Output 3.2-2

The role of Ro-Ro shipping in a stricter regulatory environment

Interreg Baltic Sea Region Project #R032 "Sustainable and Multimodal Transport Actions in the Scandinavian-Adriatic Corridor"

Work Package	WP3 - Multimodal Transport				
Activity	A 3.2 - Assessing offers and preconditions for multimodal freight transport in the Scandria®2Act partner regions				
Responsible Partners	PP18 - Technical University of Denmark PP6 - University of Turku				
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Document Approval Chronology

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Output Description (Application Form)

Activity 3.2-2 will look into Ro-Ro offers in the region and examine their stability in view of the more stringent regulations with regard to the sulphur content of marine fuels enforced on 01/01/2015. It will:

(i) identify all Ro-Ro connections along the corridor,

(ii) select 4-5 of typical ones,

(iii) estimate their market shares against land-based alternatives,

(iv) investigate market shares sensitivity in relation to fuel prices and speed, and

(v) assess the competitiveness and long-term stability of the existing offers.

Output Schedule

Source	Deadline / Milestone					
	31.10.16	30.04.17	31.10.17	30.04.18	31.10.18	30.04.19
Planned according to work plan					X	
Expected						X

Quality Criteria

- The **aim of this output** is to present the results of Activity 3.2-2, which focuses on the stability of the Ro-Ro connections along the corridor in view of the more stringent regulations on the sulphur content of marine fuels.
- The **geographical scope** of the report is identical to that of the Scandria2Act project, i.e. the northern part of the ScanMed TEN-T core network corridor consisting of Germany, Denmark, Sweden, Norway and Finland.
- In general, the **target group** consists of all stakeholders in freight transport operations: shippers and forwarders, multimodal service providers, regional, national and European transport planning authorities, knowledge institutions and industry organisations. Ro-Ro operators, port authorities and terminal operators are among the stakeholders who are directly impacted by the subject regulations. Project partners in Group of Activities 3.3 are also among the targeted recipients.
- The **intended use** of the report is the provision of assistance in the design and implementation of integrated multimodal freight transport operations. More specifically, it offers insights on the determinants of the market shares of Ro-Ro solutions against land-based alternatives, as well as their sensitivity to changes in fuel costs that are often triggered by regulatory interventions.

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Abbreviations

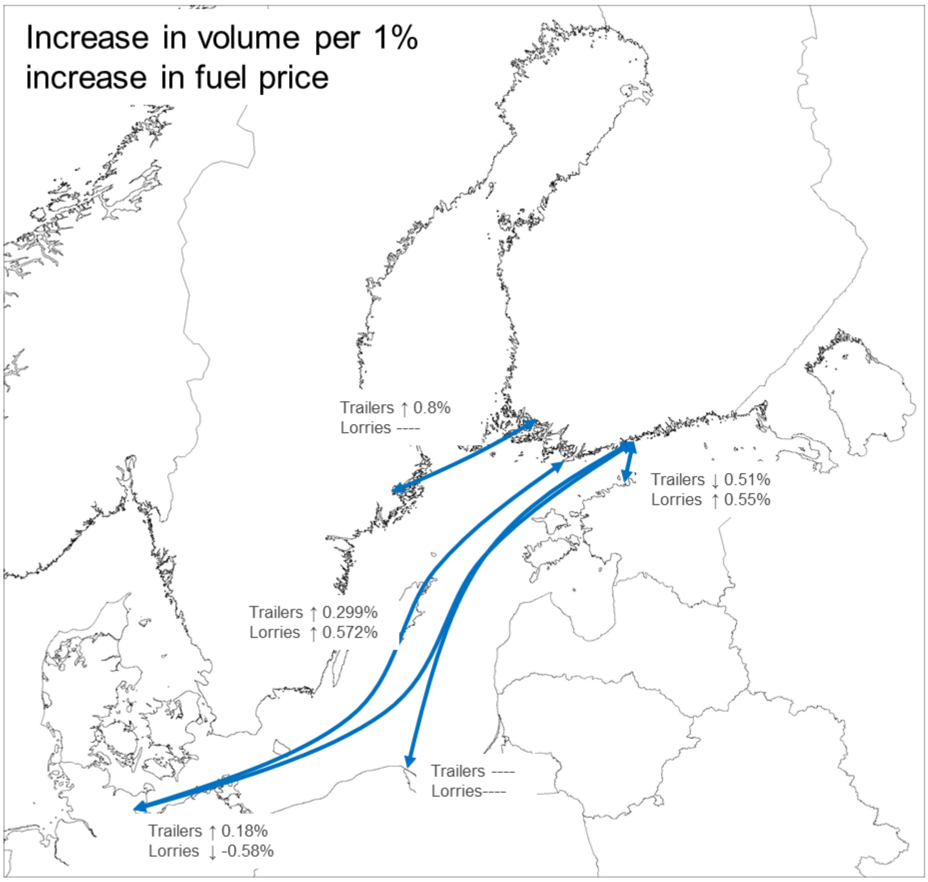
BSR	Baltic Sea Region
CNC	Core network corridor
EC	European Commission
ECA	Emission control area
EMSA	European Maritime Safety Agency
EU	European Union
GDP	Gross domestic product
GHG	Greenhouse gas
GoA	Group of activities
HFO	Heavy fuel oil
IMO	International Maritime Organisation
LNG	Liquefied natural gas
LSMGO	Low sulphur marine gas oil
MGO	Marine gas oil
NECA	Nitrogen emission control area
NOx	Nitrogen oxides
NSB	North Sea – Baltic (core network corridor)
PM	Particulate matter
Ro-Ro	Roll on / Roll off (ship type)
ScanMed	Scandinavian – Mediterranean (core network corridor)
SECA	Sulphur emission control area
SOx	Sulphur oxides
TEN-T	Trans-European transport network
ULSFO	Ultra low sulphur fuel oil
UNCTAD	United Nations Conference on Trade and Development
WP	Work package
WTO	World Trade Organization

1 Executive Summary

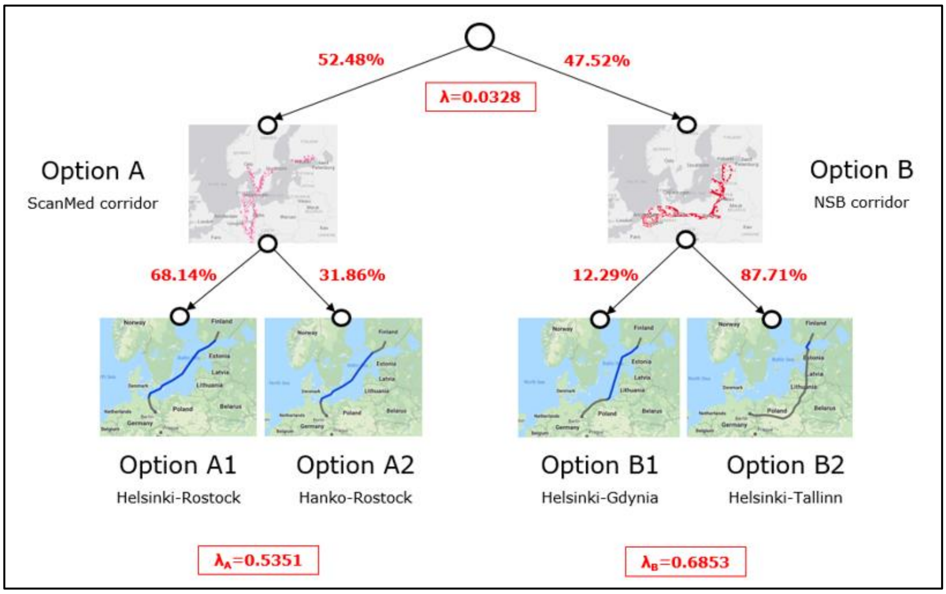
This report presents the results of Activity 3.2-2 of the Scandria®2Act project. It investigates the sensitivity of the Ro-Ro services along the Scandria® corridor to fuel cost fluctuations, anticipates the adverse effects of a possible fuel price hike and discusses potential mitigating measures.

Among the 77 Ro-Ro services that include at least one direct connection between two Baltic ports, the Finland-Germany connections were selected for further examination mainly because this is where the ScanMed and NSB core network corridors meet providing two major alternatives, each of which offer at least two options. In terms of abatement options available to the Ro-Ro operators, the study considers only the switching from Heavy Fuel Oil (HFO) to the compliant but more expensive Marine Gas Oil (MGO), which happens to be the only feasible solution in the short-run that does not require a substantial capital investment.

The study deployed two different approaches in meeting its objectives. The first one looked at the problem from the macro-level perspective and the analysis was based on aggregate annual statistics of the ports serving the Finland-Germany connections. A multiple regression model estimated the sensitivity of cargo flows to fuel price fluctuations. Although most of the cargo volumes exhibit a statistically significant sensitivity to fuel price, in all cases this is below 1.0, indicating a rather inelastic behaviour. The results show that an increase in fuel price penalises the volume of lorries on the long-distance Helsinki-Germany route in favour of the shorter Helsinki-Tallinn and Hanko-Germany options. The trailer (unaccompanied) traffic exhibit a different behaviour that might relate to the pricing policies of the Ro-Ro operators in relation to this market segment.



The second approach looked into the route selection problem from the perspective of a cargo owner/shipper and it was based on detailed information pertaining to a specific company. A logit model was used to describe route selection on the basis of the generalised cost associated with each alternative route, which in this case was a function of price, transit time and frequency of service. The selection process was modelled as a 2-stage hierarchical decision. The first stage concerns the selection among the alternative ScanMed and NSB corridors, while one of the two alternative options that correspond to each of the above corridors is selected at the second stage. The model was calibrated on the 2014 data and was used to predict the 2015 modal shares.



The use of two different approaches enables the comparison between them. The results show that in this case the macro-level approach has been much more effective in forecasting the developments of 2015. It captured the gains of NSB over the ScanMed corridor, as well as the fact that the Helsinki-Tallinn option won shares from all other alternatives. This is probably due to the fact that:

(i) the actual case reflects the aggregate port statistics of 2015, which is in line with the logic of the macro-level perspective, and
(ii) the micro-level analysis has been based on a number of assumptions that limit the accuracy of the results.

		MICRO		MACRO		Actual case	
		HFO (2014) -> MGO (2015)		HFO (2014) -> MGO (2015)		HFO (2014) -> MGO (2015)	
	2014 share (%)	2015 share (%)	Difference (%)	2015 share (%)	Difference (%)	2015 share (%)	Difference (%)
A1 (Helsinki-Rostock)	35,76	37,83	2,07	32,30	-3,46	32,74	-3,02
A2 (Hanko-Rostock)	16,72	15,80	-0,92	14,14	-2,58	15,08	-1,64
A (ScanMed)	***52,48***	***53,63***	***1,15***	***46,44***	***-6,04***	***47,82***	***-4,66***
B1 (Helsinki-Gdynia)	5,84	11,49	5,65	3,21	-2,63	5,11	-0,73
B2 (Helsinki-Tallinn)	41,68	34,88	-6,80	50,36	8,68	47,07	5,39
B (NSB)	***47,52***	***46,37***	***-1,15***	***53,56***	***6,04***	***52,18***	***4,66***

The task also briefly referred to the main measures have been proposed in the literature for mitigating the adverse effects of the stricter sulphur regulation on the competitiveness of the Ro-Ro industry. Speed reduction, lowering sailing frequency, and fleet and network reconfiguration are among those controlled by the Ro-Ro operator. Measures decided at a higher policy level include the full or partial internalisation of external costs of transport, the easing of port dues, the Eco-bonus system, subsidies for environmental investments, and a tax on land-based modes. The micro-level model was used to assess the effectiveness of an Eco-bonus system following the Swedish formulation. The results indicate that a 30% subsidy on the vessel's operating cost would favour routes involving longer maritime legs in the two corridors, and that the ScanMed corridor would gain 3.31% shares from NSB.

In general, it appears that the Ro-Ro flows have not been affected much by the stricter sulphur regulations. This can be attributed to:

(i) the large drop of fuel prices that coincided with the introduction of the stricter sulphur regulation and resulted in a reduction rather than an increase in costs,
(ii) the 'systematic' nature and long term contracts of Ro-Ro-traffic, and
(iii) the fact that Ro-Ro services pertain to a combination of sea and road transport that is affected by external influences other than the cost of marine fuel.

The sensitivity of the Ro-Ro connections to even moderate changes in demand, however, needs to be kept in mind. The withdrawal of the Helsinki-Gdynia service in 2016 due to the drop of its market shares is not uncommon.

2 Introduction

The report presents the work performed and the results achieved under Activity 3.2-2 of the Scandria®2Act project. Scandria®2Act is an initiative of regions located along the Scandria® corridor, i.e. the Baltic Sea stretch of the Scandinavian-Mediterranean core network corridor. It aims at increased connectivity and competitiveness while reducing the negative implications of transport operations.

Aiming at removing physical, technical, operational and administrative bottlenecks along the major transport axes across Europe, the core network corridors (CNCs) were introduced in 2013 as an instrument for the coordinated implementation of the EU transport infrastructure policy. A major challenge in organising transport along the CNCs is the negative environmental impact caused by emissions mainly of road transport and the limited capacity of transport infrastructure in highly utilised corridor sections.

The Scandinavian-Mediterranean (ScanMed) is one of the two CNCs that surround the Baltic Sea Region (BSR) - the North Sea-Baltic (NSB) being the other one. The transport market study of the ScanMed corridor identified a number of bottlenecks in the transport network and confirmed rising transport volumes between the corridor regions. This puts high pressure to develop cross-sectoral and cross-level solutions that minimise environmental impact of transport and optimise capacity utilisation. This is the challenge that Scandria®2Act addresses and to which Activity 3.2-2 contributes.

