

## **Reefers on Rails: Investigating User Perceptions and Technological Prospects**

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## **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 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 rail transportation 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. A major finding is that there is no established option yet to connect reefers 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 services do not offer the desired speed, reliability, and flexibility. While the authors also observed that new rail 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.

**Keywords:** Cold chain, reefer containers, intermodal transport, rail transport, technology, user requirements.

## **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).

Nowadays there is increasing attention for railway transport as a competitive 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 rail initiatives are introduced such as the 'Silk Road Initiative'. This paper focuses on the technological potentials of dedicated cool rail systems and their acceptance by key stakeholders.

The structure of the paper is as follows. Section 2 addresses the position of the reefer container and the logistical context. Section 3 presents the methodology applied. In Section 4, the authors discuss the technological opportunities, limitations and barriers. Section 5 discusses user perceptions when it comes to the adoption of the technology. Section 6 concludes.

## 2. BACKGROUND

### 2.1. 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.

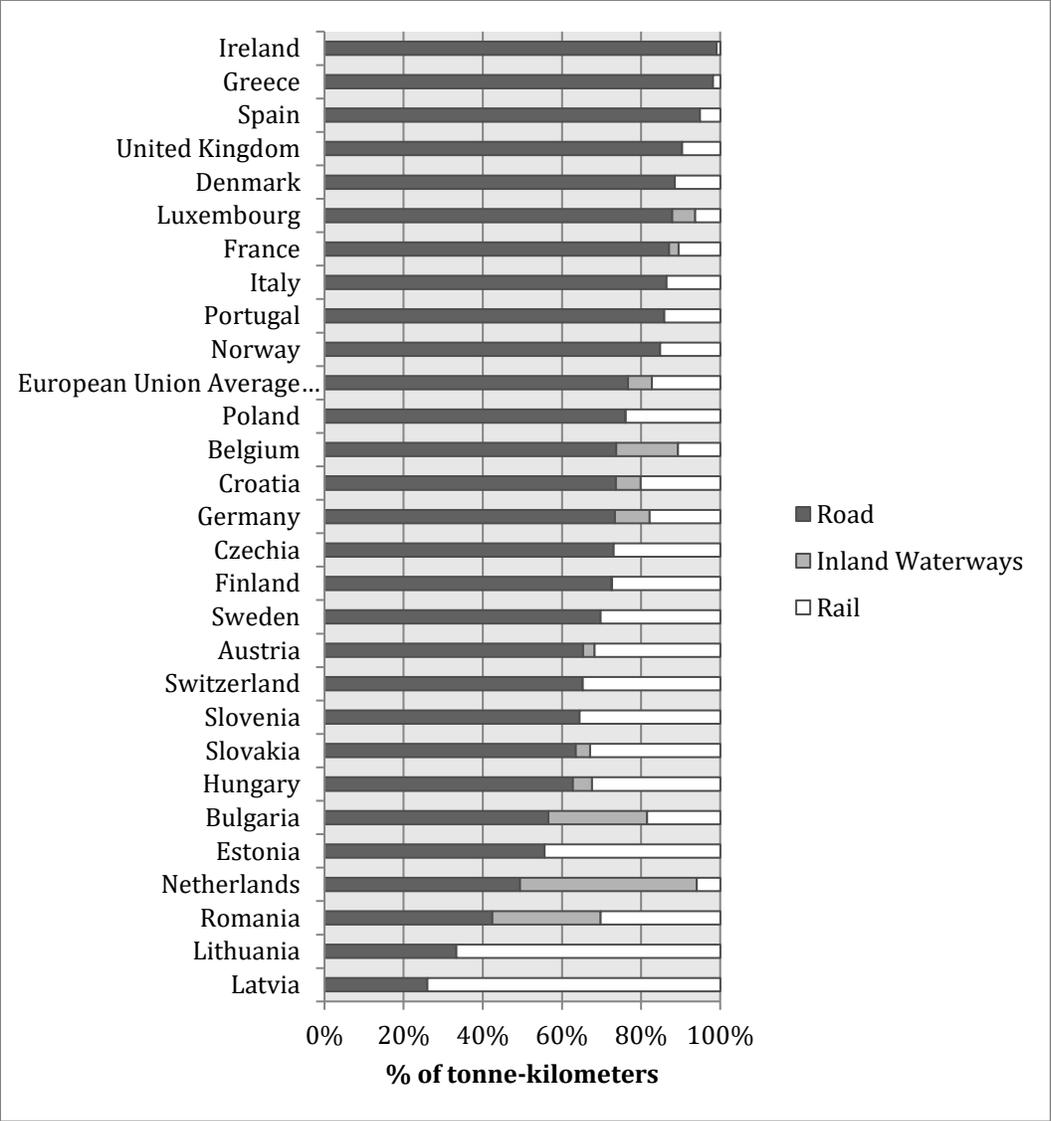
An important factor for a well-functioning cold chain for temperature-sensitive cargoes is the reliability (in terms of delivery and quality control), flexibility, and traceability that these containers and associated technology provide, making it an attractive mode of transportation (Castelein, Geerlings, 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 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 reach all final destinations. At the same time, road transport is hindered by increasing congestion in port areas and on roads, undesirable negative external effects (emissions such as CO<sub>2</sub> 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 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). Rail transportation 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<sub>2</sub> emissions – albeit with a longer transit time and less flexibility.

