were not answered. Examples include questions of total port costs (Ch. 2), sharing of pains and gains in cooperative arrangements (Ch. 3), cost levels of different transportation modes (Ch. 5, Ch. 7), and KPIs of port policies (Ch. 6), and overall a more fine-grained insight in the flows of temperature-controlled goods and for the modal split of overland transport. Apart from kicking in the open door of limited quantification, relying on survey responses and published documents has some disadvantages. In all cases, the information is brought forward (either in person, through a survey, or publically) by an actor with their own subjective perspective, limited information, and self-interest. Therefore, in no study did we rely on respondents' statements alone, but triangulated and cross-checked various sources of information (quantitative data and/or information from academic or professional literature) to arrive at an overall plausible narrative (Yin, 2009). In case of the Q-method study, understanding subjectivity was the core objective, and the survey covering the subject matter exhaustively, augmented with respondents' elaborations on their responses, made for an in-depth understanding of stakeholder perspectives. Still, for all studies relying on stakeholder respondents, it is not possible to say what relevant information may be withheld and the extent to which considerations voiced correspond with day-to-day decision-making.

Secondly, there is the question of generalizability. The study respondents were recruited in the vicinity of the institution at which this research was carried out (Erasmus

University Rotterdam, in the Netherlands), which may lend a regional bias to the findings. For example, some issues may be perceived differently in one country than in another, and focusing predominantly on one country yields mostly findings relevant to that setting. Findings regarding cold supply chains in general likely translate to other contexts. Because of the global nature of these chains, dynamics observed in Europe will – with minor differences – show similarities to some similar extent to other developed economies or other continents. Findings regarding the relationship between supply chain actors and policy may not be translated so easily. In the Q-method study (Ch. 5) a large share of respondents voiced considerable trust in port authorities, which also related to their expectations from and evaluations of port policy. Findings from a similar study in an environment with low trust in policymakers and institutions may differ considerably. Insofar as port policy and governance is concerned, chapter 6 has remarkably shown a worldwide development in more or less the same direction, with individual port authorities developing facilitating and entrepreneurial roles to differing degrees. Due to the study design with a worldwide sample, a global trend could be observed with relatively minor regional variations (the variation within regions seems to be greater than the variation between regions), suggesting that these findings translate easily to other port contexts. Apart from generalizability between countries or regions, one should consider whether the findings obtained from an investigation of the reefer container and cold chain logistics sector can be translated to other markets. As outlined in the introduction, the reefer container market has some characteristics (significant growth, and high-value, demanding and sensitive cargo) that make it an interesting case of a specific supply chain being accommodated in port clusters. It is a somewhat extreme case, in that if port actors can accommodate reefer containers and cargoes in an effective way (with efficient handling, and minimizing hold-up risks and cargo loss), these capabilities likely translate to other container cargoes. However, the findings are not likely to be generalizable beyond the container sector. The reefer as well as dry container markets has the same load unit (i.e. intermodal containers), and the supply chains are more or less comparable, with heterogeneous cargoes, dispersed actor networks and fine-grained distribution. However, for example the wet and dry bulk markets are more vertically integrated, with a smaller number of (larger) actors, and characteristics of the cargo. While the reefer-specific findings of this study may not translate to those markets, more generic implications for port policy and research include the application of the same perspective and approach to understand dynamics in non-container markets, as will be discussed below.

## 8.5 Recommendations for future research

Apart from the implications and recommendations derived from individual studies in this dissertation, three main directions for future research can be synthesized from the findings.

First, the type of in-depth study this dissertation provides for the reefer and cold chain logistics segment, future research can conduct for other segments, markets and activities. This dissertation has shown that accommodating specific chains in a port cluster requires coordination and alignment between all actors involved, as well as the development of the appropriate knowledge and capabilities – the newer and more in flux the market is, the more innovative the approach that needs to be taken. Examples may include other (still developing) complex multi-stakeholder systems with organizational as well as technical challenges, such as green energy (e.g. offshore wind), reverse logistics, and digital platforms. For seaport actors to respond to trends and opportunities in individual container markets specifically, it is indeed necessary to ‘look inside the box’ and consider specific supply chains. This, however, requires more fine-grained data on what exactly are the contents of the containers being transported through port clusters.

Second, the study has broken new ground in research on the roles of port managing bodies. The chapters show that there is an important role to fill for port policy in developing a coherent and competitive value proposition for the port cluster, either because of coordination failures and collective action problems, or lacking resources, knowledge and capabilities on part of firms in the port cluster. In doing so, the work shows how port authorities already develop roles beyond the traditional 'landlord' model into more proactive, risk-taking facilitating and entrepreneurial roles, in order to accommodate promising developments and address related challenges. This raises the interesting question how exactly they would go about doing this. With knowledge of specific market segments, it is easy to say what is required, but harder to say what exactly policymakers should develop to effectively implement certain policies. For the reefer sector, the studies inside have shown that effective policymaking requires discretion, resources and detailed knowledge of supply chains, port processes, and relevant technology (including IT). A reorientation from 'landlord' to a pro-active full-fledged supply chain partner – in any type of chain or function – requires organizational development and change. Future research should address this reorientation and provide further insight in how this process works and can be facilitated. Even broader, further theory development is needed on not only how a port authority develops new roles and capabilities, but also how this new type of port managing body relates to supply chain actors – i.e. establishing a link between port governance and supply chain governance. A more active role of port managing bodies may also lead to new tensions between their various goals, notably their (delegated) responsibilities to protect public values as well as private company benefits, as well as tensions between policymakers and supply chain actors. It is apparent that greening of supply chains and a shift away from fossil fuels are integral parts of the responsibility to reduce externalities and mitigate climate change. However, port-based companies and supply chain actors do not have the same imperative, and will likely not commit to initiatives if port policy more actively pushes for a transition towards more sustainable practices. This increasing tension between public policy goals and private interests becomes an important challenge for port managing bodies, and research should focus on policies and stakeholder management strategies that enable mitigation of this tension.

Third, extending from an aforementioned limitation of this study's methodology, a more quantitative approach to the issues addressed is desirable. Part of the challenge is in data collection. Researchers have limited insights in container movements within a port, let alone detailed information of contents of individual container. Truly looking inside the box and elucidating container flows and their bottlenecks requires this detailed information, but this may be a significant challenge to acquire. More within reach of researchers may be the collection of more fine-grained, ideally quantitative data on behavior of supply chain actors at the level of individual decisions or shipments (e.g. choice of port, partners, and mode), for example collection of real-time data with the cooperation of a relevant involved organization, or through a simulation gaming setup with simulated scenario's and relevant real-world decision-makers. At the level of individual concepts, initiatives and policies, it is desirable to better evaluate and understand their performance. The studies in this dissertation have comprehensively covered dimensions of greener logistics for the reefer and cold chain sector (Ch. 5) and current developments in port policy with rich insight in the range of measures implemented by port authorities worldwide (Ch. 6), but the question remains how well these different interventions work, what drives their performance, and how an informed decision between alternative measures can be made. Addressing this in future research can help to formulate more actionable recommendations to policy and practice.

In addition to these three recommendations that stem directly from the study findings, several other promising venues for future research can be identified when considering the increasingly relevant and ongoing developments highlighted in this research, related to the business, transportation and technology, and sustainability dimensions of the topic.

Regarding the business dimension, the introduction already highlighted the insight that for change to come about in a complex, multi-stakeholder context, acceptance and commitment of (a significant share of) the actors involved is required. In several ways, the research has shown that a port-based logistics sector is typically slow to change, characterized by locked-in routines and attitudes. This is due to a variety of factors as identified, including technological path-dependency, limited resources and capabilities of organizations, routine habits, lack of urgency, and a narrow focus on short-term operational and financial performance. However, it is this type of sector in which organizations need to adapt quicker to developments along the other two dimensions – transportation and technology, and sustainability – to ensure long-term competitiveness and a continued societal license to operate. How to foster adaptation and organizational learning in this sector, and what support and stimulation from policy can be effective are important questions to address for the future.