2.1 The Scandria®2Act framework

To meet its objective, Scandria®2Act has adopted a 3-tier approach addressing:

- the deployment of clean fuels,
- the deployment of multimodal transport services and
- the establishment of a multilevel governance mechanism, the Scandria®Alliance.

The promotion of multimodal transport of both passengers and freight along the Scandria® corridor is the subject of the project's WP3. More specifically, the package aims to:

- improve knowledge about transport flows in the corridor as a prerequisite for increasing capacity of regional stakeholders to adopt relevant policies,
- facilitate multimodal transport services that are capable of shifting freight volumes from road to other, less burdening transport modes and
- strengthen existing services in passenger transport by providing relevant information about international public transport services to customers.

Against this background, the Group of Activities (GoA) 3.2 aims at identifying the current offers of multimodal freight services in the region and investigating the necessary preconditions for enabling their advancement. The group consists of four distinct activities:

A3.2-1: Map the current services offered to/from the partner regions,

A3.2-2: Assess the stability of the Ro-Ro offers in the region in view of the recent regulations restricting the sulphur content of marine fuels,

A3.2-3: Investigate the shipper needs in relation to multimodal freight transport services and

A3.2-4: Identify appropriate business models for multimodal services along the corridor.

2.2 Activity objectives

On 1 Jan. 2015, the maximum sulphur content of marine fuels used by ships sailing in the Baltic Sea, the North Sea and all other Sulphur Emission Control Areas (SECAs) was reduced from 1% to 0.1% by mass. Unless equipped with special exhaust-gas treatment devices (scrubbers), ships had to switch into burning the more expensive Marine Gas Oil (MGO). It was feared that this substantial increase in the fuel cost would result in competitive losses of coastal ships vis-à-vis other transport modes. The Roll-on/Roll-off (Ro-Ro) ships carrying trucks and trailers between ports that are also connected via land routes were expected to incur the heaviest losses. None of these fears materialised, however, as the stricter regulation coincided with a significant drop in fuel prices that nullified the anticipated freight rate increase.

The Ro-Ro connections constitute an important component of the Scandria® corridor and a crucial element for the Scandria®2Act vision of advanced multimodal services. Thus, in searching for the necessary conditions for such multimodality, we need to investigate the sensitivity of the Ro-Ro services along the corridor to fuel cost fluctuations, anticipate the adverse effects of a possible fuel price hike and discuss potential mitigating measures.

This is the general objective of Activity 3.2-2. More specifically, the activity will:

(i) identify all Ro-Ro connections along the corridor,
(ii) select 4-5 of typical ones,
(iii) estimate their market shares against land-based alternatives,
(iv) investigate market shares sensitivity in relation to fuel prices and speed, and
(v) assess the competitiveness and long-term stability of the existing offers.

2.3 Structure of the report

The next section presents the existing policy framework on the sulphur content of marine fuels, as formed by global (IMO) and regional (EU) regulations. The section also reviews selected literature on the available abatement options and the anticipated implications.

Section 4 deals with the geographic scope of the work. It presents the set of Ro-Ro connections that will be analysed, as well as their selection process.

Sections 5 and 6 are devoted to the analysis. Each one relates to one of the two separate approaches used. Section 5 concerns the macro-level perspective, which is based on aggregate country statistics. It briefly presents the development of Ro-Ro traffic along the route examined, the macro-economic model used for estimating the price elasticities of transport volumes, the evolution of the model parameters and the results achieved.

The micro-level analysis is the subject of Section 6. It looks into the route selection problem from the perspective of a cargo owner/shipper. The section presents the modal split model that was used in the analysis and investigates the sensitivity of the results to different levels of fuel prices. The potential of various operational and policy related measures on mitigating the impact of the regulations is also examined.

The conclusions of the report are summarised in Section 7, which also provides some directions for further analysis.

2.4 Acknowledgements

This activity is co-funded by the Interreg Baltic Sea Region Programme 2014-2020, the Department of Management Engineering of the Technical University of Denmark and the Turku School of Economics of the University of Turku. We are grateful to all. We also express our gratitude to the Scandria®2Act management team, Dr. Ulrike Assig, Horst Sauer and Sven Friedrich for entrusting this activity to us. Special thanks are due to Rolf Sandberg and Staffan Herlin for providing input valuable for the analysis and our WP3 colleagues Sorin Sima, Per Gisle Rekdal, Tom Granquist and Petra Stelling for constructive comments on intermediate results of this work.

3 Policy framework and implications

3.1 IMO and EU regulations on sulphur content of marine fuels

World seaborne trade accounts for more than 80 per cent of total world merchandise trade (UNCTAD, 2018), making shipping the backbone of international trade and world economy. In the continental trades, efforts are made to shift freight from road to rail and maritime transport due to persistent road congestion problems and the favourable carbon footprint of the latter modes in comparison to trucks (EC, 2011). This is not the case with sulphur oxide (SOx) emissions, however, as shipping is responsible for 13% of global SOx emissions generated from anthropogenic sources (IMO, 2015). The fuel that ships' diesel engines burn is the main reason for that. Due to the low quality of this fuel, even the most modern marine engines produce a range of emissions, which are more of a concern in shipping compared to other modes of transport (Cullinane & Bergqvist, 2014).

At global level, the responsibility for the prevention of marine and atmospheric pollution from ships, in addition to safety and security concerns, lies with the International Maritime Organisation (IMO). The IMO's ship pollution rules are contained in the International Convention on the Prevention of Pollution from Ships, known as MARPOL 73/78. In May 2005, the MARPOL Annex VI entered into force, which sets limits on NOx and SOx emissions from ship exhausts, and prohibits deliberate emissions of ozone depleting substances. The IMO emission standards were further revised by Annex VI amendments adopted in October 2008 and October 2016 (IMO, 2016).

Two sets of emission and fuel quality requirements are defined by Annex VI: global requirements, and more stringent requirements applicable to ships in Emission Control Areas (ECAs). An Emission Control Area can be designated for SOx and PM, or NOx, or all three types of emissions from ships. The first designated SOx Emission Control Area (SECA) is the Baltic Sea, which entered into force on 19 May 2006. The North Sea Area and the English Channel SECA entered into force on 22 November 2007. These SECAs are depicted in Figure 1 below. Today, the designated ECAs include the North American and the United States Caribbean Sea Areas (IMO, 2018a). The North American ECA is also a NOx ECA (NECA), and the European SECAs will also become NECAs as of 1/1/2021.

The basic provisions of the revised MARPOL Annex VI, related to SOx emissions, include:

- a reduction in the global limit of sulphur content in fuel to 3.5% by mass (from 4.5%) effective from 1 January 2012; then to 0.5%, effective from 1 January 2020; and
- a reduction in sulphur limits for fuels in SECAs to 1%, beginning on 1 July 2010 (from 1.5%); being further reduced to 0.1%, effective from 1 January 2015.

The regulations allow for the use of suitable abatement equipment as an alternative to the fuel switching requirements described above on the basis that equivalent SOx emissions are achieved on a continuous basis. The timing of the above sulphur content limits are represented graphically in Figure 2.

At European level, Directives 2005/33/EC and 2012/33/EU transpose the IMO limits into European law and further introduce:

- a 1.5% sulphur limit for fuels used by passenger vessels on regular services between EU ports until 1 January 2020; then reduced to 0.5%; and
- a 0.1% sulphur limit on fuel used by inland waterway vessels and by seagoing ships at berth in EU ports, from 1 January 2010.

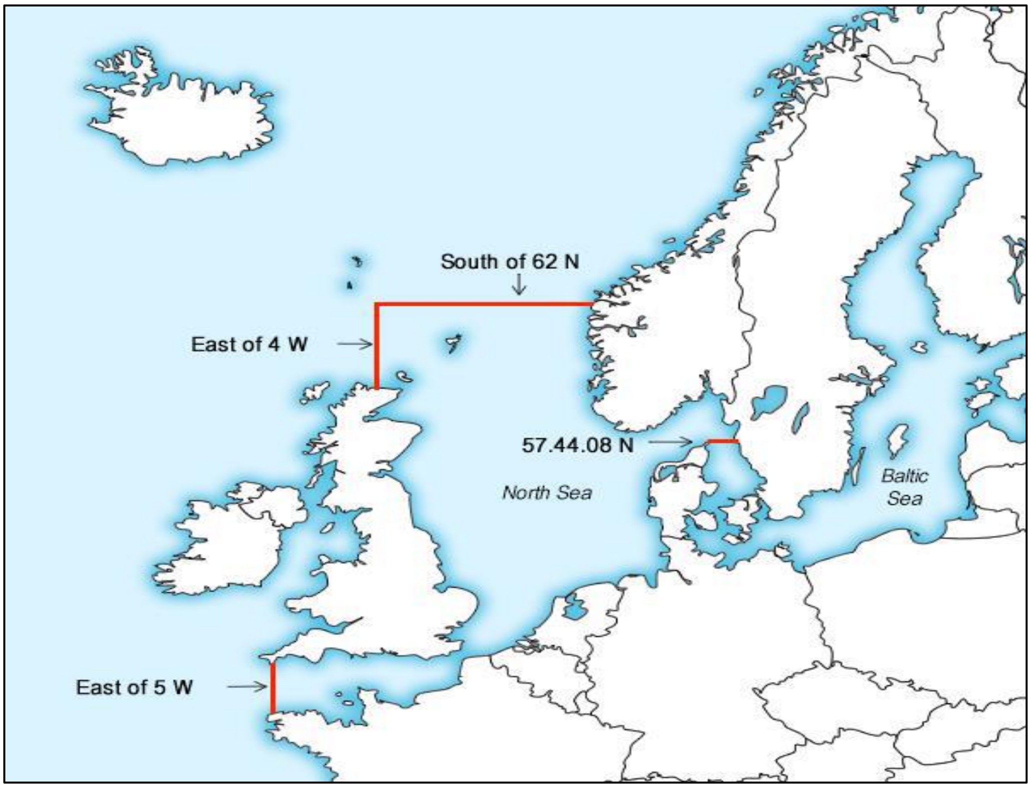


Figure 1. The Baltic, North Sea and English Channel SECAs (Source: EMSA, 2018)

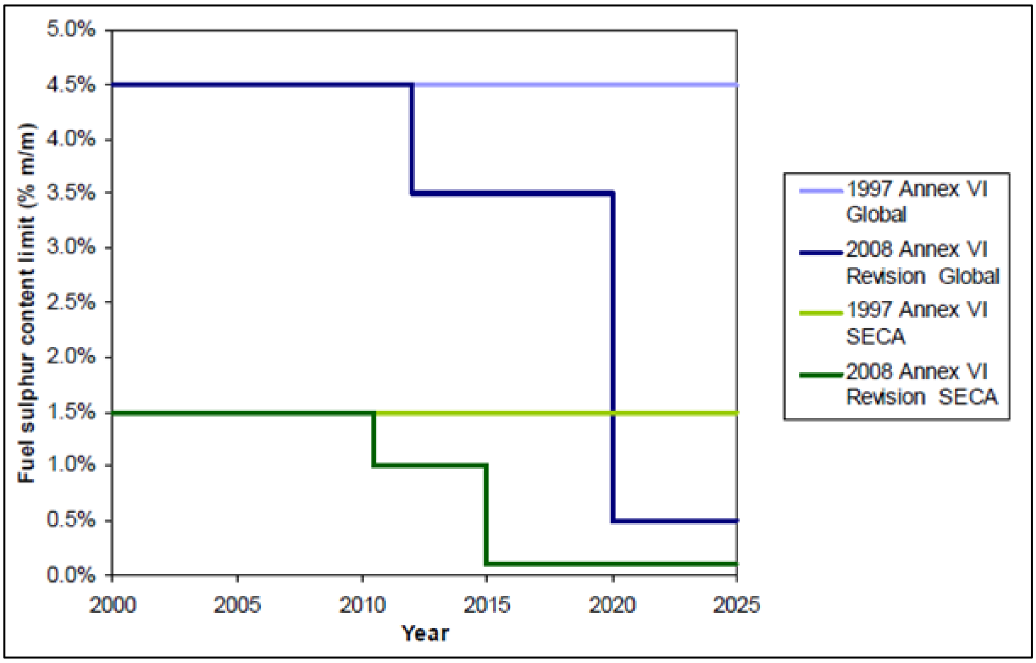


Figure 2. Revised MARPOL Annex VI – Fuel sulphur limits (Source: Entec, 2010)

3.2 Abatement options

The environmental regulations on shipping involve costs and benefits. Ship operators can apply three main strategies to comply with the lower sulphur limits. Firstly, they can switch to low-suplhur fuel, such as the marine gas oil (MGO) that is more expensive than the currently used Heavy Fuel Oil (HFO) (Vierth et al., 2015). Secondly, they can switch to cleaner energy sources, such as liquefied natural gas (LNG), methanol or biofuels (Lindstad et al., 2017). The third option is to install a scrubber that removes sulphur from the exhaust gases to allow continued use of HFO (Vierth et al., 2015; Lindstad et al., 2017). The decision on which abatement approach to choose depends on several factors, including the fuel prices, the area in which the ship usually operates, the remaining useful lifetime of the ship and the ship's sailing pattern (e.g. speed and route choices) (Abadie et al., 2017; Gu & Wallace, 2017).

Today, heavy fuel oil (HFO) is used by the majority of marine engines (Brynolf et al., 2014). In order to comply with SECA regulations, ships can use the ultra low-sulphur fuel (ULSFO) that contains less than 0.1 % sulphur. After 2020, HFO will be replaced by low sulphur fuel oil (LSFO) that can be used when the ship sails outside SECA (Gu & Wallace, 2017). The use of low-sulphur fuel does not require any major capital investments in modifying ships; but possibly a minor adjustment of tanks and engines (Bergqvist et al., 2015). For a ship operating entirely in a SECA area, the capital cost of conversion to burning low-sulphur fuel is between € 10,000 and 150,000, depending on the size and type of the ship (Antturi et al., 2016). However, the operating costs are considerably higher in the medium and long term because LSMGO is more expensive than HFO or ULSFO (Panasiuk & Turkina, 2015; Bergqvist et al., 2015; Gu & Wallace, 2017). Currently, MGO is approximately 40 % more expensive than HFO (Bunkerworld).