### 2.2. Sustainable transport and modal shift

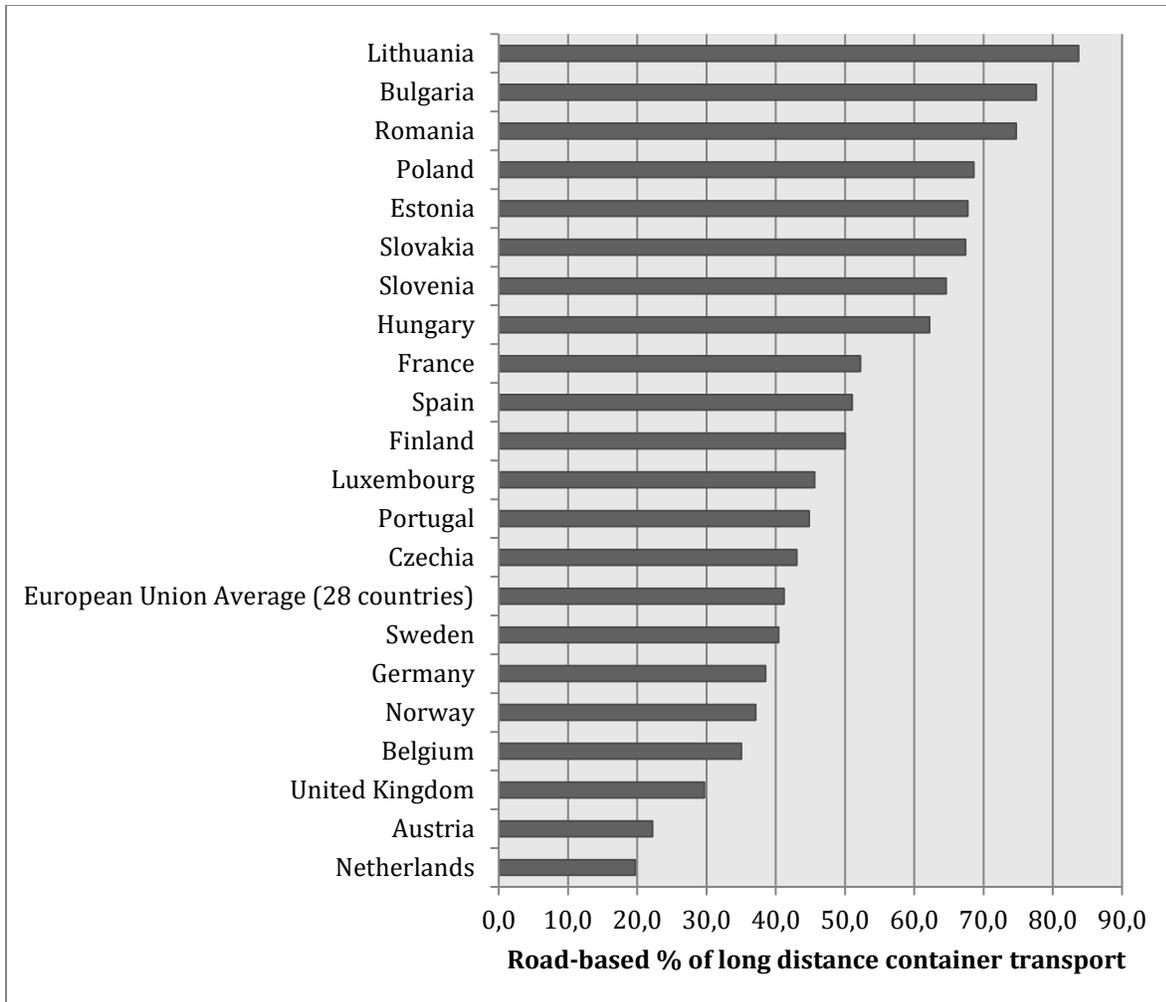
It is for this reason that governments introduced modal shift policies. A major example is found in the EU White Paper on Transport (European Commission, 2011), specifying modal shift goals (by 2050, 50% of road freight over 300km should shift to rail or inland waterways) on the European level, to be 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. (2019) 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 freight transport remains heavily skewed towards road transport. **Figure 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. Inland waterways transport is only used heavily in those few countries with naturally well-developed inland waterways networks. 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. Therefore rail transport can be a promising possibility for a modal shift where currently road transport dominates.