In terms of transportation and technology, two major developments are going to impact on the sector in the near future. The first is the increasing impetus for modal shift, necessitated by congestion in and around port clusters, and stimulated by (port) policy. The second is the rapid development of technology in the logistics sector, specifically the internet of things (IoT) and digital platforms. In the reefer sector specifically, the development of the ‘smart container’ and the prevalence of blockchain experiments for reefer cargoes puts this segment at the forefront of these developments. While selected research so far has focused on some implications for quality driven logistics of perishables (Castelein et al., 2020), there is a major open question for future research how these developments – and associated concepts such as analytics, AI and digital twins – will impact on the day-to-day practices and operating models of organizations in the sector. A similar question needs to be addressed for the development of digital platforms to share data and improve horizontal and vertical coordination. But while the IoT developments are externally driven and create the imperative for sector stakeholders to adapt, the success of data sharing platforms depend to a great extent on sector stakeholders’ willingness to commit and cooperate. Future research should address the question of how to solve these collective action problems, and how to make platforms work best for participating organizations.

Ensuring the sector’s continued societal license to operate for the future depends on its ability to reduce its environmental footprint. The Paris Agreement of 2015 has been a ‘gamechanger’ in the sense that governments have affirmed what should be the goal of environmental policy – limiting the increase in global temperature to well below 2°C above pre-industrial levels – and committed themselves to reducing greenhouse gas emissions as far as necessary to attain this goal. Also the ports and logistics sectors have a responsibility here, and greening of these sectors should come about through a mix of policy-led and sector-led initiatives to reduce emissions. Greening operations and mitigating emissions is typically a challenge where unilateral action – either from the policy side or from a private sector actor – has very limited impact, and real improvements need to come from sector-wide changes. Globally, the changes necessary for reach the goal of the Paris Agreement are profound, and will significantly change the landscape in all economic sectors – in the context of this research especially the food, logistics, and energy sectors, and the seaports sector where these sectors meet and intertwine. A more ambitious extension from this research should entail a holistic perspective on how seaport clusters can meet these climate-related responsibilities, and how policy can stimulate and complement private initiative.

## 8.6 Implications for policy and practice

The conclusions and discussion above hint at a convergence of roles of policy and practice: port managing bodies become more active supply chain partners, and the success of policy increasingly relies on acceptance and commitment of private sector participants. Also the challenges facing the sector are relevant for both policy and practice. Even if the perception of urgency is low and incentives to deviate for current profit models are limited, the growing urgency of climate conscious change and the relevance of digitization demand innovative and future-oriented decisions. These decisions are complicated by the diverse landscape of actors, visions, options, initiatives, and priorities. The nature of the challenges and the sector context in which they need to be addressed require an integrated approach, rather than the optimization of individual chains or processes. This dissertation has identified several types of opportunities to implement such an integrated approach, most of which require cooperation and alignment between policymakers and firms. Accordingly, most of the findings and recommendations apply to all actors involved in the process of accommodating cold logistics chains in seaport clusters. However still, due to their distinct goals, responsibilities, interests, and strategies, recommendations for port policy and practice will be discussed separately below.

**Implications for policy**

Every study in this dissertation has proposed some recommendations for (port) policy in order to more effectively accommodate reefer container transport and cold logistics activities in seaport clusters. In addition, some overarching recommendations can be discussed here. These recommendations are of course conditional on the port governance model and the related discretion of a port managing body to develop new roles and activities. Chapter 6 has shown a global trend of port managing bodies broadening their scope and developing roles beyond those of the traditional 'landlord' port authority, suggesting that even the bolder recommendations derived from this study can be (or become) relevant for port managing bodies. Therefore, all recommendations are made based on the premise that port managing bodies want and can do more to facilitate specific (reefer) supply chains in their port cluster – for the reasons outlined in chapter 1. Still, the relevance of recommendations for individual cases depends on the context of the case.

First, it is recommended that port managing bodies take a more holistic view of the port cluster and their policy, especially with regard to supply chains they want their port to facilitate. This entails considering the overall value proposition offered by the collective of actors in the port – something that is achieved by aligning and coordinating processes and strategies with a multitude of relevant public and private stakeholders. Unilateral port policy, without considering the individual value propositions of actors in the port cluster, may not achieve desired results. Well-aligned port policy does however require a port authority with the resources, knowledge, and capabilities that are necessary for effective alignment, and that looks beyond the boundaries of the port cluster. The latter change in perspective entails the development of a strategic vision on the position of their ports, in supply chains as well as towards their immediate environment, hinterland, and at a regional level.

This raises a second overarching recommendation, namely for port managing bodies to develop their own role. The research in this dissertation has shown that policy specifically aimed at reefer and cold supply chains places port managing bodies in a facilitating or even entrepreneurial role. This is likely true for all policy aimed at specific supply chains, since that requires a conscious decision to allocate resources to the more promising sectors and make investments under uncertainty. Moreover, it requires port managing bodies to become more actively involved in the relevant chains. Also, this study has shown that more active and involved port policy is actually expected by a significant share of supply chain actors. Especially in solving collective action problems and acting as a trusted third party, more port authority involvement in supply chains is welcomed. An example from the present study is the importance of the facilitation and implementation of new techniques or concepts being demonstrated before being adopted by a wider range of actors in the market. In the case of modal shift, decision-makers are reluctant deviate from existing routines, but simultaneously view favorably those small-scale projects where an alternative is demonstrated. A port managing body acting as a supply chain partner can stimulate innovation and experiments in cooperation with private sector partners. In these cases, port policy can provide the first impetus for alternatives to locked-in patterns, which over time can become widely recognized options. However, with such involvement in supply chain operations, a port managing body should expand its own knowledge and capabilities.

This raises the third overarching recommendation, namely that a port managing body acting as a more involved supply chain partner needs detailed, domain-specific knowledge of supply chains, stakeholder configurations, port processes, the (information) technology involved, and linkages with other chains and functions within the port cluster. This also ties in with the concept of 'looking inside the box.' Port managing bodies should develop a more detailed awareness of the cargo that flows through the port cluster, in order to recognize opportunities and challenges. Even port authorities that prioritize volume growth over value would serve themselves well to closely monitor the cargo composition of their container throughput and focus their efforts on those segments that are most important or most promising for the future. Also looking inside the box makes apparent differences in requirements for cargoes. For conditioned cargoes in reefer containers this is obvious, stemming from the sensitive nature of the cargo, but also dry container cargoes may have different handling and processing requirements once the container is opened. Knowledge of product flows (in terms of physical movement and the actors involved) and product characteristics allows a port managing body to augment its port cluster's value proposition in specific supply chains.

**Implications for practice**

Throughout this dissertation, the research focus has been predominantly on port management, port development, and port and supply chain governance, rather than on the management and operations of individual stakeholders and processes. The Q-method study conducted in chapter 5 has also shown that private sector organizations in the reefer chain differ too much in terms of priorities, perspectives, and capabilities to warrant easily generalizable recommendations at the level of the organization. However, in a more general sense, managers – as well as policymakers – can learn from this research to better understand ongoing developments that will affect the sector and their business, and plan accordingly. Especially chapter 4 of this dissertation has already sketched current developments in the reefer market that will continue to increase in relevance moving forward. In addition to this, chapter 6 has outlined the focus areas of port policy that will likely continue to impact the market as well. An important technical development that organizations will likely come to deal with on a regular basis is the introduction of the 'smart reefer' (Ch. 4). The smart reefer allows for real-time tracking of shipments, and ideally in the future the possibility for easy real-time adjustments based on cargo quality. To benefit optimally from this, organizations will need to further develop knowledge and capabilities regarding quality management and more adaptive logistics processes. A second development is the ongoing containerization of new categories of conditioned cargoes, facilitated by improvements in preservation technology. This creates opportunities for new markets to be exploited, for those organizations that are keeping pace with these developments. Overall, the reefer container market can be expected to keep growing and present new opportunities to those actors that can effectively deal with the complexity involved.

## 8.7 Closing remarks

This dissertation has attempted to unravel the process of how supply chains can be effectively accommodated in seaport clusters in an efficient, competitive, and sustainable way. The research question covers everything stakeholders in the logistics sector, including the end-consumers for whom worldwide logistics networks are at work: we want the greatest variety of products at an attractive price, we want the wealth-creation from high-value industrial and logistics activities and the employment associated with them, and ideally we want all of it to be sustainable. Given these practical and societal concerns, this PhD dissertation helps provide the knowledge needed for steps in the right direction.

Zooming out from the subject matter of the previous pages, I would like to use this opportunity to briefly question these questions, and reflect on whether we are trying to solve the right problems. The framing of the question implies maintenance of the status quo, in which our consumption behavior is a given, and production, processing, and logistics processes can be tweaked smarter and smarter until the coming climate crisis is averted. However, of all possible interventions, from green energy to closed-loop supply chains with reuse, refurbishing, remanufacturing and recycling of materials, nothing will reduce our climate footprint like moderation of consumption. So despite the focus of this dissertation, it should conclude with this question: is the improvement and optimization of existing processes, without any critical reflection on our consumption behavior, truly the best way to relate in a sustainable way to our environment and climate?