If a ship operates both inside and outside SECA, the ship operator may choose a hybrid solution, which allows switching between HFO and MGO (Gu & Wallace, 2017). Ships burn MGO within SECA and traditional HFO outside (Fagerholt et al., 2015). Fuel switching allows the introduction of speed differentiation leading to lower speed within SECA to consume less MGO and higher speed outside to maintain travel time (Gu et al., 2018). Furthermore, a ship might apply a SECA-evasion strategy. SECA-evasion means that a ship does not take the shortest route between two ports situated within SECA but instead leaves the SECA zone and takes a longer sailing route with less in-SECA sailing (Gu et al., 2018). Thus, the ship would reduce the consumption of expensive MGO.

Alternatively, ships can use cleaner energy sources. LNG is one of the best available options in terms of environmental performance (Bergqvist & Cullinane, 2013). It has no SOx and NOx and a lower carbon footprint than HFO and MGO, although the latter is moderated by methane slip, the fugitive emissions from using LNG for vessel operations and bunkering. By using LNG, a ship operator can avoid the consumption of expensive MGO (Gu & Wallace, 2017). However, LNG involves high up-front investments so that the ship can store and burn this fuel. In addition, one needs to make sure that there are sufficient refuelling facilities at the ports the vessel calls (Fagerholt et al., 2015). At the moment, only a few ports provide LNG as a maritime fuel (Brynolf et al., 2014). Furthermore, LNG tanks require more space than conventional fuel tanks, a fact that reduces load capacity and makes such an adjustment impossible or uneconomical for many existing vessels (Bergqvist et al., 2015). There is also a high uncertainty on the price differential between LNG and conventional maritime fuels. Only if HFO was to become more expensive than today, could LNG become a more feasible option (Acciaro, 2014). To conclude, it is possible to convert existing vessels to use LNG but conversion is very costly (around 12 to 16 million EUR) (Bergqvist et al., 2015). Hence, LNG is mainly used for new-built vessels.

Another alternative is to continue using HFO and install an exhaust gas cleaning system, a so-called scrubber that removes sulphur from exhaust gas. Scrubbers can be installed on new builds or older vessels can be retrofitted. There are two types of scrubbers: wet and dry. Wet scrubbers are considered more acceptable for ships due to their lower price and smaller size (Panasiuk & Turkina, 2015). Wet scrubber technology includes three types of exhaust gas cleaning systems: open loop, using only seawater; closed loop, using fresh water mixed with caustic soda; and hybrid (Abadie et al., 2017). In the Baltic Sea Region, a closed loop system must be used (Panasiuk & Turkina, 2015). Dry scrubbers use chemicals instead of water in the purification process (Bergqvist et al., 2015).

While scrubbers enable ships to continue using cheap high-sulphur fuel, the installation cost is significant. The cost of scrubbers starts at approximately 1.5 million EUR (Antturi et al., 2016; Lindstad et al., 2017). It is estimated that the payback time for the installation of a scrubber is 2-5 years compared to switching to LSMGO (Bergqvist et al., 2015). Hence, it is not feasible to install a scrubber to vessels at the end of their lifespan (Jiang et al., 2014). Furthermore, the vessel needs to stay in layup during retrofitting, which means loss of income (Bergqvist et al., 2015; Zis & Psaraftis, 2017). The market for scrubbers is still very dynamic and it is expected that the costs of scrubbers will decrease over time as the technology matures (Acciaro, 2014). Another downside of scrubbers is that the income of the ship operator will be reduced due to lower cargo capacity (Panasiuk & Turkina, 2015).

In addition to these three options, biofuels and methanol are emerging as ship fuels (Lähteenmäki-Uutela et al., 2017). Biodiesel is renewable and can be produced from various feedstocks, such as vegetable oils, recycled waste vegetable oils and animal fats (Lin, 2013). However, biofuels are not currently considered a serious alternative due to limited supply capacity (Holmgren et al., 2014). The technology related to using methanol as a fuel is still in development stage, meaning uncertain outcome, fuel prices and availability (Bergqvist et al., 2015). The energy requirements of a ship could also be covered at berth by supplying electrical energy from land-based grid (so-called cold ironing) (Sciberras et al., 2015). This means that the ship can shut down engines when calling at a SECA port.

3.3 Implications on seaborne trade

The consequences of the stricter regulations on the sulphur content of marine fuels are still much debated among the academic community. Some of the previous studies expected a rise in costs and, thus, a modal backshift from maritime transport to land-based transportation, especially in shortsea shipping (e.g. Notteboom, 2011; Odgaard et al., 2013; Fagerholt et al., 2015). Furthermore, certain routes may become less viable economically due to increasing operating costs and loss of market share and, as a result, some ship operators may have to shut down certain services, which leads to even higher modal shifts (Zis & Psaraftis, 2017). Nevertheless, Holmgren et al. (2014) and Zis and Psaraftis (2017) conclude that such a backshift from sea to road is unlikely to happen unless fuel prices increase. Fagerholt et al. (2015) posit that environmental regulations affect routing of ships to avoid or to reduce sailing in SECAs. Sys et al. (2016) suggest that SECAs could also provoke potential port shifts if certain zones with more severe emissions caps become less attractive for maritime transport. Another possible side effect is that ship operators may reduce their speed in SECA to save on low-sulphur fuel and to speed up in non-regulated areas to compensate for the loss of time (Doudnikoff & Lacoste, 2014).

The geographical distribution of costs and benefits of environmental regulations has also attracted a lot of discussion. Geographically isolated countries at the end of the Baltic Sea have claimed to be the net payers. Antturi et al. (2016) studied the costs of benefits of the SECA regulation and concluded that net benefits were negative and that the countries located far from Central European markets bear most of the costs while the countries with high population and closer to the main shipping routes and markets are the main beneficiaries. Antturi et al. (2016) concluded that Sweden and Finland would bear the largest proportion of costs. In Finland, the share of fast ships, such as Ro-Ro ships using a lot of fuel is large, and they suffer economically more than slower ships (Kalli et al., 2015). Repka et al. (2017) estimate that the impact of sulphur regulations will be around 175 million EUR for Finnish seaborne trade in 2013-2025. It is worth noting that the costs of compliance with SECA will ultimately affect peripheral northern industries, such as paper, forest or metal industries (Kalli et al., 2015; Lähteenmäki-Uutela et al., 2017). While the contemporary SECA areas have only limited geographical coverage, a global sulphur cap to 0.5% is due to enter in force by 2020 (IMO, 2018b).

4 Selection of Ro-Ro connections

4.1 Available connections along the corridor

The Baltic Sea provides improved accessibility to the 85 million people living in its vicinity within a large territory that houses world-renowned industries, features a competitive economic and scientific capacity, but also embraces comparably small urban regions depending strongly on foreign trade in goods and services (EC, 2015). The Baltic Sea is, thus, vital for a well-functioning transport system that contributes to the prosperity and economic growth of the region.

It is not surprising that the Baltic is one of the most trafficked seaways in the world. A map of merely the Ro-Ro connections of the region looks as stuffy as in Figure 3. In Table 1, we have identified the existing services that include at least one direct connection between two Baltic ports. There are 77 such services operated by 30 companies. The majority of them (51 in total) deploy Ro-Pax vessels that carry both vehicles and passengers. Pure Ro-Ro ships that carry exclusively trucks and trailers (and up to 12 truck drivers) operate another 22 services. The remaining 4 services concern car-carriers that serve the automotive industry and lie outside the scope of Scandria®2Act.

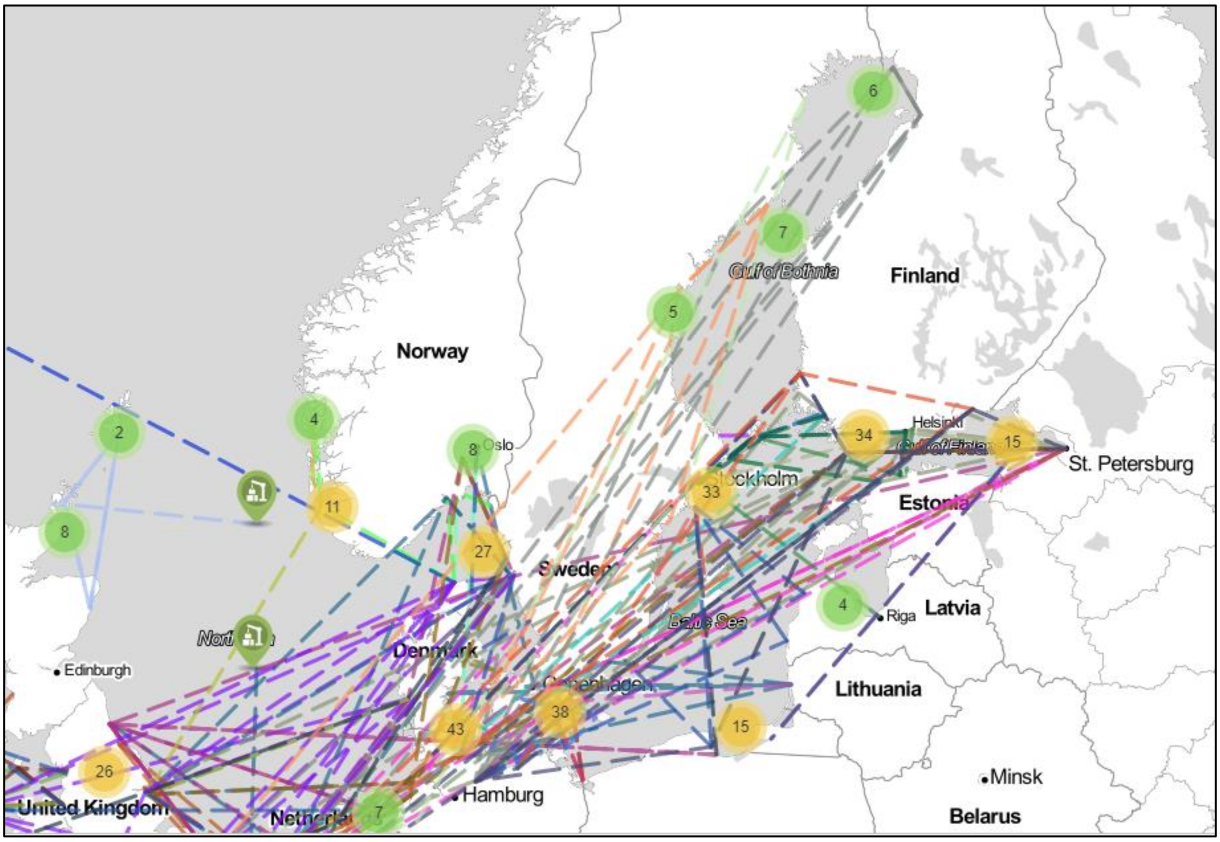


Figure 3. A Ro-Ro map for the Baltic Sea
(Source: ETM, 2018)

Table 1. Ro-Ro services along the Scandria® corridor

No.	Operator	Service	Ro-Ro	Ro-Pax	Car-carrier
1	AnRussTrans	Ust-Luga-Baltiysk	√		
2	Black Sea Ferry	Ust-Luga-Baltiysk	√		
3	Bornholmslinjen	Køge-Rønne		√	
4		Ystad-Rønne		√	
5		Mukran-Rønne		√	
6	Color Line	Kiel-Oslo		√	
7	Destination Gotland	Nynäshamn-Visby		√	
8		Oskarshamn-Visby		√	
9	DFDS Seaways	Klaipėda-Fredericia	√		
10		Klaipėda-Kiel		√	
11		Klaipėda-Karlshamn		√	
12		Paldiski-Kapellskär		√	
13		Copenhagen-Oslo		√	
14		Paldiski-Hanko		√	
15	Eckerö Linjen	Helsinki-Tallinn		√	
16		Grisslehamn-Eckerö		√	
17	Euro Marine Logistics (EML)	Baltic Trade (Newcastle-Zeebrugge-Gothenburg-St. Petersburg-Hanko-Emden)			√
18	Færgen	Spodsbjerg-Taars		√	
19		Bøjden-Fynshav		√	
20	Finnlines	HansaLink (Helsinki-Lübeck)		√	
21		Nordö-Link (Malmö-Lübeck)		√	
22		FinnLink (Naantali-Långnäs-Kapellskär)		√	
23		Hanko-Gdynia	√		
24		TransRussiaExpress (HaminaKotka-Lübeck-Bronka)	√		
25		Uusikaupunki-Turku-Lübeck	√		
26		Aarhus-Helsinki	√		
27	Gotlandsbåten	Nynäshamn-Visby-Västervik		√	
28	HH Ferries Group	Scandlines Helsingør-Helsingborg		√	
29	KESS	Baltic Sea Express (Zeebrugge-Malmö-St. Petersburg)			√
30		Baltic Sea Express II (Malmö-St. Petersburg-Cuxhaven-Halland-Zeebrugge)			√
31	Lillgaard	Naantali-Långnäs	√		
32	Mann Lines	Service 1 (Turku-Bremerhaven-Harwich-Cuxhaven-Paldiski)	√		
33	Moby SPL	St. Petersburg-Helsinki		√	
34		St. Petersburg-Stockholm		√	
35	Mols-Linien	Odden-Aarhus		√	
36		Odden-Ebeltoft		√	
37	Polferries	Świnoujście-Ystad		√	
38		Gdańsk-Nynäshamn		√	

(Continued on next page)

Table 1. Ro-Ro services along the Scandria® corridor (continued)