**Figure 1. Modal split of freight transport for EU countries, 2017. Source: Eurostat (2019b).**

When considering the modal split of containerized freight, there is considerable potential for a modal shift. **Figure 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 2. Modal shift potential of container for EU countries. 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<sub>2</sub> footprint of transport has been taken into account in the future.

### **2.3. Growing attention for reefer transport by rail**

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 to less polluting modes – principally from road to rail. This paper focuses on the latter. Rail can be considered the most promising mode for emissions reduction and de-carbonization of the transport sector: for road

transport the CO<sub>2</sub> emissions are 90.3 grams per ton-km, while rail transport emits 11.3 grams of CO<sub>2</sub> per ton-km (Jonkeren et al., 2019). A modal shift represents a promising option where the environmental and the economic added value is demonstrated, but user acceptance still depends on the attractiveness of new logistics concepts based on the traditional criteria of costs, speed, reliability, and flexibility.

The growing attention for rail transport of perishable cargoes is illustrated by three examples from Europe, North America, and Asia.

Recently (May 6<sup>th</sup>, 2019), a new direct train shuttle for fresh products (CoolRail) 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<sub>2</sub> emissions (RailFreight, 2018). Transport to the Netherlands via this train is just as fast as road transport, but more sustainable.

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 (Sowinsky, 2018). 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 (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 infrastructure development and investments worldwide. This initiative includes a 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, 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.

### 3. METHODOLOGY

Considering the developments sketched above, this paper addresses the following questions: 1) What technologies are available to transport (operating) reefers by rail? And 2) What are the user requirements that an intermodal rail logistics concept 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 transport, and identify what challenges should be addressed in technology and logistics concept development.

The analysis follows a two-pronged approach: mapping the current technological options for rail transportation of reefers and their characteristics, and elucidating user requirements and perceptions of the current service offer through stakeholder interviews.

The first research question is answered by mapping and evaluating the existing technological options to transport operating reefer containers on a train. Apart from asking respondents about the options they are aware of, the authors conducted a web-based search of available technologies, drawing on information from industry publications, corporate websites and presentations. New technologies were found using different search terms on search engines and in the archives of industry publications, until the point where information saturation was reached and new searches only yielded 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 train,
- Other options (e.g. real-time temperature monitoring),
- Examples of cases where it is implemented.

For the user interviews, the authors approached stakeholders active in cold chain logistics 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 case 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.

The authors aimed 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) as well as actors focusing on different types of cargo (fruit, flowers, meat etc.). 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, and to elaborate on their considerations. To identify stakeholders' evaluation of the service offer of reefer transportation by rail, these statements (or discussion questions of equal wording) were used:

- *Hinterland transport of reefers by rail is a good option*
- *The infrastructure for hinterland transport of reefer containers by rail meets our expectations*
- *The performance of hinterland transport of reefer containers by rail meets our expectations*
- *We find the costs of hinterland transportation by rail too high*

Using 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 1** lists the respondents by their function title and the type of company they represent. Company names are omitted to preserve respondents' anonymity.

**Table 1. Interview respondents**

<b>Type of organization</b>	<b>Role respondent</b>
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

#### 4. TECHNOLOGY: 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 cargo at the desired temperature, and reliable temperature control is therefore a crucial element for the success of reefer transport by rail. On container ships, reefers are plugged in and powered through the ship's engine, and at terminals they are connected to the grid. On trains, there is no standard technology (yet) to provide the necessary power. Technology is the key to these challenges as performance depends on technological innovations. Technological innovations evolve regularly from R&D processes, but their implementation in transportation markets encounters considerable difficulty. This especially applies to the rail sector for long distance transportation of temperature-sensitive goods.