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## English summary

The writing of this dissertation is motivated by the strong growth in the transport of perishable and temperature-sensitive goods in refrigerated containers - or reefers. While the container transport market overall is only growing slowly, the transportation of perishable goods in reefer containers is growing strongly. This growth also means that reefer containers are becoming an increasingly important cargo flow for seaports, which presents both opportunities and challenges. This research focuses on the question of how actors in port clusters can deal with this. Specifically, this dissertation addresses the question of *how actors in seaport clusters can facilitate the supply chains of reefer containers in a way that meets requirements for efficiency, competitiveness and sustainability.*

This dissertation starts from the more general question of how seaports can better facilitate specific container supply chains, taking the segment of refrigerated containers and cold supply chains as a relevant case study. This segment has increasing relevance to seaports due to strong growth, high-quality cargo, stringent requirements, and implications for seaports' logistics processes and energy management. The studies in this dissertation conceptualize reefer supply chains as complex multi-stakeholder systems with social and technical aspects, and seaport clusters as functional and geographical clusters of stakeholders, processes, challenges and risks in these chains. These challenges and risks include the physical hold-up risks in the port cluster, and the various sustainability issues that are relevant for reefer and cold chain logistics, such as energy demand and quality assurance. Due to the important role of seaport clusters in these chains and the fact that port managing bodies are explicit problem owners of all relevant issues (related to efficiency, competitiveness and sustainability), the approach of this dissertation also includes an strong policy-oriented component, as well as a broader focus on the characteristics of the reefer container and cold chain logistics sector as a complex multi-stakeholder socio-technical system and the associated governance challenges. The articles in this dissertation address different facets of this issue.

Chapter 2 examines several new relationships in an overarching conceptual framework covering properties of container ports, port choice by chain actors, and port policy and competitiveness. The chapter discusses the interdependencies in the decision-making processes of actors, and how the strategies and decision-making of actors together with port policy determine the ultimate value proposition of a port. Findings from interviews with stakeholders, supplemented with data on port throughput and information from the professional literature, show that port pricing in combination with port characteristics and the strategic positioning of port users are important for strategic market positioning of port clusters. Too strong a focus on cost competitiveness and throughput growth undermines port performance on other indicators such as service level and added value. Moreover, the attractiveness of a port for carriers does not always translate into attractiveness for shippers. The most important finding is that physical port characteristics and pricing cannot be seen in isolation from the choices made by other port users in the creation of the value proposition of a port. The value proposition of a port also depends on how port users (shippers, terminals, and carriers) strategically position themselves and how they use the port. The congruence between port policy and other drivers of the value proposition of ports is an important determining factor for port performance and competitiveness.

Chapter 3 deals with competition and coordination between terminals in container ports. Most major container ports have multiple container terminals, operated by different terminal operating companies. Within the same port they compete for the business of carriers, but face

the need to coordinate activities among themselves, such as the loading and unloading barges and trains that call at multiple terminals, and the exchange of containers between terminals for transfer to deepsea and feeder ships. Interviews with chain actors reveal the problems that can arise in the physical flow of containers within a port when cooperation between terminals is under pressure. These problems result from poor coordination between container terminals, which does not spontaneously arise or improve between organizations that compete directly. By analyzing information from the interviews and professional literature using a theoretical framework on cooperation and competition between organizations, the chapter identifies the root causes of bottlenecks in flows of goods and information. In addition, solutions are proposed - both technical and organizational - aimed at these specific bottlenecks. The chapter emphasizes that effective implementation depends on various underlying factors that determine the willingness of actors to cooperate. Most importantly, this chapter shows that when organizations in a (port) cluster compete, horizontal cooperation and coordination does not always come about, which can affect the overall competitiveness of the (port) cluster.

Chapter 4 introduces the market for maritime refrigerated containers (‘reefers’) as well as a systematic review of the academic research conducted on this market to date. Considering that this segment of the container market is quite 'new' - first introduced in the 1970s and 80s, but with more recent explosive growth continuing to this day - the questions of how this segment is embedded in seaports and how actors can position themselves in this market are still unanswered. Data on the global reefer market shows three main trends. First, strong growth in the reefer market, with an average growth of about 4% per year. Second, a shift of cargo from conventional refrigerated vessels to reefer containers. Third, increasing differentiation in the form of new niche technologies and services. A closer look at the ‘cold’ logistics chains that reefer containers are part of and data on damage to reefer container cargoes, show that cold chain failure and loss of cargo can occur due to technical failures at every point in the chain, but also as a result of organizational errors, in particular due to the risk of delay at container transfer points in seaports. A bibliometric analysis of the academic research into these chains shows that it mainly consists of highly specialized technical studies on product characteristics and quality preservation, measurement and control technology, cooling technology, and temperature management. This chapter shows that while technological advances in these areas have facilitated the expansion of containerized refrigerated and frozen transport, many of the current pressing issues in the transport of reefers are of an organizational or logistics nature - something that has so far been rarely researched in academic literature. This finding motivates the other substantive chapters in this dissertation.

In the introduction, the market for reefer transportation and cold chain logistics was conceptualized as a complex, multi-stakeholder socio-technical system with an important role for (port) policy in tackling persistent issues related to efficiency and sustainability. Since resolving these issues depends to a large extent on the willingness of the actors involved to cooperate, it is important to understand the (subjective) perspectives of these actors on these problems and potential solutions. Chapter 5 uses Q methodology to understand the wide variety of stakeholder perspectives. Through a combination of survey and interview data, this method summarizes a multitude of individual perspectives through a handful of underlying more widely shared perspectives – so-called ‘dominant’ perspectives. So far, Q methodology has rarely been used in freight transport research, but it has yielded interesting findings in other complex settings where it is relevant to understand the perspectives of a great diversity of stakeholders. The Q-method survey, supplemented with respondents’ elaborations on their answers, shows that stakeholders' perspectives in this domain can be summarized in four "dominant" perspectives, that together explain a large share of the variation in individual perspectives. These perspectives can be described as:

- Sustainability as part of strategy
- Short term constraints
- Optimistic about technology, limited role for policy
- Long-term willingness under risk avoidance

The organizations investigated varied widely in their prioritization of problems and risks in the chain, in their resources and possibilities, and in what they see as an appropriate role for policy. Interestingly, the reluctance of companies to invest in more sustainable practices or to address inefficiencies in the chain stems from financial and operational constraints imposed by other (more powerful) actors in the chain, such as retailers and carriers. The main finding for further recommendations is that there is broad consensus on the potential for sustainability gains in hinterland transport, and many respondents indicated that they are open to a 'modal shift', provided that alternatives to road transport meet their requirements in terms of cost, speed, flexibility, and reliability.

In addition to the attention for all types of supply chain stakeholders in chapter 5, chapter 6 focuses specifically on port policy for reefer transportation and cold chain logistics. An inventory of such policies, implemented by the world's 50 largest container ports, yields a database of more than 70 policies, which are then classified according to instrument, goal, geographical scope, stakeholder involvement, and the role of the port authority concerned (varying from conservator to facilitator to entrepreneur). Usually, the scope of these policies is limited to the port cluster, where port authorities invest or co-invest in cold stores or strive to form cold logistics clusters around these cold stores. Where port authorities extend their scope to their hinterland, this tends to be in line with policy objectives formulated at higher levels of government, such as modal shift targets, or the development of domestic food distribution systems. Port authorities with a wider scope contribute to initiatives that span the entire cold chain, often related to technical innovations for the monitoring and control of reefer containers, including recent experiments with blockchain technology. Overall, there is little evidence that port authorities are developing overarching, comprehensive cold chain strategies, addressing the logistics, marketing, technology, and sustainability dimensions related to this sector. Based on the findings, this chapter outlines the general elements that such a strategy should contain. The main conclusion is that port authorities very often pursue policies that go far beyond their traditional 'landlord' responsibilities, developing facilitating and entrepreneurial roles that require active investment decisions under significant uncertainty, and the development of new roles and capabilities. The vast majority of the managing bodies of the world's major container ports are developing these new roles and capabilities to improve the value proposition of their ports in the segment of reefer containers and cold chain logistics, suggesting that the traditional 'landlord' port governance model is no longer sufficient to understand and explain the strategies and behavior of port authorities.