No.	Operator	Service	Ro-Ro	Ro-Pax	Car-carrier
39	SCA Logistics	Germany service (Umeå-Sundsvall-Iggesund-Kiel-Malmö)	√		
40		Nord Sea Service (Umeå-Sundsvall-Sheerness-Rotterdam-Helsingborg-Oxelösund)	√		
41	Scandlines	Puttgarden-Rødby		√	
42		Rostock-Gedser		√	
43	SOL Continent Line	North Sea Route 1 (Oulu-Kemi-Husum-Lübeck-Gothenburg-Zeebrugge-Tilbury)	√		
44		Lübeck Route (Oulu-Kemi-Lübeck)	√		
45	Stena Line	Liepāja-Nynäshamn		√	
46		Gothenburg-Kiel		√	
47		Gothenburg-Frederikshavn		√	
48		Varberg-Grenaa		√	
49		Karlskrona-Gdynia		√	
50		Rostock-Trelleborg		√	
51		Mukran Port-Trelleborg		√	
52		Lübeck-Liepāja		√	
53		Lübeck-Ventspils		√	
54	Tallink/Silja	Stockholm-Turku	√		
55		Paldiski-Kapellskär	√		
56		Stockholm-Helsinki		√	
57		Stockholm-Tallinn		√	
58		Stockholm-Riga		√	
59		Helsinki-Tallinn		√	
60		Helsinki-Tallinn Second Line (Maardu)	√		
61	Transfennica	Baltic Network (Hanko-Paldiski-Gdynia-Lübeck-Rostock-HaminaKotka)	√		
62		HaminaKotka-Lübeck	√		
63		Finland-Tilbury (HaminaKotka-Hanko-Tilbury-St. Petersburg)	√		
64	TT-Line	Rostock-Trelleborg		√	
65		Travemünde-Trelleborg		√	
66		Świnoujście-Trelleborg		√	
67	UECC	Baltic (Southampton-Zeebrugge-Bremerhaven-Malmö-Hanko-St. Petersburg)			√
68	Unity Line	Świnoujście-Ystad		√	
69		Świnoujście-Trelleborg		√	
70	Universal Logistic System	Sillamäe-Ust-Luga	√		
71	UPM	Rostock-Rauma	√		
72		Spain Service (Rauma-Kotka-Amsterdam-Ferrol-Santander)	√		
73	Viking Line	Helsinki-Mariehamn-Stockholm		√	
74		Turku-Mariehamn/Långnäs-Stockholm		√	
75		Stockholm-Mariehamn		√	
76		Mariehamn-Kapellskär		√	
77		Helsinki-Tallinn		√	

(Source: Own compilation based on ETM (2018))

4.2 The selection process

The following criteria were considered in selecting the connections to be analysed in Activity 3.2-2:

- **Port-to-port distance:** The length of the maritime leg of the connection examined is to a large extent proportional to the amount of fuel needed and the relevant cost. A wide range of distances would, thus, enable a sensitivity analysis in relation to this parameter.
- **Traffic volumes:** The volume of freight moved along a specific service determines not only the significance of this connection in the overall BSR trade but also the stability of the service with respect to exogenous influences.
- **Types of vessels used:** Passenger and freight tariffs exhibit different elasticities to fuel price. Furthermore, the existence of a scrubber on board determines the quality and cost of fuel consumed. As such, the analysis should involve both Ro-Ro and Ro-Pax vessels with and without scrubbers.
- **Needs of other project activities:** Given that the project partners in GoA 3.3 are also among the targeted recipients of this report, the potential application of the output in other project activities adds value to the output produced.
- **Availability of data:** This is probably the most decisive criterion in the selection process, as the analysis depends on access to information, which can be sensitive in nature.

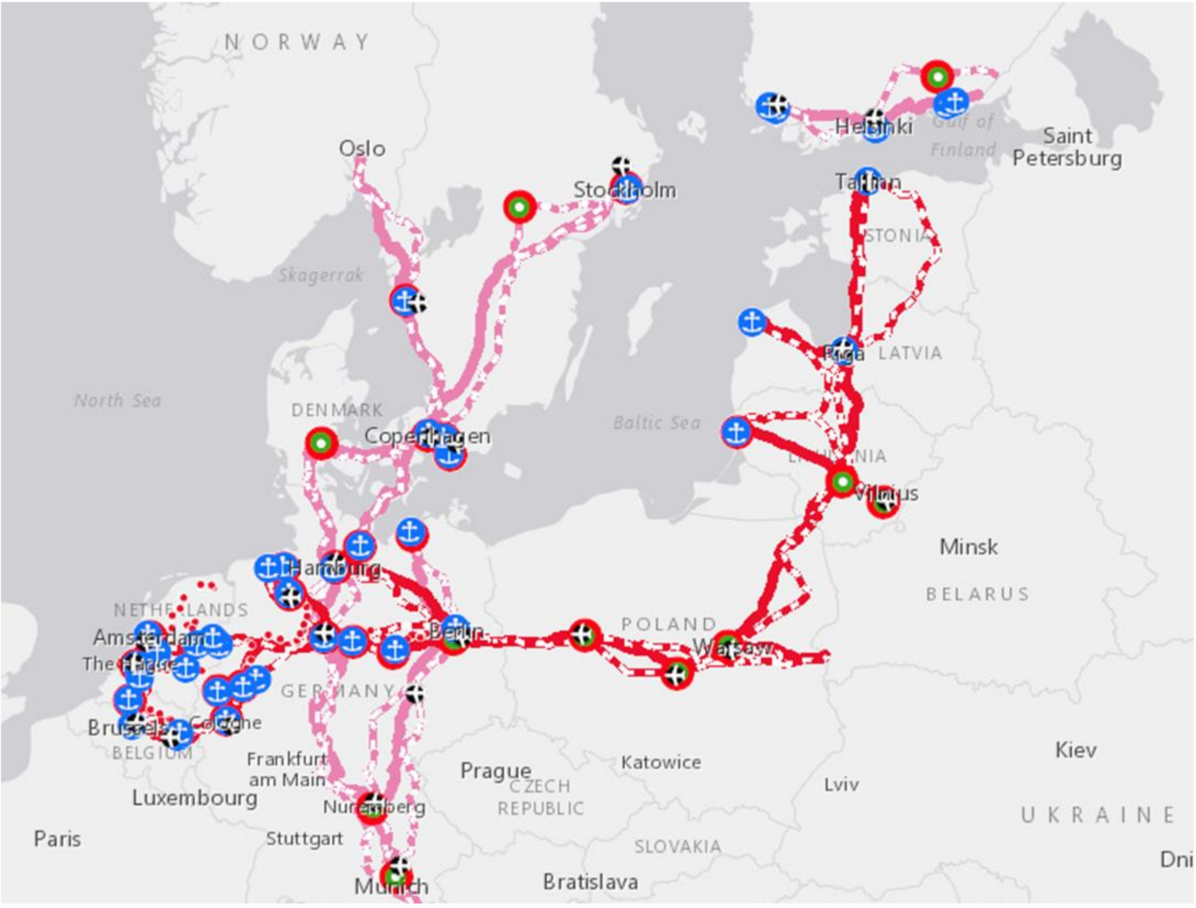


Figure 4. The alignment of the ScanMed and NSB core network corridors
(Source: http://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/map/maps.html)

In view of the subsequent formal cooperation agreement of Scandria®2Act with the Interreg projects TENTacle and NSB CoRe, it was decided to expand the criterion on project needs to cover relevant needs of all three projects. The relation of these projects to the TEN-T core network corridors is what brings them together. As shown in Figure 4, the ScanMed and NSB CNCs that surround the Baltic Sea meet in Finland and Germany. By examining the Finland-Germany connections, then, the activity could serve the needs not only of the Scandria®2Act stakeholders but also those of the NSB CoRe and eventually TENTacle, as the latter one is an umbrella project covering the entire BSR.

Lahti (FI) and Berlin (DE) were selected as the specific origin and destination points of the routes to be examined due to the fact that the sister projects have partners and associated organisations in these two areas that might prove helpful in providing the necessary information. Figure 5 presents the alternative routes that a truck/trailer originating in Lahti can take to reach Berlin, including the corresponding maritime connections. No railway alternatives are considered here as the Ro-Ro cargoes are non-crane-able in their vast majority and there is very little, if any, penetration of rail transport in this trade.

The proposed set of connections cover the entire Scandria® and NSB corridors, provide a wide distance range (from 48 miles of Helsinki-Tallinn to 611 miles of Helsinki-Travemünde), carry all road exports of Finland to Europe, involve Ro-Pax in addition to Ro-Ro vessels (in all but Option 3 connections), while almost half of the ships deployed are equipped with scrubbers. The additional advantage of this set of connections that will be examined at the micro-level (Section 6), is that they are compatible with the Finland-Germany connection of the macro-level analysis (Section 5), thus constituting a perfect testbed for applying both methodologies.

Option 1:

Lahti – Turku (road)
Turku – Stockholm (maritime)
Stockholm – Trelleborg (road)
Trelleborg – Rostock* (maritime)
Rostock* – Berlin (road)

(*) In this context, Rostock denotes either Rostock or Travemünde.

Option 2:

Lahti – Helsinki (road)
Helsinki – Rostock* (maritime)
Rostock* – Berlin (road)

(*) In this context, Rostock denotes either Rostock or Travemünde.

Figure 5. The Ro-Ro connections examined by the project
(Continued on next page)

Option 3:

Lahti – Hanko (road)
Hanko – Rostock* (maritime)
Rostock* – Berlin (road)

(*) In this context, Rostock denotes either Rostock or Lübeck.

Option 4:

Lahti – Helsinki (road)
Helsinki – Gdynia (maritime)
Gdynia – Berlin (road)

Option 5:

Lahti – Helsinki (road)
Helsinki – Tallinn (maritime)
Tallinn – Berlin (road)

Figure 5. The Ro-Ro connections examined by the project
(Source: Own compilation using the EcoTransIT World application)

5 The macro-level perspective

The first of the two analytical approaches used in the task looks at the problem from the macro-level perspective. The analysis stays at the country level and is based on aggregate annual statistics of the ports serving the Finland-Germany Ro-Ro connections. The results are presented and discussed after a brief note on the recent trends in the key parameters that enter the analysis, and on the methodology deployed.

5.1 Development of key economic indicators

5.1.1 Economic development

Figure 6 presents the development of GDP of the European Union and selected countries in the BSR between 2002 and 2018. In a longer perspective, the economic development has been positive for the entire area, with the GDP of the new EU member states growing faster than the economies of the old member states. The financial crisis of 2008 and the subsequent crisis in the real economy affected some member states more than others. Especially the Estonian and Finnish economies suffered major setbacks. After the crisis, most of the economies rebounded and returned to their previous growth path, with the GDP reaching and exceeding the pre-crisis level rather quickly.

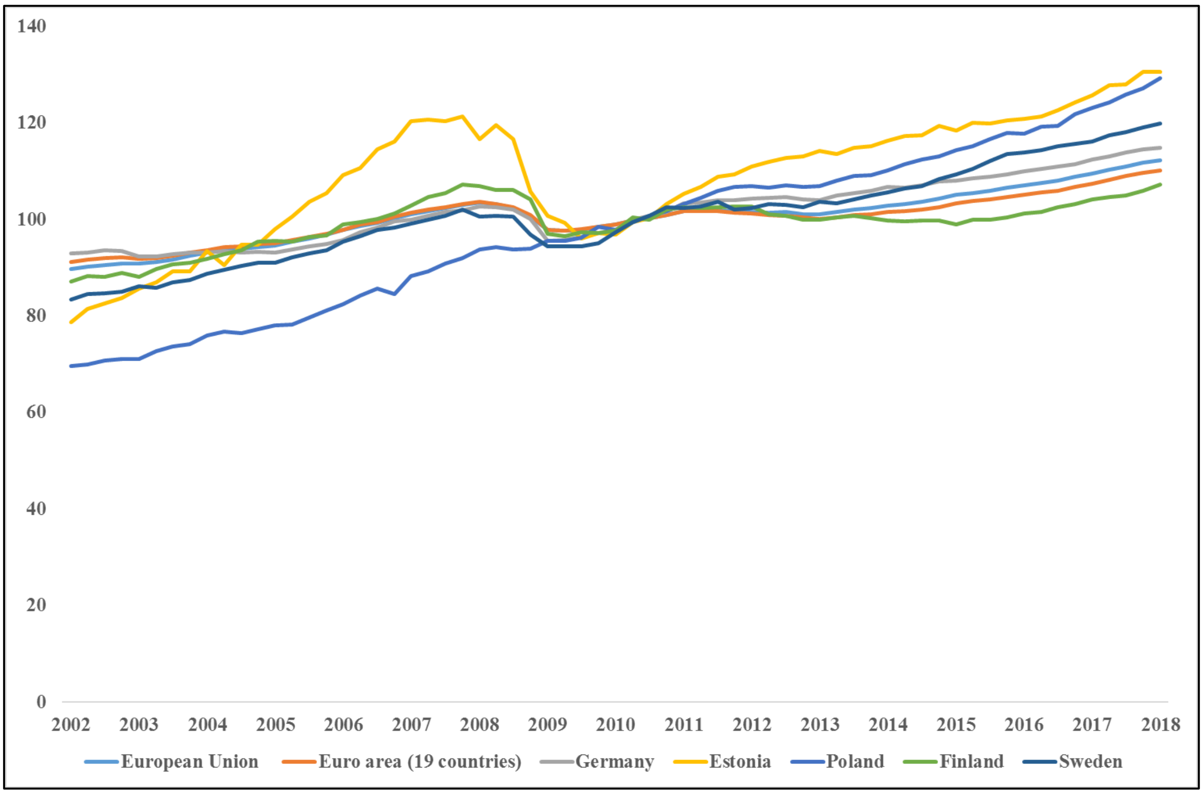


Figure 6. GDP development in the EU and selected countries in the BSR (2010=100) (Source: Eurostat, 2018a)

This was not true for the Finnish economy, however. The Finnish GDP, suffering from structural change and the dominant role of a single industrial sector, the telecommunications industry, continued to decline as long as until 2015, after which the economy started to grow again. The Finnish GDP did not reach its pre-crisis levels until 2018.