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), and MacAndrews (Spain)), a system in which a larger diesel generator (fixed on a wagon) is used to supply power to a train of reefer containers (numbers quoted range between 8-18 connections). In the concept operated by Sungate, the wagon with the generator is equipped with living space for 2 mechanics, who do 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.

- 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.

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  $-30^{\circ}\text{C}$  to  $50^{\circ}\text{C}$ ). 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 very remote areas where energy supply is difficult and monitoring and maintenance are impossible.

These conclusions are derived from examination of the operation of reefer transport services. It should be noted that in manufacturing technology and infrastructure technologies further work is required as well, considering whole life cycle effects, and geared towards disposal and recycling needs.

Wiegman 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 rail transport 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 rail 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. 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, Wiegman et al. (2010) address the growing concern for sustainability as a criterion in users' decision-making. These user requirements and considerations are addressed in the following section.

## **5. USER PERSPECTIVES**

The focus of the stakeholder interviews was on two types of corridors on which reefer containers could be transported by train: the hinterland link of a maritime reefer chain (hence having the rail leg starting or ending in a seaport), and the continental rail 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 is in question.

### **5.1. General requirements**

Before discussing their considerations regarding rail transport specifically, the respondents elaborated on their general requirements of reefer container transport. While the transportation costs by rail 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 have to be delivered at an auction (as can be the case for fruit, vegetables, 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. 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.

### **5.2. Evaluation of rail 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.

### **5.3. Evaluation of current rail logistics concepts**

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 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.

The latter is a particularly relevant point for the supply side of rail-based reefer transportation, considering the imbalances in food trade (i.e. major importing regions are rarely major exporting regions). One respondent estimated an occupancy rate of approximately 80% necessary to break even on a rail shuttle service. 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.

Concerning rail 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, 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, who 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 shipment would.

Also users’ evaluation of hinterland networks illustrates some barriers to the adoption of rail transport for reefer containers. Inland terminals usually have limited availability of reefer plugs, and considering their sometimes-limited connectivity, they involve considerable risks of delays, even for last-mile trucking. Moreover, after every trip, a reefer’s cooling unit requires an 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, but in practice most reefers still have to be transported back to a port empty before being reused.

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.

#### **5.4. Competition with other modes**

The common frame of reference when evaluating reefer transportation by rail 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 he compares 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. 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.

### **5.5. 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.

One terminal operator supports the idea that dominant ways of thinking and organizing processes work as barriers to change in the sector. He points 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 intermodal rail transportation is a viable option.

These stakeholder considerations illustrate two barriers to the development of reefer transportation by rail. One is the current absence of a logistics concept that sufficiently satisfies user needs. The other 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.

## 6. CONCLUSION

In freight transportation, the concept of a modal shift from road to rail receives increasing attention due to externalities and capacity constraints. In the fast-growing perishables transport market however, the share of rail freight is negligible. In this exploratory study, the authors surveyed existing technologies to transport refrigerated containers by rail, and mapped user requirements and evaluations of existing rail freight concepts 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.

Several examples were discussed of corridors where rail-based reefer logistics concepts 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 atypical 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.

Two European examples were discussed as well. Interestingly, both involve direct dedicated shuttle trains (i.e. terminal to terminal, no shunting en route) with reefer containers. Considering the user requirements of shippers of perishables, this may be the most acceptable model of reefer transportation by rail. Stakeholders view these new services as promising user cases where rail transportation still meets their demand for rapid service at a high frequency. These examples also illustrate the conditions under which a modal shift from road to rail is feasible and acceptable to stakeholders: 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. In the future, the flexibility of rail-based logistics concepts can be further enhanced by combining different modalities to meet customers' specific preferences in terms of price and speed.

Ultimately, our 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.