Since chapters 5 and 6 identified a potential modal shift of reefer containers as a type of change that is broadly supported by sector stakeholders, and that is within the scope of most port authorities' policies, chapter 7 addresses the feasibility of a modal shift of reefer containers from road transport to more sustainable modes such as train or barge. This chapter is based on information from interviews to clarify stakeholder requirements and perspectives, and a detailed exposition of the technical and logistical possibilities of transporting operating reefer containers on barges or trains. An important finding is that for rail transport, there is no established option yet to connect refrigerated containers an energy supply from the catenary, as most existing options rely on some form of diesel-electric generator to power the reefers. A limiting factor for inland waterways transport is the limited number of available reefer plugs on inland vessels. For both, limited speed and reliability of service are cited as major drawbacks. The current dominance of road transport in the reefer sector is not only a result of the limitations of physical transport and power supply, but also of an ingrained habit of opting for truck transport without regular deliberate consideration of different options. This suggests that a 'modal shift' first requires a 'mental shift'. Such a shift can be brought about through experimental pilot projects that demonstrate the feasibility of reefer transport on other modalities. Even actors who are cautious about a 'modal shift' are considerably more positive about examples of current intermodal reefer services by train or barge in specific corridors. These examples, and the expansion of comparable logistics concepts to other corridors, can reduce the hesitation of supply chain actors, and make obarge or train transport options part of their consideration.

The research question formulated in the introduction, namely *how seaport-related actors can effectively accommodate reefer container supply chains in a seaport cluster, meeting demands for efficiency and competitiveness, as well as sustainability*, is of an explorative nature, asking for a multi-dimensional 'how'. A key assumption here is that these actors in a seaport cluster may compete, cooperate, or otherwise interact to differing degrees, but are interdependent in that they have a shared interest in the performance of the cluster (either through their geographical location, or through their logistics chains). This requires them to align and coordinate processes and activities where necessary for an efficient flow of goods and information – even between competitors (Ch. 3). In the same vein from a policy perspective, port policy should support these initiatives and complement the value proposition developed by chain actors in the port cluster with the appropriate pricing and concession policies, in order to enhance port competitiveness (Ch. 2). This requires strategic decision-making on part of actors that have a role in multiple supply chains. The reefer container market is growing fast and is potentially interesting for actors in the port and logistics communities (Ch. 4). However, a conscious choice to target competitiveness in one segment has an opportunity cost of foregone specialization in other niches – even though capabilities developed in one type of supply chain activities (e.g. the reefer segment) may translate to other (sensitive and high-value) supply chains. The majority of the world's major container ports are implementing port policies directed specifically at accommodating reefer container transport and cold chain logistics activities (Ch. 6). Also for these port managing bodies, a choice to focus specifically on one market segment is a strategic decision of a commercial nature, detecting and responding to opportunities in the market environment. In addition, most policies observed involve some form of investment to be made under uncertainty. These elements of the behavior of port managing bodies indicate that the 'landlord' port authority is not an insightful model to understand decision-making, but that facilitating and entrepreneurial port authority roles have become ubiquitous worldwide. To adequately respond to challenges and opportunities in relevant markets, port managing bodies actually need to develop additional roles and capabilities, and become actively involved in port-oriented supply chains (either financially or otherwise). Expectations from policy differ between supply chain actors (Ch. 5), but a large share of actors see a (potential) role for policy in overcoming collective action problems, and acting as a trusted third party in initiatives where trust and (data) confidentiality are relevant. This mirrors the growing worldwide involvement of port managing bodies in data sharing initiatives and coalitions experimenting with blockchain technology for maritime supply chains. The roles of port managing bodies in experimental initiatives is also seen in other domains (Ch. 6), such as energy management, innovation and modal shift. A closer look into modal shift (as a type of change that is both broadly supported by stakeholders (Ch. 5) and within the scope of (port) policy (Ch. 6)) shows the relevance of stimulating pilot projects and experiments (Ch. 7). In case of reefer transportation, truck transport is by far the most dominant mode of overland transportation, but is associated with congestion and emissions. The research in this dissertation shows that a modal shift from road transport to barge or train transport first requires a 'mental shift' within the sector: a deviation from locked-in routines and a singular focus on truck transport without considering alternatives (Ch. 7). Despite the current dominance of trucking, numerous small-scale, experimental logistics services by barge or train are set up in specific corridors – all of which are evaluated positively by stakeholders. This shows that small-scale examples and small policy steps can help bring about the necessary 'mental shift' and bring intermodal alternatives into the consideration of supply chain decision-makers. To overcome inertia in the sector, policymakers can stimulate these projects through a wide range of instruments they have at their disposal, including direct investment, subsidies, coalition-building, and contributing knowledge and capabilities. This does however – as described – require the development of new facilitating and entrepreneurial roles. These observations are derived from a study of the port-oriented reefer container transport and cold chain logistics sector, but may also serve as a modal of a strategic reorientation of port managing bodies becoming more full-fledged supply chain partners with specific objectives and well-developed capabilities. Especially in cases of locked-in routines in the sector, appropriate port policy is crucial in stimulating a transition to more sustainable freight transport.

In conclusion, the work compiled in this dissertation makes the following contributions to scientific debate and practice:

- The first scientific contribution is conceptual in nature, and lies in the answer – outlined above – to the research question of how specific logistics chains are accommodated in seaport clusters, and how networks of actors can position themselves in these chains, while meeting a variety of demands. The case study of the reefer market elaborated in this dissertation highlights the importance of congruence between processes, policies and strategies of mutually dependent actors in (port) clusters, and the changing role of port managers in this.
- The second scientific contribution is methodological. Existing research into logistics and freight transport is predominantly quantitative in nature, while the work in this dissertation is characterized by a more qualitative social science approach. This approach has provided in-depth insights into the behavior and motivations of chain parties, and has shed light on completely new dynamics, relationships and questions.
- The dissertation also proposes several recommendations for further research. Where in this work the focus was on the reefer market and cold logistics chains, a similar approach can be applied to other segments and sectors. In a broader sense, this invites the question of how ports and chain actors can remain relevant in a dynamic and changing environment, in which also the long-term sustainability of practices is becoming an increasingly relevant criterion. This dissertation has emphasized the importance of strategic decision-making to achieve this and the development of different roles - and the associated knowledge and capabilities - by port authorities. This finding invites the follow-up question of how these roles, knowledge, and capabilities of a port authority can be developed in a targeted manner. There is also room for further quantification of the (new) aspects of the subject matter that have emerged in this study. Examples are cost-benefit analyzes and decision support methods for various policy options and initiatives. Building on the findings from this study is necessary for more useful recommendations and better decision support.

- For (port) policy, this dissertation highlights the importance of a holistic perspective on chains, port cluster and policy. The value proposition of a port depends on the entirety of decisions, processes, and strategies of port actors, and the complementary role of port policy. In order to effectively deal with opportunities and challenges in the reefer market, a port authority must develop its own roles and capabilities – as a full-fledged chain partner - and make strategic choices for the markets and segments that are actively attracted and facilitated. There is also an important stimulating role for port authorities with regard to introducing new concepts and overcoming locked-in patterns in the sector.
- The study has explored the reefer market in detail as a highly dynamic sector, in which the position of ports and chain parties is still very much in flux. Various emerging developments in the sector are becoming increasingly relevant, also outside the reefer sector, such as the 'smart container' and blockchain technology. This technology and demands from end users will accelerate a move towards greater flexibility of logistics processes. This increases the value for the end user, but also offers opportunities to reduce cargo loss and emissions.