5.1.2 Volumes of production and international trade

A similar trend can be observed in the development of world merchandise trade. Figure 7 presents the development of world trade in US$ between 2007 and 2016.

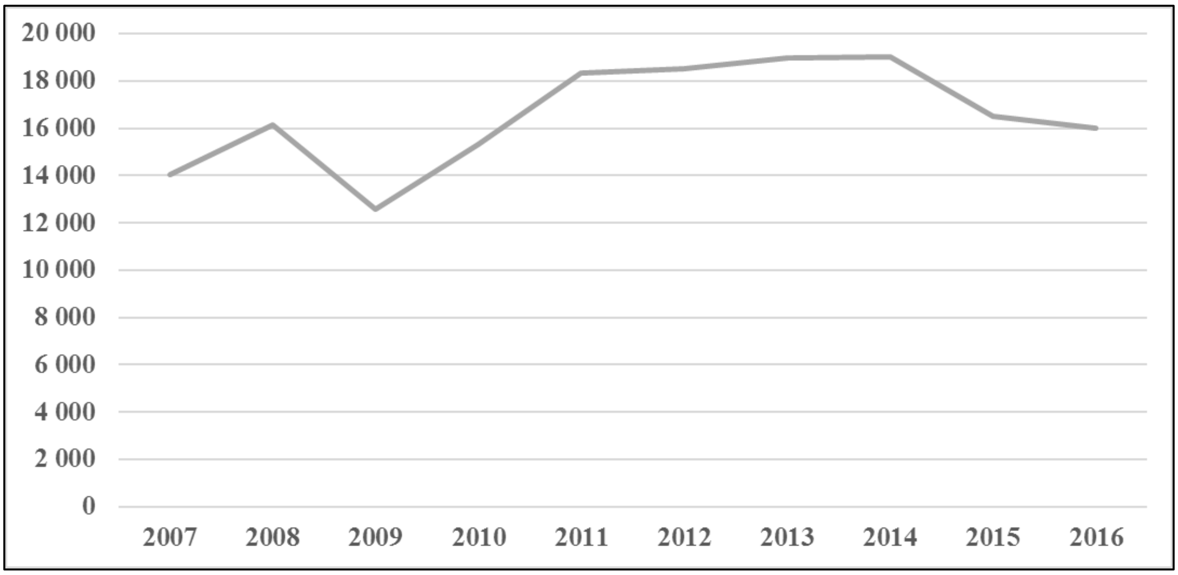


Figure 7. World merchandise trade (billion US$) 2007-2016 (Source: WTO, 2018)

Before the financial crisis, the world trade reached its peak in 2008 with around 16 000 billion US$, after which it diminished by over 20% to around 12 500 billion US$ in 2009. Since then, the world trade exceeded 19 000 billion in 2013 and 2014, before declining once again to close to 16 000 billion in 2016.

As a relatively large share of GDP consists of services and public expenditure, less sensitive to fluctuations in economic development, the development of industrial production can be considered a better indicator, especially considering the impact to transportation. Figure 8 illustrates the development of industrial production in the European Union and selected countries in the BSR.

Prior to the financial crisis of 2008, the development of industrial production had two clearly different patterns. Even though the entire European Union (and the Eurozone) were on a path of steady growth, it would seem that the new EU –countries such as Estonia and Poland were able to enjoy a faster growth of industrial production than countries such as Germany, Finland and Sweden. The scale of the effects of the financial crisis, however, was also different. The two extremes were Poland, whose industrial production had a minor setback (around 10%) after the financial crisis, and Estonia, whose industrial production declined well over 30% due to the crisis. Both of them recovered rapidly from the setback. The industrial production of Poland exceeded the pre-crisis levels already in 2010, and the same occurred for the Estonian industrial production in 2011. Since then, the industrial production has remained on the same growth path until today. Of the old EU-member states, Germany suffered the least from the crisis with an industrial production around 25% higher in 2018, compared to 2010.

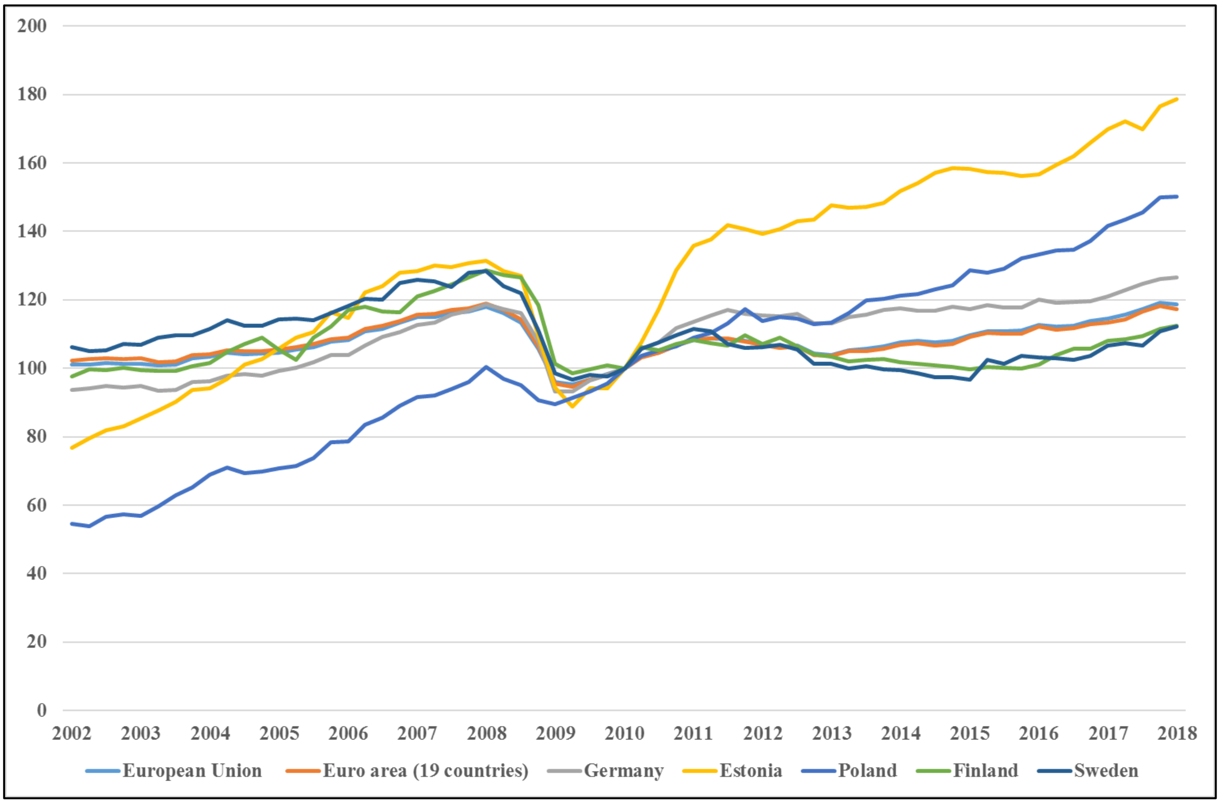


Figure 8. Industrial production (2015=100) in the EU and selected countries in the BSR (Source: Eurostat, 2018b)

5.1.3 Transport volumes and price of transport

The cost structure of maritime transport highlights the key role of fuel price in determining the competitiveness of shipping compared to other transport modes. Figure 9 illustrates the cost structures of sea transport and a major competitor, road transport.

In sea transport, the fuel costs are the single largest cost component. The share of fuel costs depends on the vessel type; the slower bulk vessels have relatively low fuel costs compared to the faster container and Ro-Ro vessels. In any case, the share of fuel costs is close, or even above 50 per cent of the costs in sea transport. This makes the competitiveness of sea transport more sensitive to changes in fuel price, than the land based options. The other consequence of the different cost structures is that the relative cost difference between the two modes is also affected by changes in fuel prices.

Figure 10 presents the price developments of IFO380 (HFO) and MGO/LSMGO marine fuels between 2010 and 2017. The price developments of the two fuel grades are almost identical, and the price spread of the two remained almost the same during most of the observation period.

Both prices reached their peak in 2012, when the price of IFO380 exceeded 700 US$ per ton, and the price of MGO was above 1 100 US$. Both prices started declining rapidly in 2014. Interestingly, this led to a situation where the price of low sulphur fuel in 2015 was close to the levels of IFO in 2014. This created a situation where, despite the relative price difference between the low sulphur and regular fuel, the absolute fuel cost level experienced by the shipping operators was not severely affected.

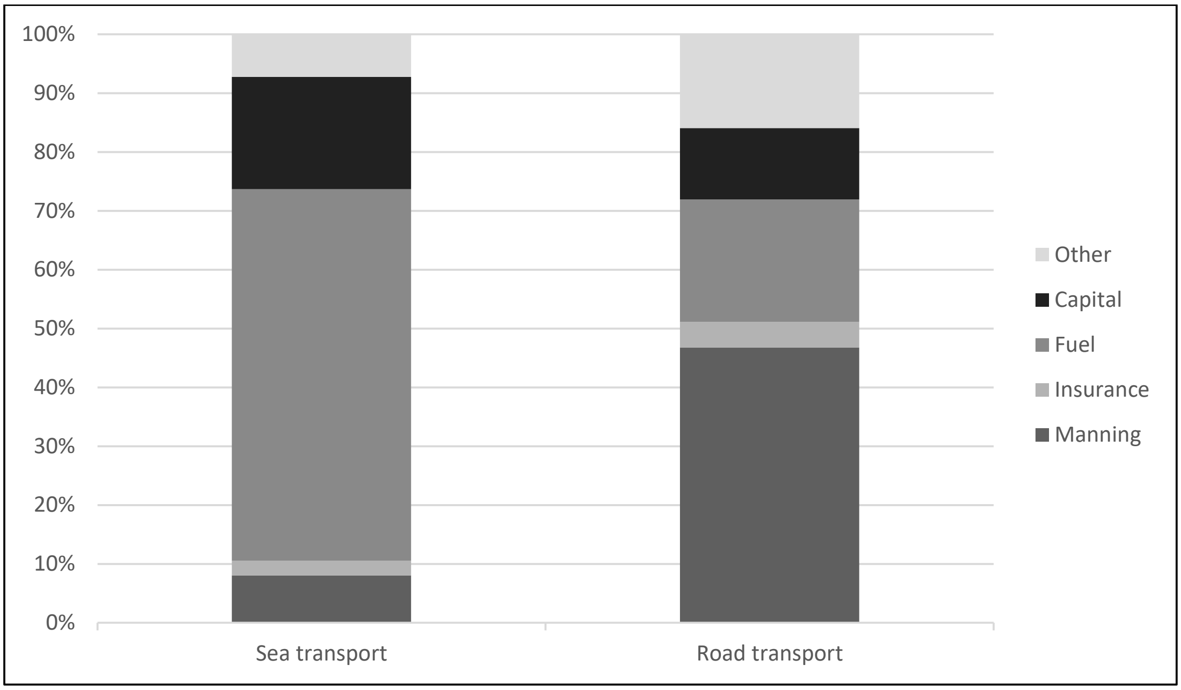


Figure 9. Cost structure in sea and road transport
(Source: Own compilation based on Statistics Finland (2017) and Solakivi et al. (2017))

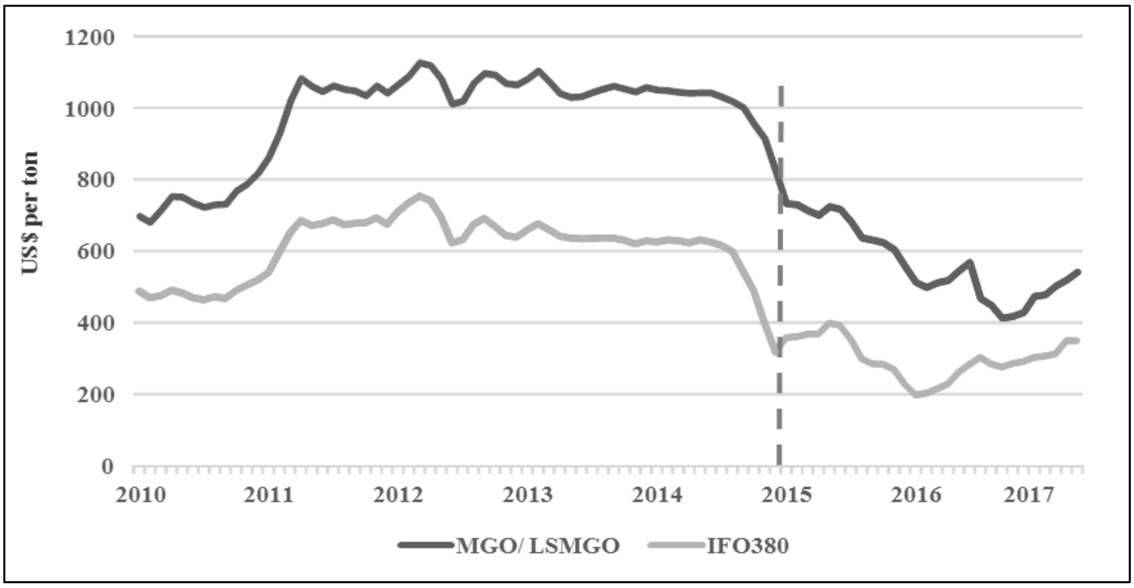


Figure 10. Price of IFO380 and MGO/LSMGO marine fuels between 2010 and 2017
(Source: Bunkerworld)