## REFERENCES

- Arduino, G., Carrillo Murillo, D. and Parola, F. (2015) 'Refrigerated container versus bulk: evidence from the banana cold chain', *Maritime Policy & Management*, 42(3), pp. 228–245. doi: 10.1080/03088839.2013.851421.
- BestFact (2013) *Green Rail - FloraHolland*. Available at: [http://www.bestfact.net/wp-content/uploads/2013/08/bestfact\\_Quick\\_info\\_greenlogistics\\_2-046\\_GreenRail.pdf](http://www.bestfact.net/wp-content/uploads/2013/08/bestfact_Quick_info_greenlogistics_2-046_GreenRail.pdf).
- Boyer, K. D. (2014) 'Why is the Rail Share of US Freight Traffic So Low?', *Journal of Transport Economics and Policy*, 48(2), pp. 333–344.
- Castelein, B., Van Duin, R. and Geerlings, H. (2019) 'Identifying Dominant Stakeholder Perspectives on Sustainability Issues in Reefer Transportation. A Q-Method Study in the Port of Rotterdam', *Sustainability*, 11, p. 3425.
- Castelein, B., Geerlings, H. and Van Duin, R. (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.
- Drewry (2017) *Reefer Shipping Market Review and Forecast 2017/18*. London.
- European Commission (2011) 'White Paper. Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system', p. 31. Available at: <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0144&from=EN>.
- Eurostat (2019a) *Modal shift potential of long-distance road freight in containers - tonne-kilometre*. Available at: <http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do> (Accessed: 24 July 2019).
- Eurostat (2019b) *Modal split of freight transport*. Available at: [http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=tran\\_hv\\_frmod&lang=en](http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=tran_hv_frmod&lang=en) (Accessed: 24 July 2019).
- FruitDelta Rivierenland (2018) *RIF-project ReeferExpress tussen Rotterdamse haven en CTU Rivierenland gestart*. Available at: <https://www.fruitdelta.nl/rif-project-reefer-express-gestart/> (Accessed: 24 July 2019).
- Guerrero, D. and Rodrigue, J. (2014) 'The waves of containerization: shifts in global maritime transportation', *Journal of Transport Geography*, 34, pp. 151–164. doi: 10.1016/j.jtrangeo.2013.12.003.
- International Transport Journal (2018) 'New wagon to be introduced to market in May', *International Transport Journal*, June, p. 19.
- Jonkeren, O., Francke, J. and Visser, J. (2019) 'A shift-share based tool for assessing the contribution of a modal shift to the decarbonisation of inland freight transport', *European Transport Research Review*, 11(8).
- De Langen, P., Van den Berg, R. and Willeumier, A. (2012) 'A new approach to granting terminal concessions: the case of the Rotterdam World Gateway terminal', *Maritime Policy & Management*, 29(1), pp. 79–90. doi: 10.1080/03088839.2011.642311.
- Nooteboom, B. (1989) 'Diffusion, uncertainty and firm size', *International Journal of Research in Marketing*, 6, pp. 109–128.
- RailFreight (2018) *First cooled train Rotterdam-Valencia is now a fact*. Available at: <https://www.railfreight.com/railfreight/2019/05/13/first-cooled-train-rotterdam-valencia-is-now-a-fact/> (Accessed: 24 July 2019).
- Reis, V. et al. (2013) 'Rail and multi-modal transport', *Research in Transportation Economics*. Elsevier Ltd, 41(1), pp. 17–30. doi: 10.1016/j.retrec.2012.10.005.
- Rodrigue, J.-P. and Notteboom, T. (2015) 'Looking inside the box: evidence from the containerization of commodities and the cold chain', *Maritime Policy & Management*, 42(3), pp. 207–227. doi: 10.1080/03088839.2014.932925.
- Rogers, E. M. (2003) *Diffusion of innovations, fifth edition*. New York: The Free Press.
- Sowinsky, L. L. (2018) 'As truck capacity tightens, reefer shippers board the rail', *Journal of Commerce*.

- Available at: [https://www.joc.com/rail-intermodal/us-truck-capacity-tightens-reefer-shippers-board-rails\\_20180223.html](https://www.joc.com/rail-intermodal/us-truck-capacity-tightens-reefer-shippers-board-rails_20180223.html).
- UNCTAD (2017) *Review of Maritime Transport 2017*. Available at: [http://unctad.org/en/PublicationsLibrary/rmt2017\\_en.pdf](http://unctad.org/en/PublicationsLibrary/rmt2017_en.pdf).
- Unit45 (2014) *UNIT45 lanceert innovatieve diesel-electric reefer voor lange afstanden*. Available at: [https://www.unit45.com/nl/UNIT45 lanceert innovatieve diesel-electric reefer voor lange afstanden](https://www.unit45.com/nl/UNIT45_lanceert_innovatieve_diesel-electric_reefer_voor_lange_afstanden) (Accessed: 25 July 2019).
- United Nations (2015) 'Paris Agreement (adopted 12 Dec. 2015, entered into force 4 Nov. 2016)', in. Available at: [https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg\\_no=XXVII-7-d&chapter=27&clang=\\_en](https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27&clang=_en).
- Wiegmans, B. W. and Geerlings, H. (2010) 'Sustainable port innovations: barriers and enablers for successful implementation', *World Review of Intermodal Transportation Research*, 3(3), pp. 230–250. doi: 10.1504/writr.2010.034664.