## Nederlandse samenvatting

Het onderzoek in dit proefschrift heeft als aanleiding de sterke groei van het vervoer van bederfelijke en temperatuurgevoelige goederen in koelcontainers – ofwel reefers. Terwijl de markt voor containervervoer slechts mondjesmaat groeit, neemt het vervoer van voedsel (fruit, groente, vlees, vis) en andere temperatuurgevoelige goederen (bloemen, planten, chemicaliën en farmaceutische producten) in zeecontainers sterk toe. Deze groei betekent ook dat reefercontainers een steeds belangrijker ladingstroom worden voor zeehavens, wat zowel kansen als uitdagingen met zich meebrengt. Dit onderzoek richt zich op de vraag hoe actoren in havenclusters hiermee om kunnen gaan. Specifiek de vraag *hoe actoren in zeehavenclusters de toeleveringsketens van reefercontainers kunnen faciliteren op een manier die voldoet aan de eisen voor efficiëntie, concurrentievermogen, en duurzaamheid.*

Dit proefschrift gaat uit van de meer algemene vraag hoe zeehavens specifieke toeleveringsketens beter kunnen faciliteren, waarbij het logistieke segment van koelcontainers en koelketens als een relevante casestudy wordt genomen. Dit segment heeft een toenemende relevantie voor zeehavens vanwege de sterke groei, hoogwaardige lading, stringente eisen, en implicaties voor zeehavens' logistieke processen en energiebeheer. De studies in dit proefschrift conceptualiseren de bewuste reefercontainerketens als complexe multi-stakeholdersystemen met sociale en technische aspecten, en zeehavenclusters als functionele en geografische clusters van stakeholders en processen - evenals uitdagingen en risico's – in deze koelketens. Deze uitdagingen en risico's hebben betrekking op de fysieke hold-up risico's in het havencluster, en de diverse duurzaamheidsaspecten die relevant zijn voor koel- en vrieslogistiek zoals de energievraag en kwaliteitsborging. Vanwege de belangrijke rol van zeehavenclusters in deze ketens en het feit dat havenbeheerders expliciet probleemeigenaar zijn van alle relevante kwesties (met betrekking tot efficiëntie, concurrentievermogen en duurzaamheid), omvat de aanpak van dit proefschrift ook een expliciet beleidsgerichte component, evenals een brede focus op de kenmerken van de koelcontainer- en koelketenlogistieke sector als een complex multi-stakeholder sociaal-technisch systeem en de bijbehorende governance-uitdagingen. De artikelen in dit proefschrift behandelen verschillende facetten van dit vraagstuk.

Hoofdstuk 2 onderzoekt een aantal nieuwe verbanden in een overkoepelend conceptueel kader met eigenschappen van containerhavens, havenkeuze door ketenpartijen, en havenbeleid en concurrentievermogen. Het hoofdstuk belicht de onderlinge afhankelijkheden in de besluitvormingsprocessen van actoren, en hoe de strategieën en besluitvorming van actoren samen met het havenbeleid de uiteindelijke waardepropositie van een haven bepalen. Bevindingen uit interviews met belanghebbenden, aangevuld met gegevens over havenoverslag en informatie uit de vakliteratuur, laten zien dat prijsbeleid in combinatie met havenkenmerken en de strategische positionering van havengebruikers van belang zijn voor strategische marktpositionering van havenclusters. Een te sterke focus op concurrentie op kosten en groei van de overslag ondermijnt de havenprestaties op andere indicatoren zoals serviceniveau en toegevoegde waarde. Bovendien vertaalt de aantrekkelijkheid van een haven voor vervoerders zich niet altijd in aantrekkelijkheid voor verladers. De belangrijkste bevinding is dat de fysieke havenkenmerken en prijsbeleid niet los gezien kunnen worden van de keuzes van andere havengebruikers bij de totstandkoming van de waardepropositie van een haven. De waardepropositie van een haven is ook afhankelijk van hoe havengebruikers (verladers, terminals en vervoerders) zichzelf strategisch positioneren en hoe ze de haven gebruiken. De congruentie tussen havenbeleid en andere drijvende factoren van de waardepropositie van havens is een bepalende factor voor havenprestaties en concurrentievermogen.

Hoofdstuk 3 behandelt concurrentie en coördinatie tussen terminals in containerhavens. De meeste grote containerhavens hebben meerdere containerterminals die worden geëxploiteerd door verschillende bedrijven. Binnen dezelfde haven concurreren ze om de klandizie van rederijen, maar ze hebben ook te maken met de coördinatie van activiteiten onderling, zoals het laden en lossen van binnenschepen en treinen die meerdere terminals moeten aandoen, en de uitwisseling van containers tussen terminals voor transfer naar diepzee- en feederschepen. Uit interviews met ketenpartijen komen de problemen naar voren die kunnen optreden in de fysieke stroom van containers binnen een haven wanneer de samenwerking tussen terminals onder druk staat. Deze problemen zijn het gevolg van gebrekkige coördinatie tussen containerterminals, die ook niet spontaan ontstaat of verbetert tussen organisaties die direct concurreren. Door informatie uit de interviews en de vakliteratuur te analyseren aan de hand van een theoretisch kader over samenwerking en concurrentie tussen organisaties, identificeert het hoofdstuk grondoorzaken van knelpunten in stromen van goederen en informatie. Daarnaast worden enkele oplossingen voorgesteld – zowel technisch als organisatorisch – gericht op deze specifieke knelpunten. Het hoofdstuk benadrukt dat een effectieve implementatie afhangt van verschillende onderliggende factoren die de medewerkingsbereidheid van actoren bepalen. Het belangrijkste is dat uit dit hoofdstuk blijkt dat wanneer organisaties in een (haven) cluster concurreren, maar ook belang hebben bij horizontale samenwerking en coördinatie, deze samenwerking en coördinatie niet altijd tot stand komt, wat de algehele concurrentiekracht van de (haven) cluster kan schaden.

In hoofdstuk 4 wordt de markt voor maritieme koelcontainers – reefers – geïntroduceerd, evenals een overzicht van het tot nu toe uitgevoerde academische onderzoek naar deze markt. Gezien het feit dat dit segment van de containermarkt vrij 'nieuw' is - voor het eerst geïntroduceerd in de jaren '70 en '80, maar met een recentere explosieve groei die tot op de dag van vandaag voortduurt - zijn de vragen hoe dit segment is ingebed in zeehavens en hoe zeehavens zouden in deze markt kunnen positioneren nog onbeantwoord. Gegevens over de wereldwijde reefermarkt tonen drie belangrijke trends. Ten eerste sterke groei van de reefermarkt, met een gemiddelde groei van zo’n 4% per jaar. Ten tweede een verschuiving van ladingpakketten van conventionele koelschepen naar reefercontainers. Ten derde toenemende differentiatie in de vorm van nieuwe niche-technologieën en -diensten. Een nadere beschouwing van de toeleveringsketens van gekoelde producten (‘koelketens’) waar reefercontainers deel van uitmaken, en gegevens over schade aan ladingen van reefercontainers, laten zien dat het falen van de koelketen en het verlies van lading kan optreden als gevolg van technische storingen op elk punt in de keten, maar ook als gevolg van organisatorische fouten, met name door vertragingsrisico bij containeroverslagpunten in zeehavens. Een bibliometrische analyse van het academisch onderzoek naar deze ketens toont aan dat het voornamelijk bestaat uit zeer gespecialiseerde, technische studies over productkenmerken en kwaliteitsbehoud, meet- en regeltechniek, koeltechniek en temperatuurbeheer. Dit hoofdstuk laat zien dat technologische vooruitgang op deze gebieden de ontwikkeling van het gecontaineriseerde koel- en vriesvervoer grotendeels mogelijk heeft gemaakt, maar dat veel actuele urgente vraagstukken in het transport van reefers van een organisatorische of logistieke aard zijn – iets dat in de academische literatuur nog nauwelijks onderzocht wordt. Deze bevinding motiveert de rest van de inhoudelijke hoofdstukken van dit proefschrift.