5.2 Methodology

In order to analyse the impact of the SECA regulation on selected transport volumes and the route choice, the macro-level approach investigates the trade flows between Finland and Germany. There are at least three options for these cargo flows (refer to Figure 11):

1. The direct sea route from the ports in the southern coast of Finland to Northern Germany and Poland.
2. The sea-land connection combining a sea leg from Helsinki to Tallinn and a land transit through the Baltic States
3. The sea-land connection combining a sea leg from Turku and Naantali to Sweden, and a land transit through Sweden and Denmark

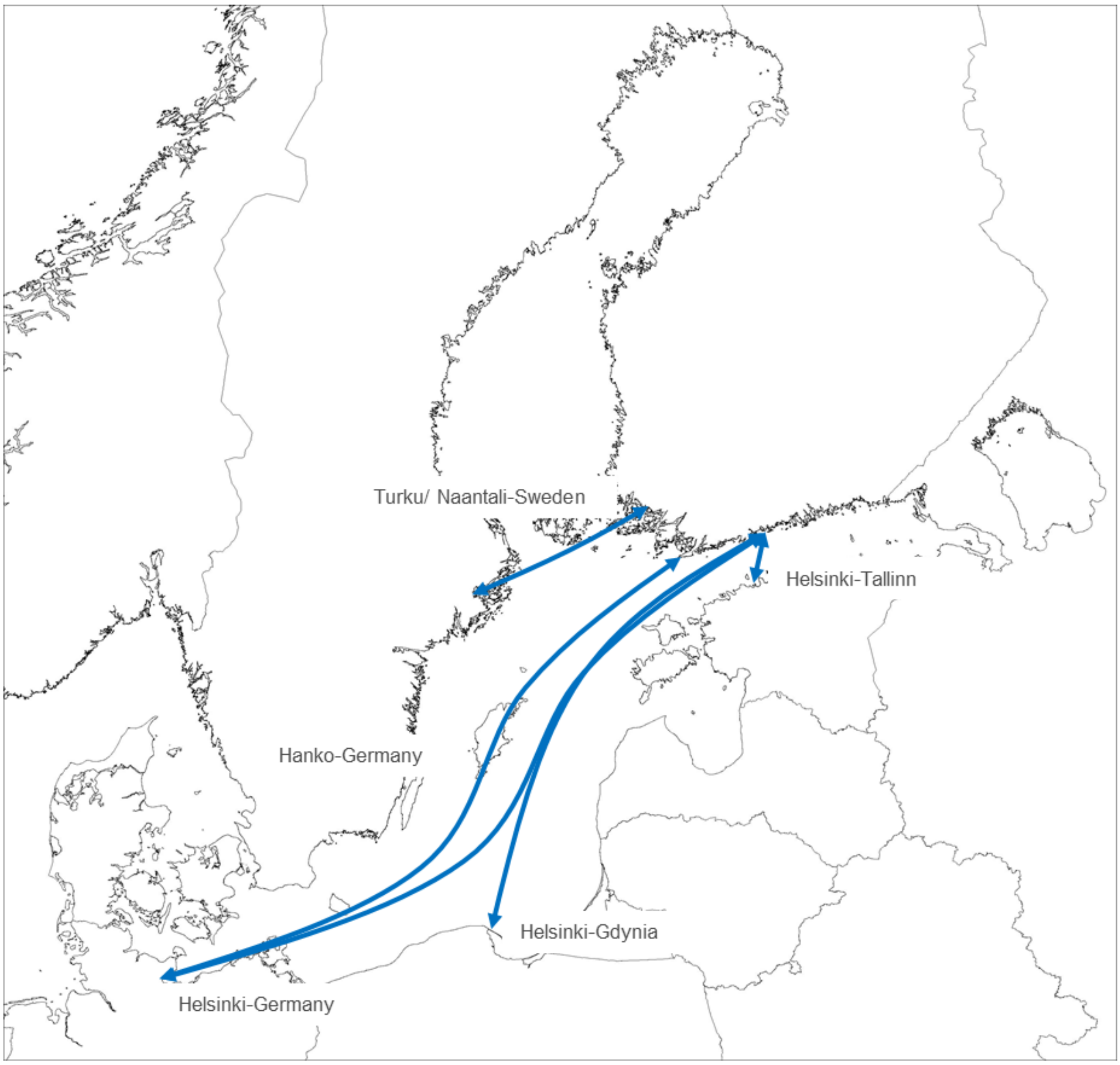


Figure 11. The connections included in the macro-level analysis (Source: Own compilation)

The analysis uses both descriptive statistics and multiple regression analysis. The cargo volumes of the sea transport legs are described in order to identify, whether the SECA regulation (introduced on 1.1.2015) had any observable effect on the cargo flows. The cargo flows that were chosen to be analysed are the Ro-Ro related traffic flows (basically lorries and trailers), as they are considered the most likely ones to be affected. The cargo flows were obtained from the Marine Traffic Statistics of the Finnish Transport Agency.

In the multiple regression analysis, the cargo flows were explained by the fuel price to identify the effect of fuel price on the route choice. As it is most likely that the overall macroeconomic environment has a direct bearing on the cargo flows, the industrial production and GDP were used as control variables. To minimise randomness, the time series were seasonally adjusted. Furthermore, as the units of cargo volumes and fuel price are not reasonably comparable (resulting in an interpretation of units per dollar of increase/decrease) the analysis was conducted as a log-log model, which can be interpreted in terms of percentage changes.

5.3 The impact of SECA on transport volumes and route choice

5.3.1 Descriptive results

Figures 12 & 13 illustrate the development of monthly traffic volumes on selected Ro-Ro connections that serve the Finland-Germany trade during the period 2000-2016. In these figures, the term 'lorry' refers to all vehicles that include a tractor unit, whereas 'trailer' is limited to unaccompanied units that are transported without a tractor.

There are a few observations worth noting. In the long run, the lorry traffic on most of the routes has remained at a relatively stable level. The Helsinki-Germany lorry traffic increased significantly in 2007, after which it has gradually declined. On the Naantali-Kapellskär connection, the number of lorries transported declined over 2,000 units in 2009, after which it has been on a monthly level of around 4,000 units. On the other hand, the growth of lorry volumes on the Helsinki-Tallinn connection has been strong. In 2000, the monthly volume on the route was under 3,000 units, whereas in 2016, the volume exceeded 14,000 units per month.

The number of lorries on the Helsinki-Tallinn connection is remarkably high, considering the trade volume between Finland and Estonia. In practice, this means that a large share of the cargo using the connection is in fact transit traffic with a final origin or destination somewhere else.

The major trailer volumes seem to be concentrating on the Helsinki-Germany and Hanko-Germany connections. There has been a lot of variation especially on the Helsinki-Germany route, where both the export and import volumes have at highest been over 7,000 units per month in 2007 and 2008, whereas the current monthly volumes are around 5,000 units. The Helsinki-Hanko connection has had a rather stable volume between 2,000 and 3,000 units per month. Among the other connections, though, the trailer volumes on the Helsinki-Tallinn and Turku-Stockholm routes have been on decline.

In view of the above, it can be concluded that especially the lorry volumes have been increasing, whereas the trailer volumes have been much more stable.

From the perspective of the SECA regulation, no major observable changes in the trade volumes can be identified. This is true for the time the regulation came into force, as well as the periods before and after that. Therefore, as far as the descriptive statistics are concerned, it seems challenging to identify any major impacts of the SECA regulation on the transport volumes or route choices.

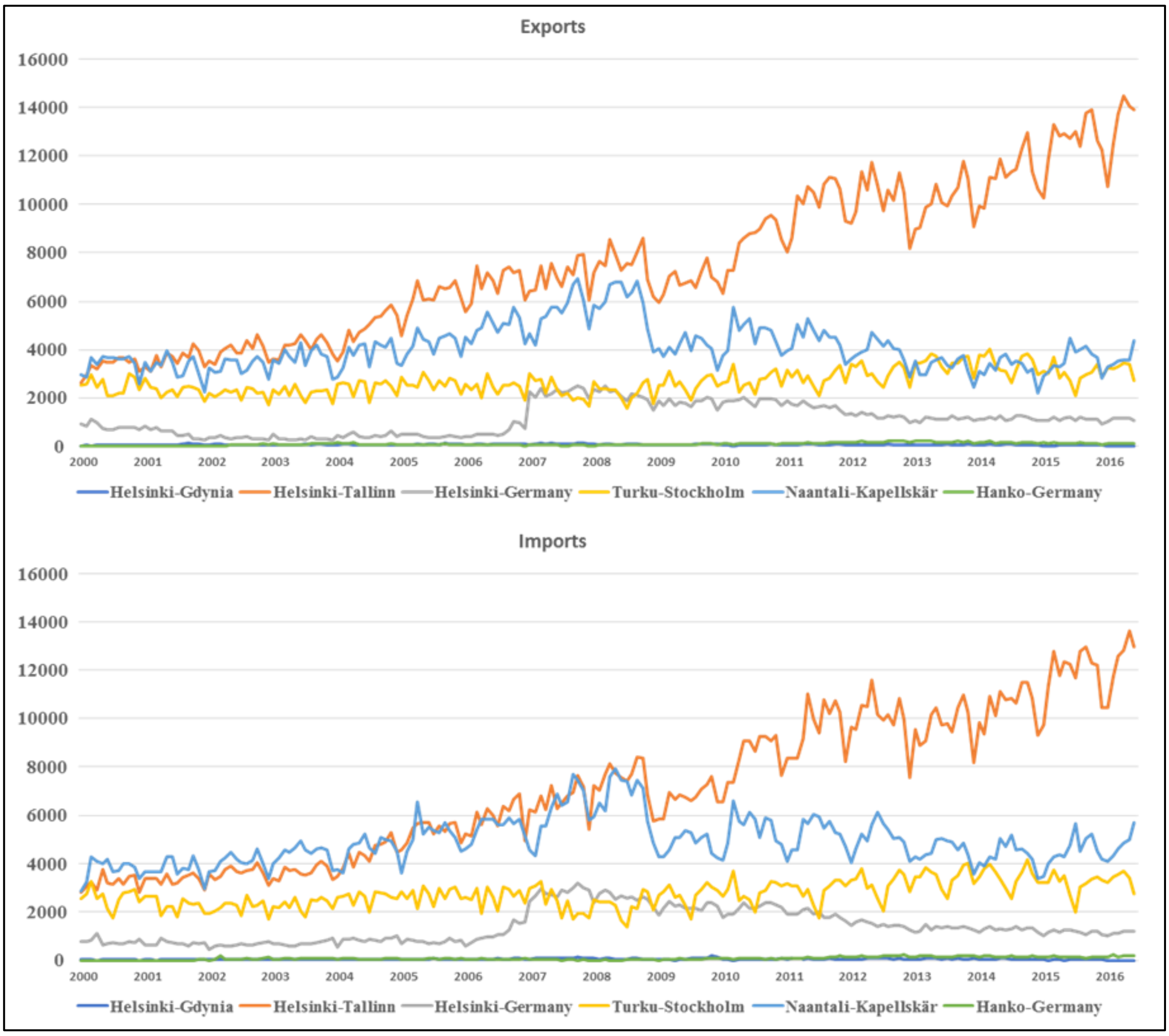


Figure 12. Monthly number of lorries transported along selected Ro-Ro connections between Finland and Central Europe 2000-2016 (Export= from Finland, Import= to Finland)
(Source: Finnish Transport Agency, 2017)

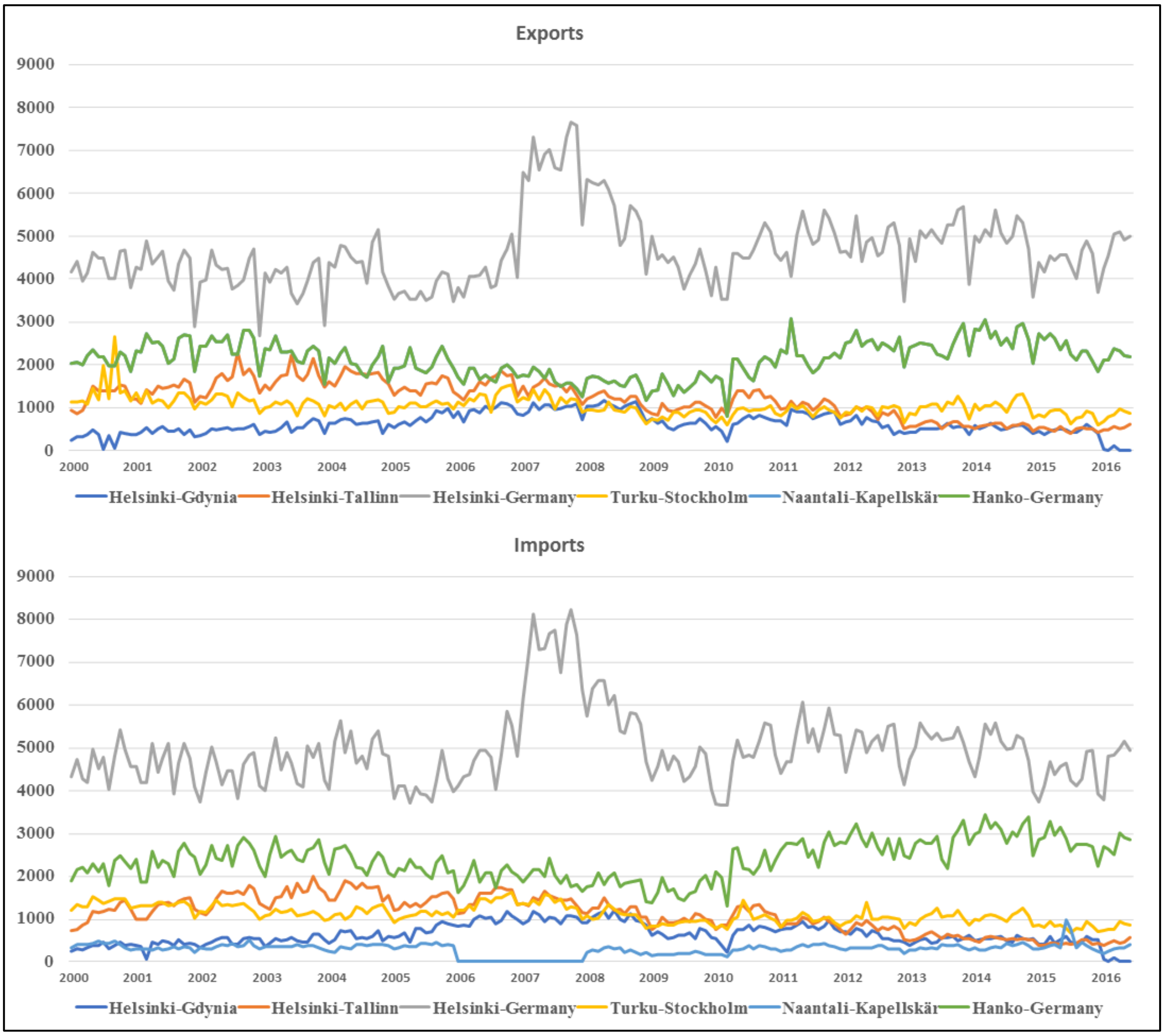


Figure 13. Monthly number of trailers transported along selected Ro-Ro connections between Finland and Central Europe 2000-2016 (Export= from Finland, Import= to Finland)
(Source: Finnish Transport Agency, 2017)

5.3.2 Model based results

To further analyse the impacts of SECA regulations, or from the wider perspective the impact of fuel price changes on the transport flows and route selection, the cargo flows were subjected to regression analysis, as described in Section 5.2. The results of the regression analysis are presented in Figure 14 as percentage changes per one percent increase of the fuel price.