In de inleiding werd de markt voor koelcontainers en koelketenlogistiek geconceptualiseerd als een complex, multi-stakeholder socio-technisch systeem met een belangrijke rol voor (haven-) beleid om hardnekkige kwesties met betrekking tot efficiëntie en duurzaamheid aan te pakken. Aangezien een oplossing voor deze kwesties in belangrijke mate afhangt van de bereidheid van betrokken actoren om daaraan mee te werken, is het belangrijk om de (subjectieve) perspectieven van deze actoren op deze problemen en potentiele oplossingen te begrijpen. In hoofdstuk 5 wordt Q-methodologie gebruikt om inzicht te krijgen in de grote verscheidenheid aan perspectieven van belanghebbenden. Met deze methode wordt met een combinatie van enquêtes en interviews een veelvoud aan individuele perspectieven teruggebracht tot een handvol onderliggende – ofwel 'dominante' – gedeelde perspectieven. Tot dusver is Q-methodologie slechts zelden gebruikt in onderzoek naar vrachtvervoer, maar heeft het interessante bevindingen opgeleverd in andere complexe situaties waarin het begrip van perspectieven een grote diversiteit aan belanghebbenden van belang is. De Q-methode-enquête, aangevuld met de toelichting van respondenten op hun antwoorden, laat zien dat de perspectieven van belanghebbenden in dit domein kunnen worden samengevat in vier 'dominante' perspectieven die samen een groot deel van de variatie in individuele perspectieven verklaren. Deze perspectieven kunnen omschreven worden als:

- Duurzaamheid als onderdeel van strategie
- Beperkte middelen en korte-termijnfocus
- Optimistisch over technologie, beperkte rol voor beleid
- Bereidheid op lange termijn, risicomijdend

De onderzochte organisaties varieerden sterk in hun prioritering van problemen en risico's in de keten, hun eigen middelen en mogelijkheden, en in wat zij zien als een passende rol voor beleid. Interessant is dat de terughoudendheid van bedrijven om te investeren in duurzaamheid of het aanpakken van inefficiënties in de keten voortkomt uit financiële en operationele beperkingen die worden opgelegd door andere (machtiger) actoren in de keten, zoals supermarkten en reders. De belangrijkste bevinding voor verdere aanbevelingen is dat er een brede consensus bestaat over het potentieel voor duurzaamheidswinst in het achterlandvervoer, en talrijke respondenten gaven aan open te staan voor een 'modal shift', mits de alternatieven voor wegvervoer van reefers voldoen aan hun eisen aan kosten, snelheid, flexibiliteit en betrouwbaarheid.

Naast de aandacht voor alle soorten ketenpartijen in hoofdstuk 5, richt hoofdstuk 6 zich specifiek op het havenbeleid voor koelketens en het vervoer van reefercontainers. Een onderzoek naar het beleid van de 50 grootste containerhavens ter wereld levert een database op met meer dan 70 beleidsmaatregelen, die vervolgens worden geclassificeerd op basis van instrument, doel, geografische reikwijdte, betrokkenheid van belanghebbenden, en de rol van het havenbedrijf in kwestie (variërend van conservator tot facilitator tot ondernemer). Meestal is de reikwijdte van dit beleid gericht op reefervervoer en koelketenactiviteiten beperkt tot het havencluster, waar havenautoriteiten (mee-) investeren in koelhuizen of streven naar de vorming van koude logistieke clusters rond deze koelhuizen. Waar havenautoriteiten hun reikwijdte uitbreiden naar hun achterland, is dit meestal in lijn met beleidsdoelstellingen die zijn geformuleerd op hogere bestuursniveaus, zoals modal shift-doelen, of de ontwikkeling van binnenlandse voedseldistributiesystemen. Havenbeheerders met een bredere reikwijdte dragen bij aan initiatieven die effect hebben op de gehele koelketen, vaak gerelateerd aan technische innovaties voor monitoring en controle van reefercontainers, waaronder recente experimenten zijn met blockchain-technologie. Over het algemeen zijn er zeer weinig aanwijzingen dat havenbedrijven gerichte alomvattende strategieën voor de koelketen ontwikkelen, waarbij ze de logistieke, marketing-, technologie- en duurzaamheidsdimensies met betrekking tot deze sector aanpakken. Dit hoofdstuk schetst, op basis van de bevindingen, de algemene elementen die een dergelijke strategie zou moeten bevatten. De belangrijkste bevinding in dit hoofdstuk is dat havenautoriteiten zeer vaak beleid voeren dat veel verder reikt dan hun traditionele verantwoordelijkheden (beperkt tot infrastructuur en regelgeving), waarbij ze faciliterende en ondernemende rollen ontwikkelen die actieve investeringsbeslissingen vereisen onder aanzienlijke onzekerheid, en de ontwikkeling van nieuwe rollen en capaciteiten. Het overgrote deel van de havenbedrijven van 's werelds grootste containerhavens ontwikkelen deze nieuwe rollen en mogelijkheden om de waardepropositie van hun haven in het segment van reefercontainers en koelketenlogistiek te verbeteren, wat suggereert dat het traditionele model van havenbestuur niet meer voldoende is om de strategieën en het gedrag van havenbedrijven te verklaren.

Aangezien hoofdstukken 5 en 6 een mogelijke 'modal shift' van reefercontainers hebben geïdentificeerd als een verandering die zowel breed wordt gedragen door actoren in de sector als binnen de reikwijdte ligt van het beleid van de meeste havenautoriteiten, gaat hoofdstuk 7 in op de haalbaarheid van een modal shift van reefercontainers van wegvervoer naar duurzamere vervoerswijzen zoals per trein of binnenschip. Dit hoofdstuk is gebaseerd op informatie uit interviews om de eisen en perspectieven van belanghebbenden te verduidelijken, en een gedetailleerde uiteenzetting van de technische en logistieke mogelijkheden van het vervoeren van werkende koelcontainers op binnenschip of trein. Een belangrijke bevinding is dat er voor het spoorvervoer nog geen gestandaardiseerde optie is om koelcontainers aan te sluiten op een energievoorziening van de bovenleiding, aangezien de meeste bestaande opties afhankelijk zijn van een of andere vorm van dieselelektrische generator om de reefers van stroom te voorzien. Voor binnenvaartvervoer is een beperkende factor het beperkte aantal beschikbare aansluitingen op binnenschepen. Voor beide worden de (relatief laag gewaardeerde) snelheid en betrouwbaarheid van de diensten genoemd als een groot nadeel. De huidige dominantie van het wegvervoer in de reefersector is niet alleen een gevolg van de beperkingen van fysiek transport en stroomtoevoer, maar ook van een kwestie van gewoonte om voor vervoer per truck te kiezen zonder regelmatige bewuste afweging van verschillende opties. Dit suggereert dat een 'modal shift' eerst een 'mental shift' vereist. Een dergelijke verschuiving kan worden bewerkstelligd door experimentele proefprojecten die de haalbaarheid van reefervervoer met andere modaliteiten aantonen. Actoren die terughoudend zijn over een 'modal shift' zijn aanzienlijk positiever over voorbeelden van huidige intermodale reeferdiensten per trein of binnenschip in specifieke corridors. Door deze voorbeelden en de uitbreiding van vergelijkbare logistieke concepten naar andere corridors, kan de schroom van actoren in de toeleveringsketen worden verminderd en kunnen opties voor het vervoer van reefers per binnenschip of trein onderdeel worden van hun overweging.

De onderzoeksvraag die in de inleiding werd geformuleerd is verkennend van aard en vraagt om een multidimensionale benadering. Een belangrijke veronderstelling hier is dat actoren in een zeehavencluster in meerdere of mindere mate kunnen concurreren of samenwerken, maar altijd een gedeeld belang hebben bij de prestaties en concurrentiepositie van het cluster – hetzij door hun geografische positie, hetzij via hun logistieke ketens. Dit vereist dat ze processen en activiteiten waar nodig afstemmen en coördineren voor een efficiënte stroom van goederen en informatie - zelfs tussen directe concurrenten (hoofdstuk 3). Havenbeleid kan de waardeproposities die ontwikkeld worden door ketenactoren in het havencluster aanvullen met het juiste prijs- en concessiebeleid om het havenconcurrentievermogen te versterken (hoofdstuk 2). Dit vereist strategische keuzes door actoren die een rol spelen in meerdere logistieke ketens. Een specifiek type keten is te vinden in de reefermarkt, een markt die vanwege de sterke groei en hoogwaardige lading steeds relevanter wordt voor actoren in zeehavens en logistieke sectoren, en vanwege de eigenschappen van de lading vraagt om specialisatie (hoofdstuk 4). Echter, een bewuste keuze om het concurrentievermogen in een bepaald segment te ontwikkelen, brengt alternatieve kosten met zich mee voor specialisatie in andere niches – ondanks het feit dat capaciteiten ontwikkeld in één type ketens (bijv. het reefersegment) vaak te vertalen zijn naar andere (gevoelige en hoogwaardige) ketens. Het merendeel van de grootste containerhavens ter wereld voert havenbeleid dat specifiek gericht is op het faciliteren van reefercontainertransport en koel- en vrieslogistiek (hoofdstuk 6). Ook voor deze havenbeheerders is een keuze om zich specifiek op één marktsegment te richten een strategische en commerciële beslissing, waarbij kansen in de marktomgeving worden opgespoord en aangegrepen. Deze geobserveerde keuzes van havenbeheerders geven aan dat de traditionele opvatting van een havenbedrijf als ‘landlord’ – de traditionele, beperkte rol van beheerder, verhuurder, en regelgevende entiteit – geen inzichtelijk model meer is om besluitvorming te begrijpen, maar dat meer faciliterende en ondernemende rollen de standaard zijn geworden. Om adequaat te kunnen reageren op uitdagingen en kansen in relevante markten, moeten havenbeheerders juist extra rollen en capaciteiten ontwikkelen en actief betrokken worden bij havengeoriënteerde ketens (al dan niet financieel). Verwachtingen van beleid verschillen tussen ketenactoren (hoofdstuk 5), maar een groot deel van de actoren ziet een belangrijke potentiële rol voor havenbeleid bij het overwinnen van collectieve actieproblemen, en verwachten dat een havenbedrijf optreedt op als vertrouwde derde partij in initiatieven waar vertrouwen en (data) vertrouwelijkheid relevant zijn. Dit weerspiegelt de groeiende wereldwijde betrokkenheid van havenbeheerders bij initiatieven voor het delen van gegevens en coalities die experimenteren met blockchain-technologie voor logistieke ketens. De rol van havenbeheerders in experimentele initiatieven wordt ook gezien in andere domeinen, zoals energie, innovatie en ‘modal shift’ – een verschuiving van ladingstromen van wegvervoer (een modaliteit met relatief hoge uitstoot en die samenhangt met congestie op het wegennet) naar andere modaliteiten zoals trein en binnenvaart (hoofdstuk 6). Het onderzoek in dit proefschrift laat zien dat een verschuiving van reefers van wegvervoer naar binnenvaart of trein eerst een mentaliteitsverandering – een 'mental shift’ – binnen de sector vereist: een afwijking van ingesleten routines waarin nu de keuze voor vrachtwagenvervoer vanzelfsprekend is, zonder alternatieven te overwegen (hoofdstuk 7). Ondanks de huidige dominantie van het wegvervoer, worden tal van kleinschalige, experimentele logistieke diensten per binnenschip of trein opgezet, die positief worden beoordeeld door belanghebbenden. Dit laat zien dat kleinschalige voorbeelden kunnen helpen de noodzakelijke mentaliteitsverandering tot stand te brengen en actoren prikkelen om intermodale alternatieven te overwegen. Om de terughoudendheid in de sector te overwinnen, kunnen beleidsmakers deze projecten stimuleren door middel van een breed scala aan instrumenten waarover zij beschikken, waaronder directe investeringen, subsidies, coalitievorming en het inbrengen van kennis en capaciteiten. Dit vereist echter - zoals beschreven - de ontwikkeling van nieuwe faciliterende en ondernemende rollen door beleidsmakers. Deze waarnemingen zijn ontleend aan een onderzoek naar de markt voor reefercontainervervoer en koel- en vrieslogistiek, maar kunnen ook dienen als een meer algemene leidraad voor een strategische heroriëntatie van havenbeheerders, die zich willen ontwikkelen tot meer betrokken ketenpartners. Zeker in het geval van conservatisme en ingesleten routines in de sector, is gericht beleid wenselijk in het stimuleren van een transitie naar duurzamer vervoer.

Samenvattend levert het werk in dit proefschrift de volgende bijdragen aan het wetenschappelijke debat en aan de praktijk:

- De eerste wetenschappelijke bijdrage is conceptueel van aard, en ligt in het antwoord dat het werk in dit proefschrift geeft op de vraag hoe specifieke logistieke ketens een plek krijgen in havenclusters, en hoe netwerken van actoren in zeehavens zich kunnen positioneren in specifieke ketens. De casus van de reefermarkt die in dit proefschrift is uitgewerkt belicht het belang van congruentie tussen processen, beleid, en strategieën van wederzijds afhankelijke actoren in (haven)clusters, en de veranderende rol van havenbeheerders hierin.
- De tweede wetenschappelijke bijdrage is methodologisch. Bestaand onderzoek naar logistieke ketens en vrachtvervoer is overwegend kwantitatief van aard, terwijl het werk in dit proefschrift wordt gekenmerkt door een meer kwalitatieve, sociaalwetenschappelijke benadering. Deze aanpak heeft diepgaande inzichten opgeleverd in gedrag en beweegredenen van ketenpartijen, en licht geworpen op volledig nieuwe dynamieken, relaties en vragen.
- Uit het proefschrift komen ook enkele aanbevelingen voor verder onderzoek. Waar in dit werk de focus lag op de reefermarkt en koelketens, kan een vergelijkbare benadering op andere segmenten en sectoren worden toegepast. Breder getrokken nodigt dit de vraag uit hoe havens en ketenpartijen hun relevantie kunnen behouden in een veranderende omgeving, waarin ook duurzaamheid op de lange termijn steeds relevanter wordt. Dit proefschrift heeft het belang onderstreept van strategische keuzes om dit te bereiken, en de ontwikkeling van verschillende rollen – en bijpassende kennis en capaciteiten – door havenbeheerders. Deze bevinding nodigt de vervolgvraag uit hoe deze rollen, kennis, en capaciteiten van een havenbeheerder gericht ontwikkeld kunnen worden. Ook is er ruimte voor verdere kwantificatie van de (nieuwe) aspecten van het vraagstuk die in dit onderzoek naar voren zijn gekomen. Voorbeelden zijn kosten-baten analyses en beslissingsondersteuningsmethoden voor verschillende beleidsopties en initiatieven. Deze doorontwikkeling van bevindingen uit deze studie is noodzakelijk voor meer bruikbare aanbevelingen en beter ondersteuning van beslissingen.
- Voor (haven)beleid onderschrijft dit proefschrift het belang van een holistisch perspectief op ketens, havencluster, en beleid. De waardepropositie van een haven hangt af van het geheel aan keuzes van ketenpartijen, en de congruentie hiermee van het beleid. Om effectief om te kunnen gaan met kansen en uitdagingen in de reefermarkt moet een havenbeheerder zich ontwikkelen – niet alleen als beheerder ook als ketenpartner – en strategische keuzes maken voor de markten en segmenten die actief aangetrokken en gefaciliteerd worden. Ook is er een belangrijke aanjagende rol weggelegd voor havenbedrijven met betrekking tot nieuwe concepten en het overkomen van terughoudendheid in de private sector.
- Het onderzoek heeft de reefermarkt in detail uitgelicht als een sector die volop in ontwikkeling is, en waarin de positie van havens en ketenpartijen niet uitgekristalliseerd zijn. In de sector komen verschillende beginnende ontwikkelingen op die steeds relevanter gaan worden, ook buiten de reefersector, zoals de ‘smart container’ en blockchain technologie. Deze technologie en vragen uit de markt zullen een beweging versnellen naar meer flexibiliteit van logistieke processen. Hiermee wordt de waarde voor de eindgebruiker vergroot, maar biedt ook mogelijkheden om ladingverlies en uitstoot te verminderen.

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My dissertation is mine, but it came out of a project that was very much the work of Harry Geerlings and Ron van Duin, my promotor and copromotor. Thank you both for giving me this opportunity, and for giving me the space to turn the project into something of my own. I’ve been told that every PhD-track has a ‘dip,’ and mine was in 2017 when I seriously doubted whether I would be able to successfully produce a dissertation on this topic. Luckily, both of you were immensely supportive, and open to redefining the scope of the project to address my concerns. The fact that now a finished dissertation has come out of the project is for an important part due to you – thank you both. It has been a pleasure to work under your supervision, and I’m grateful for your contributions to my learning process and the ultimate quality of our work. Moreover, our informal meetings, trips like the one to TRB in Washington, and having you present at my wedding, prove to me that a great working relationship is also evidenced by the ability to have a good time.

Harry, we’ve seen each other almost daily at T17, and I appreciate the easy contact we had over the years. I think particularly fondly of the afternoons we spent facing a beamer screen, piecing together the argument of our TRB-paper section by section. Sessions like these, and the thorough feedback you gave on my work, encouraged me to weigh my words carefully and make sure the essence of my argument was unmistakably clear to my readers. Moreover, your example set for me the standard of collegiality and organizational responsibility. It was a privilege working with you.

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Now that I am close to defending this dissertation, I also want to thank the members of the ‘kleine promotiecommissie’ – Sander de Leeuw, Albert Veenstra, and Bart Wiegmans – for taking the time to thoroughly read my dissertation and for their encouraging feedback. I look forward to discussing further with you during my defense. In addition, I want to thank Bart Kuipers and ManWo Ng in advance for their willingness to complete the committee during my defense – I look forward to hearing and engaging with your thoughts and questions.