Most of the cargo volumes were found to be statistically significantly connected to the fuel price. Only the Helsinki-Poland trailer and lorry volumes and the Turku/Naantali-Sweden lorry volumes were not statistically significant. At the same time, it would seem that most of the significant volumes are rather inelastic towards the price of the fuel, with none of the volumes exceeding the 1.0 value. Although the relationship between traffic volumes and fuel price is not simple and straightforward, the results show that an increase in fuel price penalises the volume of lorries on the long-distance Helsinki-Germany route in favour of the shorter Helsinki-Tallinn and Hanko-Germany options.

The Turku/Naantali-Sweden connection provides some interesting results. It would seem that the lorry traffic on that connection is not significantly affected by the changes in the fuel prices. The trailer traffic on the other hand is, with a coefficient of 0.8. In general, the different behaviour of the trailer (unaccompanied) traffic might relate to the pricing policies of the Ro-Ro operators in relation to this market segment.

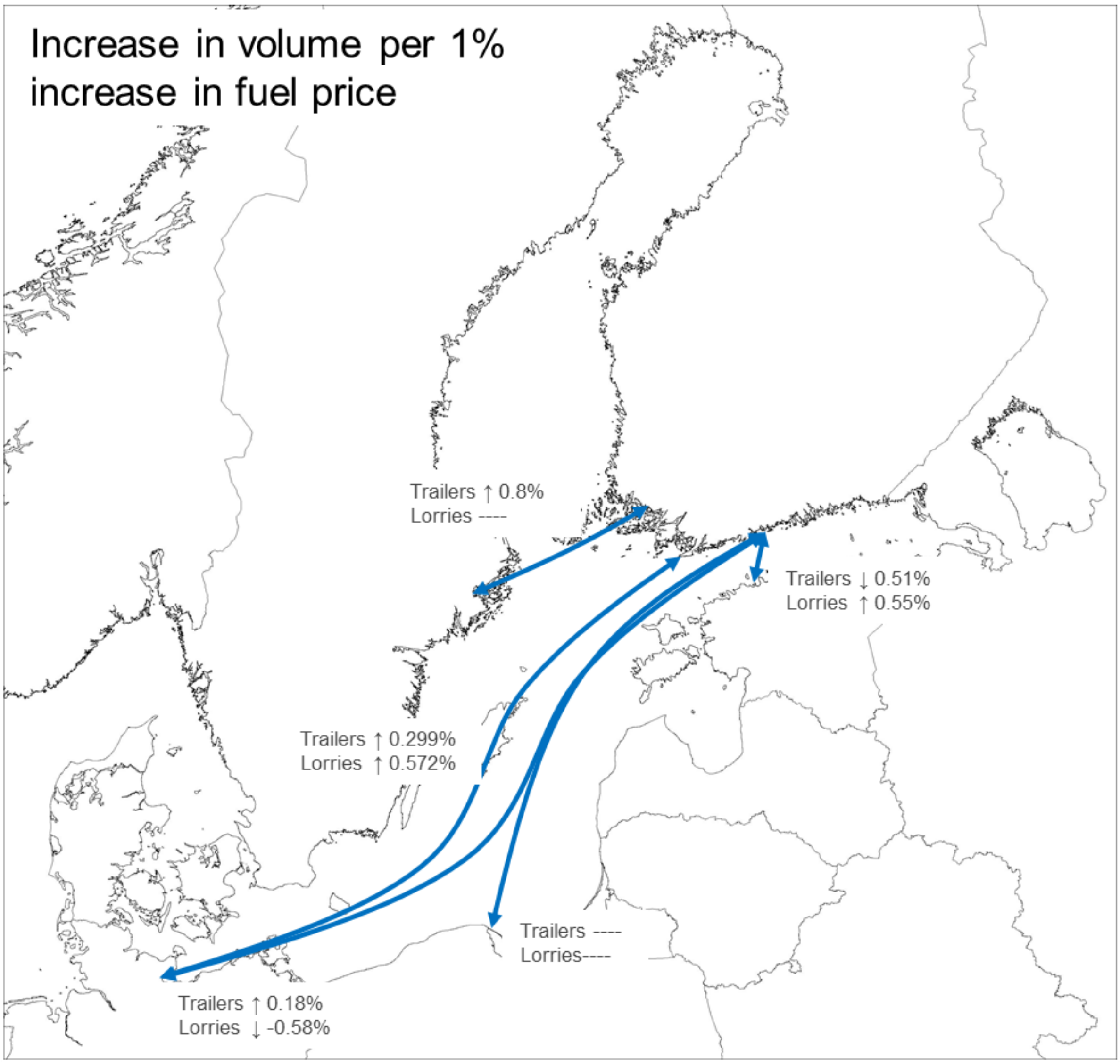


Figure 14. The increase (%) in trailer and lorry numbers on Finland-Central Europe connections per 1% increase of fuel price
(Source: Own compilation)

5.4 Discussion of findings

The purpose of this analysis was to estimate the impacts of the SECA regulation on the route selection of the Ro-Ro flows between Finland and Germany. It seems that there were no remarkable changes in the cargo flows during the months before and after the enforcement of the SECA regulation. One explanation relates to the price development of marine fuels. During that time, the prices of both crude oil and marine fuels were on decline. For the shipping companies, and consequently their customers, this meant that even though the low-sulphur fuel was, and still is, significantly more expensive than the higher sulphur fuel grades, the absolute fuel costs were not affected as much as expected. In practice, this meant that the competitiveness of sea transport against other transport options was not deteriorated as much.

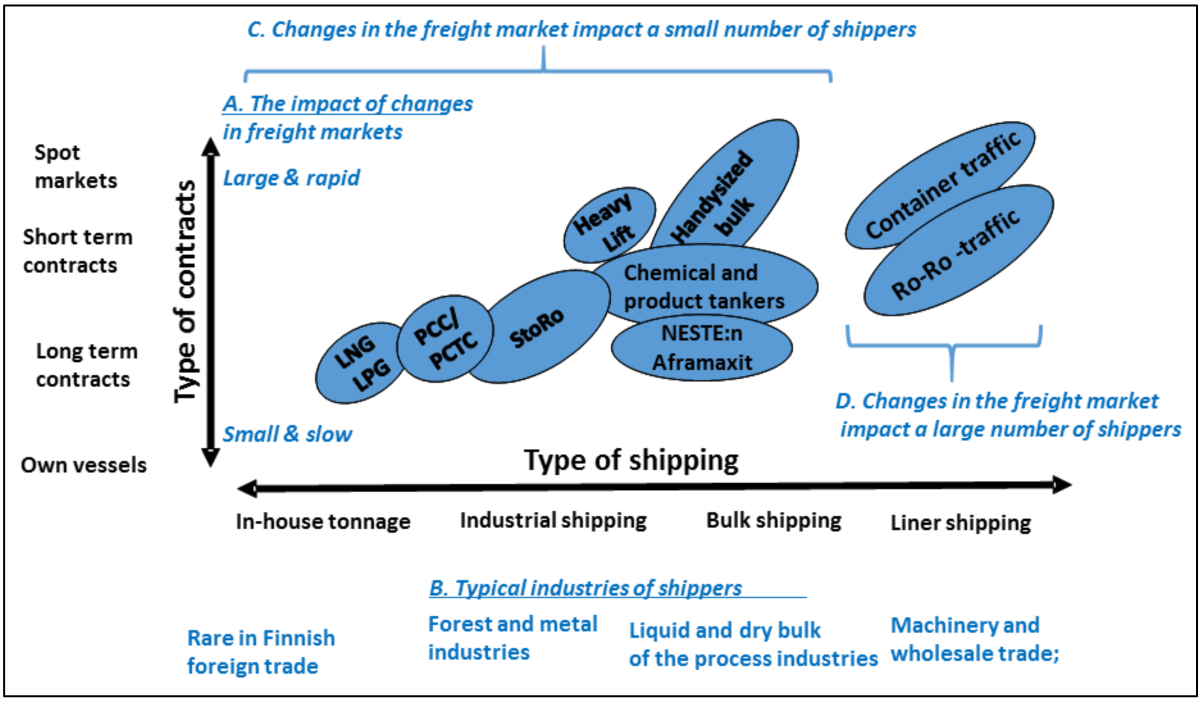


Figure 15. A simplification of the shipping market (Source: Ojala, 2017)

Another explanation for the absence of any major changes in the transport volumes relates to the market organisation of Ro-Ro traffic. Ojala has illustrated the market characteristics of the shipping market (Ojala, 2017). As shown in Figure 15, the Ro-Ro traffic is characterised as the liner shipping with the longer-term contracts. This is particularly so for the cargo flows to and from Finland due to the special characteristics of the country's industrial structure. The forest industry plays a dominant role in the Finland-Central Europe cargo flows and these flows are typically organised through long-term contracts. It follows that such arrangements reduce the sensitivity of cargo flows to changes in the freight market, especially in the short term.

The option that Ro-Ro operators have selected to comply with the SECA regulation might be yet another reason for minimal changes in transport volumes. According to Figure 16, almost half of the Ro-Ro vessels that visited Finnish ports between 2015 and 2017 (Finnish Customs, 2018) were equipped with exhaust scrubbers. Although the capital cost of a scrubber is significant, its equivalent annual outflow, calculated over its useful life, plus the relevant additional operating costs might still be advantageous in comparison to the higher price of low-sulphur fuel.

To validate the explanations mentioned above, a number of major shippers were interviewed. In fact, these interviews confirmed that many of the larger Finnish shippers enter into long-term agreements with Ro-Ro operators in order to secure stable freight prices for the shippers and stable freight flows for the shipping companies. These arrangements have played a major role in stabilising the cargo flows in their established routes.

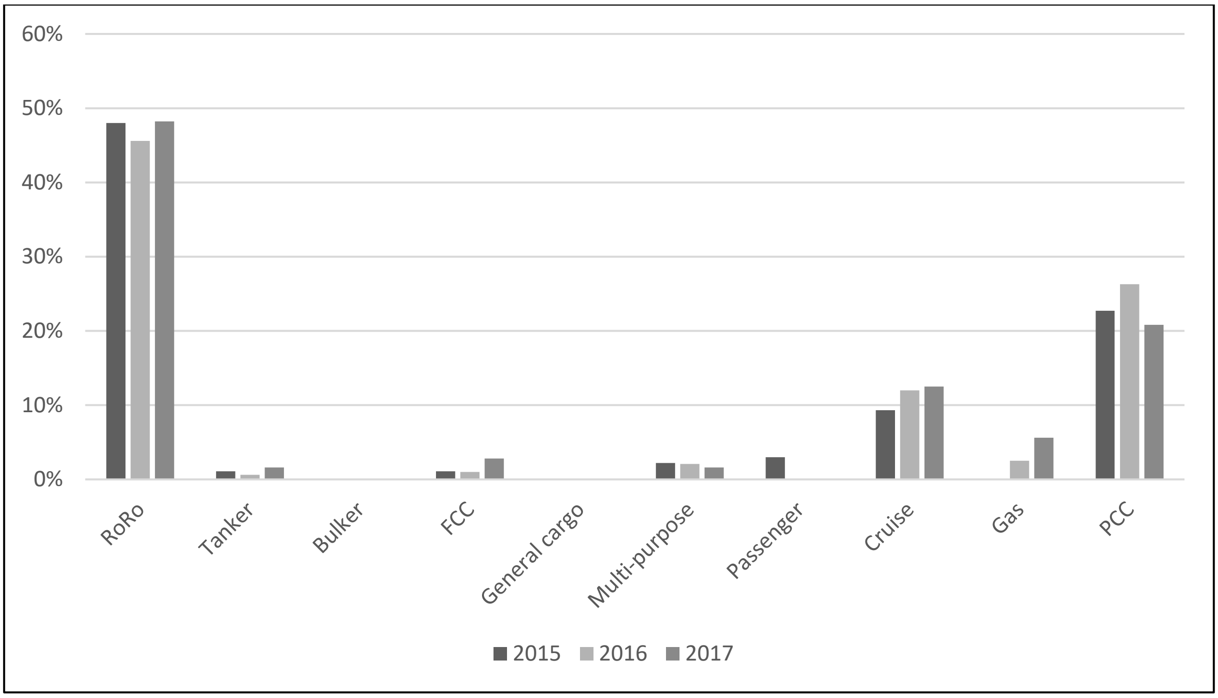


Figure 16. Share of vessels (%) equipped with a scrubber by vessel type
(Source: Kiiski et al. 2018 based on data from Clarkson Research Services Limited, 2018)

In addition to these long-term contracts, the interviews also revealed the fact that companies have considered and even rerouted some transports from sea- to land-based options. In parallel to the SECA regulation, there has been pressure from declining costs in the road haulage sector. Combined with the effects of the SECA regulation, this has made the land-based routes more attractive, especially when it comes to transport companies from the Baltic States due to their significantly lower personnel costs. The result was the rerouting of some traffic through the Baltic States. On the opposite, the route through Sweden was still considered as unattractive for cargo flows between Finland and Central Europe. Due to the costs of either the Øresund and Great Belt bridges or the Trelleborg-Rostock ferry connection, the route is considered too expensive in comparison to other options, and thus, meaningful only in cases of unavailability of other solutions. The limited capacity of the Swedish road network and restrictions in securing competent truck drivers were also mentioned as problems concerning this route.