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Schiedam, Oktober 2020

## About the author

Bob Castelein (Arnhem, 1990) completed Master's degrees in International Economics and Business (2016, cum laude) and Modern History and International Relations (2016, cum laude) at the University of Groningen. While in Groningen he was an active member of Groningen Students Rowing Club 'Aegir' and during his time spent on or near the water, the container barges passing by fostered a lasting fascination with transportation and trade. His bachelor thesis (2013) traced the historical development of international shipping fleets and networks. This project was later extended into a research internship at the Norwegian School of Economics (2014), under the supervision of prof. Stig Tenold and prof. Jan Tore Klovland, on the role of shipping markets in international trade in the interwar period. In the context of his Master IE&B, Castelein spent a semester (2015) as an intern at the Permanent Representation of the Netherlands to the Organization for Economic Cooperation and Development (OECD) in Paris, France.

In 2016 Castelein started as a PhD candidate at Erasmus University Rotterdam in project EURECA – Effective Use of Reefer Containers through the Port of Rotterdam, under supervision of prof. Harry Geerlings (EUR) and dr. Ron van Duin (TU Delft). In this project, he collaborated with partners at Delft University of Technology, Rotterdam University of Applied Sciences and Wageningen University and Research, as well as with partners in the port and (cold) logistics sectors, including the Port of Rotterdam, SmartPort, Seamark, ABB, Hutchison Ports ECT Rotterdam, FloraHolland and GroentenFruithuis.

Apart from his activities in academic and applied research, Castelein has taught numerous courses at Erasmus University. He has fulfilled junior lecturer roles in Quantitative Methods, SPSS, Economics, Project Management, and Academic Writing seminars for Bachelor students, and he has designed and coordinated courses at the Bachelor (Economics: Welfare & Distribution at the Erasmus School of Social and Behavioral Sciences) and Master level (Research Methods and Techniques at the Institute for Housing and Urban Development Studies). In addition, he advised bachelor and master thesis students at Erasmus University, TU Delft, Rotterdam University of Applied Sciences, University of Groningen, and the Scheepvaart en Transport College (STC Group).

From September 2020, Castelein works as Researcher/Project Leader Supply Chain Development at Wageningen Food & Biobased Research.

## Academic portfolio

**PhD training (2016-2020)**
Erasmus Graduate School of Social Sciences and the Humanities (2016-2019)

- Qualitative comparative analysis
- Work-life balance for PhD
- Self-presentation: presenting yourself and your research
- Big data analysis and visualization
- Doing the literature review
- How to get your article published
- Delphi technique for elicitation of experts' judgments
- Multi-criteria analysis for complex decision-making
- Professionalism and integrity in research

Dutch Research School for Transportation, Infrastructure and Logistics (TRAIL) (2016-2019)

- Writing and publishing a TRAIL research article
- Fundamental domain knowledge of TIL systems (audit)
- TRAIL theories and methods (audit)
- Societal relevance of your PhD research (audit)
- TRAIL data analysis and statistics
- Writing a literature review in the TIL domain
- Discrete choice modeling
- Transport logistics modeling (audit)
- Freight transport management
- From horse to Porsche: Innovations in transport & logistics (audit)
- Capita Supply Chain Management
- Sustainable Operations Management (audit)

Other

- Antwerp Rail School, University of Antwerp, 11-15 March 2019
- Basic Didactics, RISBO, Rotterdam, April 19th, 2018

**Teaching (2016-2020)**
Academic year 2015-2016

- Practical Project Management, Bachelor Public Administration, Erasmus University Rotterdam

Academic year 2016-2017

- Seminar Quantitative Methods, Bachelor Public Administration, Sociology, and MISOC, Erasmus University Rotterdam
- Practical SPSS, Bachelor Public Administration, Sociology, and MISOC, Erasmus University Rotterdam
- Practical Academic Writing, Bachelor Public Administration, Erasmus University Rotterdam

Academic year 2017-2018

- Seminar Quantitative Methods, Bachelor Public Administration, Sociology, and MISOC, Erasmus University Rotterdam
- Practical SPSS, Bachelor Public Administration, Sociology, and MISOC, Erasmus University Rotterdam
- Seminar Economics, Bachelor Public Administration, Sociology, and MISOC, Erasmus University Rotterdam

Academic year 2018-2019

- Seminar Quantitative Methods, Bachelor Public Administration, Sociology, and MISOC, Erasmus University Rotterdam
- Practical SPSS, Bachelor Public Administration, Sociology, and MISOC, Erasmus University Rotterdam
- Lectures and supervision Research Methods and Techniques (SPSS), Institute for Housing and Urban Development Studies, Erasmus University Rotterdam

Academic year 2019-2020

- Course coordinator and lecturer Economics, Bachelor Public Administration, Sociology, and MISOC, Erasmus University Rotterdam
- Lectures and supervision Research Methods and Techniques (SPSS), Institute for Housing and Urban Development Studies, Erasmus University Rotterdam

**Full papers published (journals and conference proceedings)**

2020 Cold chain strategies for seaports. Towards a worldwide policy classification and analysis. *European Journal of Transportation and Infrastructure Research* 20(3). DOI: https://doi.org/10.18757/ejtir.2020.20.3.4074.

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2019 The ostensible tension between competition and cooperation. Intra-port competition and inter-organizational relations in the Rotterdam container handling sector. *Journal of Shipping and Trade* 4(7). DOI: https://doi.org/10.1186/s41072-019-0046-5. With H. Geerlings and R. Van Duin.

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Cold chain strategies for seaports. Towards a worldwide policy classification and analysis. In: Witlox, F. (Ed.). Moving towards more sustainable mobility and transport through smart systems. Proceedings of the BIVEC-GIBET Transport Research Days 2019. Ghent, Belgium.

Divergent effects of port choice incentives on users' behavior. *Transport Policy* 84: 82-93. DOI: https://doi.org/10.1016/j.tranpol.2019.04.010. With H. Geerlings and R. Van Duin.

2015 The Fairplay freights. Compiling a dataset of interwar coal freight rates. *International Journal of Maritime History* 27(2): 302-327.

2014 Abel Santamaria: De onfortuinlijkste man van de Cubaanse revolutie [Abel Santamaria. The most unfortunate man of the Cuban revolution]. *Groniek* 200.

2013 Barry Goldwater: The 1964 election campaign and the rise of the GOP conservative movement. *Groniek* 196: 333-343.

2012 Veranderingen in beleid en ideologie tijdens Cuba's *Periodo Especial* (1990-1995) [Shifts in policy and ideology during Cuba's *Periodo Especial* (1990-1995)]. *Leidschrift* 27(3): 129-144.

**Conference presentations (academic and industry)**

2020
- Conference of the International Association of Maritime Economists, Hong Kong, 13-16 June (contribution accepted, conference conducted online due to COVID-19)
- International Academic Conference on Sustainable Maritime Business, Hamburg, Germany, 27-29 May (contribution accepted, conference cancelled due to COVID-19)
- Transportation Research Board Annual Meeting, Washington D.C., 12-16 January

2019
- Rotterdam Food Port Seminar, Rotterdam, 3 October
- Conference of the International Association of Maritime Economists, Athens, Greece, 25-28 June
- BIVEC-GIBET Transport Research Days, Ghent, Belgium, 23-24 May
- The Future of Agrologistics Seminar, Rotterdam, 17 April

2018
- TRAIL PhD Congress, Utrecht, 15 November
- World Conference on Transportation Research Society, SIGA 2, Maritime and Ports, Antwerp, Belgium, 2-4 May

2017
- TRAIL PhD Congress, Utrecht, 9 November
- Logistics and Maritime Systems Conference, Bergen, Norway, 23-26 August

2016
- TRAIL PhD Congress, Utrecht, 8 November
- Historical Globalization and the Integration of Markets Workshop, Belfast, N. Ireland, 13 June

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## Summary

The global market for conditioned container transport - in refrigerated or 'reefer' containers - is growing rapidly, but also poses significant challenges related to logistics processes and sustainability. This dissertation addresses the question how seaport-related actors can effectively accommodate these logistics chains in seaport clusters. The research findings show how dynamics within actor networks influence a seaport's performance and competitiveness, and how actors can respond to challenges and opportunities in a changing environment.

## About the Author

Bob Castelein studied Economics (cum laude) and History (cum laude) at the University of Groningen (2016), and worked as a PhD candidate at Erasmus University Rotterdam from 2016 until 2020. As of September 2020, he works as Researcher/Project Leader Supply Chain Development at Wageningen Research.

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