6 The micro-level perspective

Unlike the country-level analysis described in Section 5, the micro-level approach of this section looks into the route selection problem from the perspective of a cargo owner/shipper. Thus, it is based on detailed information pertaining to a specific company. The section presents the modal split model that was used in the analysis and compares the results for a number of scenarios concerning fuel prices. It also examines the potential of various operational and policy related measures on mitigating the impact of the regulations.

6.1 The modal split model

In general, modal split models determine the number of trips on different modes given the travel demand between an origin-destination (O-D) pair. They try to describe mathematically the mode choice mechanism, based on the assumption that the probability of choosing a particular mode is the probability that the perceived utility from that mode is greater than the perceived utility from each of the other available modes.

There are various forms of modal split models but by far the most common one is the logit model, which has been found to fit the mode choice behaviour quite well. The binomial form of the logit model, where there are only two alternative modes of transport to choose from, is being used for this application. According to this formulation, if x_i is the fraction of the cargo that will choose mode i (i = 1, 2), the binomial logit model defines x_i as:

$$x_i = \frac{e^{-\lambda C_i}}{e^{-\lambda C_1} + e^{-\lambda C_2}} \qquad \text{(Eq. 1)}$$

where C_i is the generalised cost or disutility associated with mode i, and λ is a positive constant to be estimated at model calibration. C_i can be expressed as a function (usually linear) of a number of variables. Depending on the particular application, the following variables have been proposed in the literature as determinants of C_i:

- total monetary costs (freight rates and other direct or indirect costs);
- total transport time (in-vehicle, idling, border-crossing, etc.);
- frequency of service (number of services in a specific period)
- reliability (in terms of on-time delivery);
- flexibility (ability to adapt to changes in annual demand/volume, size of consignment and time table);
- resilience (ability to cope with serious disruptions);
- safety and security; and
- environmental performance (e.g. emissions of GHG and air pollutants).

The present application builds on the formulation applied by Zis and Psaraftis (2017) in the framework of the research project RoRoSECA (http://www.roroseca.transport.dtu.dk). This earlier formulation defines the generalised cost C_i on the basis of the first two of the variables listed above. The equation used is:

$$C_i = p_i + kt_i \qquad \text{(Eq. 2)}$$

where p_i stands for the total transport cost associated with mode i (€/lane-meter), t_i is the corresponding total transport time (days) and k is a positive constant (€/lane-meter/day). The coefficient k in the generalised cost function (Eq. 2) is known in literature as 'value of time.' It is usually expressed as:

$$k = CV\,r\,/\,365 \qquad \text{(Eq. 3)}$$

where:

CV = the unit cargo value (€/lane-meter), and

r = the annual opportunity cost of capital (%).

It is worth mentioning that in the binomial logit model of Eq. 1 the shares x_1 and x_2 are linked by the constraint:

$$x_1 + x_2 = 1 \quad \text{(Eq. 4)}$$

and that no restrictions on the available capacity exist, meaning $0 \leq x_i \leq 1$. In addition, since this task concerns Ro-Ro ships exclusively, as was the case with the RoRoSECA project, the ship capacity is measured in lane-meters (lm) and all economic variables (C_i, p_i, k) are expressed in terms of lm instead of the usual tonne denomination.

For the purposes of the present application, the frequency of service has entered the definition of generalised cost, which is given now by:

$$C_i = p_i + kt_i + k\,365/2f_i \quad \text{(Eq. 5)}$$

where f_i denotes the number of services offered per year. The underline assumption here is that both ship departure and cargo arrival follow a uniform distribution during the period examined.

A common way of depicting Eq.1 is a graph like that of Figure 17, which presents the share of Route 1 (x_1) as a function of differences in the generalised cost of Route 2 (C_2). In the example of Figure 17, if nothing changes in the cost of Route 2, the share of Route 1 will remain at the current level of 68%. However, x_1 is increased if Route 2 becomes more expensive and vice versa. The λ of Eq. 1 determines the slope of the curve at its intersection with the y-axis at the point of zero difference in C_2 (x-axis).

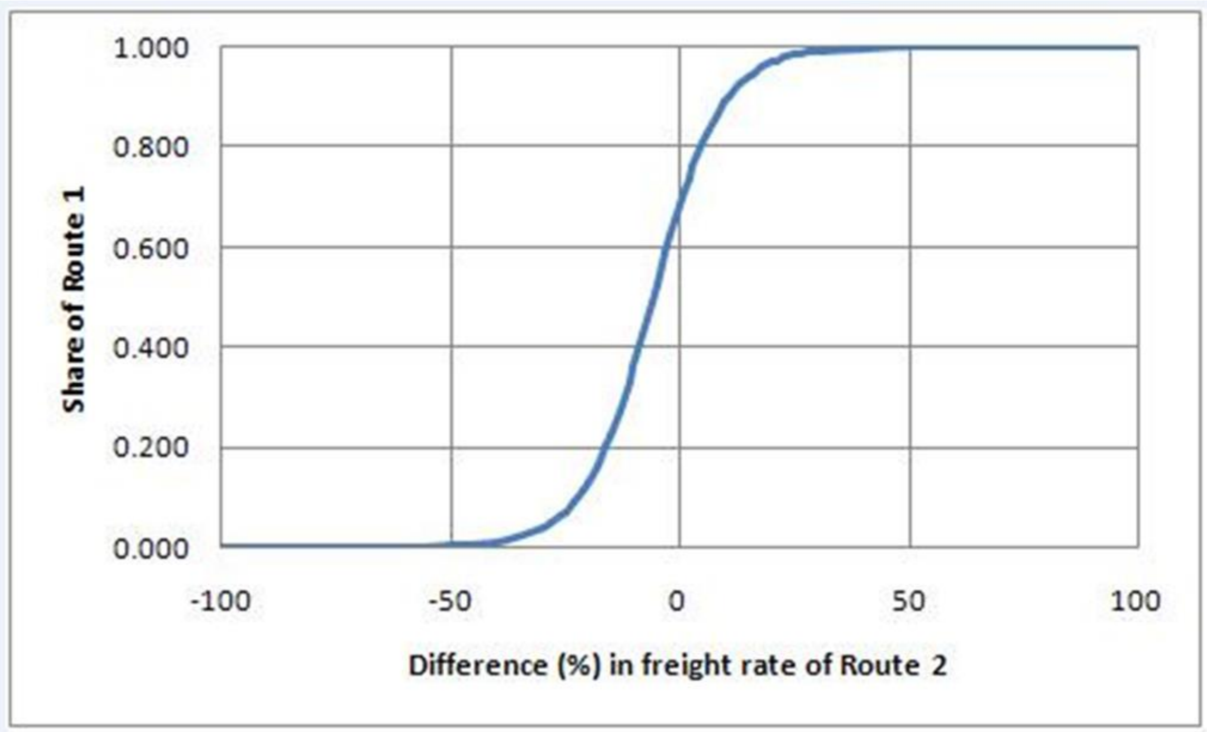


Figure 17. The graphical form of the binomial logit model
(Source: Own compilation)

In modelling the Lahti – Berlin trade, we were informed that under normal conditions no cargoes take the Lahti-Turku-Stockholm-Trelleborg-Rostock-Berlin route (Option 1 of Figure 5), as it is both longer and more expensive than the other alternatives. The remaining four options, then, were modelled through a so-called ‘nested binomial logit formulation’ (Figure 18). This formulation, also suggested by Zis and Psaraftis (2017) for some of the routes examined by the RoRoSECA project, models route selection as a hierarchical decision consisting of two stages. The first stage concerns the selection among alternative corridors, in this case among ScanMed (Option A) and NSB (Option B). At the second stage, a selection is made between the two alternative options that correspond to each of the corridors selected at Stage 1.

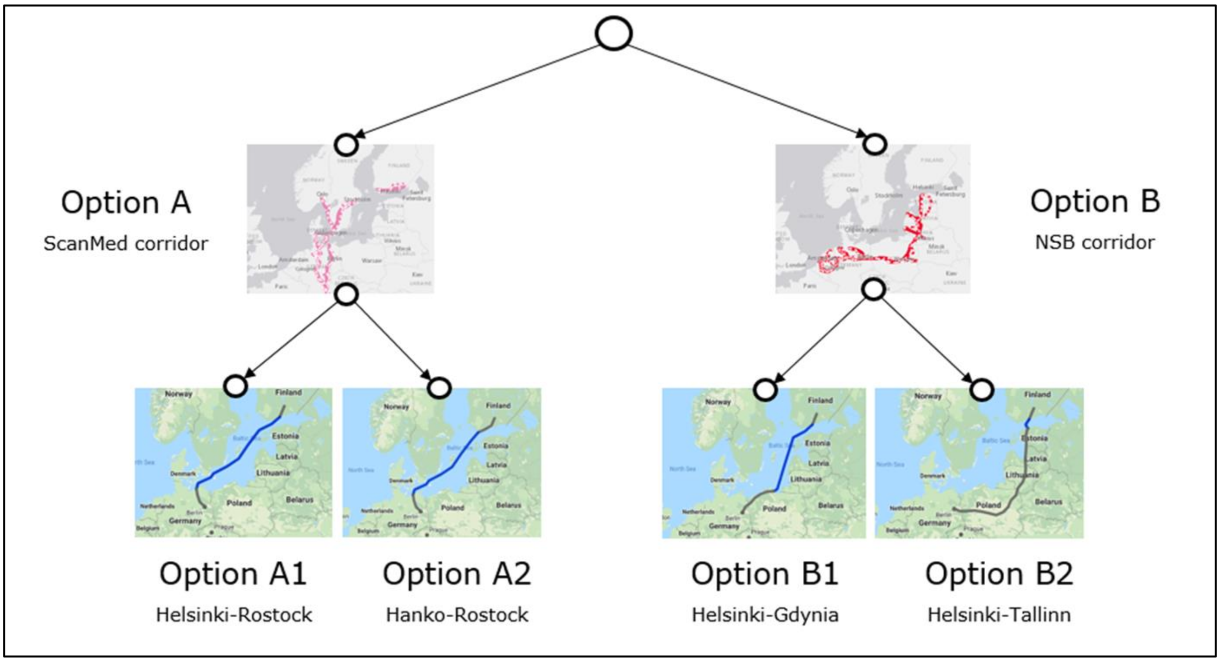


Figure 18. The nested binomial logit formulation for the Lahti-Berlin connections (Source: Own compilation)

6.2 Model calibration

The model presented above is calibrated on the basis of data concerning 2014, the year preceding the introduction of the stricter SECA regulation. Export traffic and service frequencies along the routes of interest were estimated based on the official port statistics of Section 5. The round voyages performed in 2014 along these routes are shown in Tables 2 – 4 below. Information on the name of the vessel, its type and the corresponding operator is also provided. For reasons of simplicity, the notation of Figure 18 is used. It is worth noting that the Helsinki-Travemünde services have been added to those of Helsinki-Rostock due to the geographic vicinity of the two German ports. The same applies to the B2 services from Hanko to Rostock and Lübeck. It is assumed that 30% of the lorries and trailers carried by the connections of Options A1 and A2 are destined to the Berlin area. The corresponding shares along Options B1 and B2 are 50% and 20% respectively.

Table 2. Voyages performed in 2014 on the Helsinki-Travemünde/Rostock route (Option A1)

Ship	Type	Company	Voyages
Helsinki-Travemünde			
Finnlady	Ro-Pax	Finnlines Oyj	105
Finnmaid	Ro-Pax	Finnlines Oyj	98
Finnstar	Ro-Pax	Finnlines Oyj	99
Nordlink	Ro-Pax	Finnlines Oyj	9
Subtotal (Helsinki-Travemünde)			*311*
Helsinki-Rostock			
Finnbreeze	Ro-Ro	Finnlines Oyj	9
Finnhansa	Ro-Pax	Finnlines Oyj	37
Finnkraft	Ro-Ro	Finnlines Oyj	18
Finnmill	Ro-Ro	Finnlines Oyj	46
Finnpulp	Ro-Ro	Finnlines Oyj	40
Finnsea	Ro-Ro	Finnlines Oyj	21
Finnsky	Ro-Ro	Finnlines Oyj	22
Subtotal (Helsinki-Rostock)			*193*
TOTAL A1			**504**

(Source: Own compilation based on Finnish Transport Agency, 2017)

Table 3. Voyages performed in 2014 on the Hanko-Rostock/Lübeck route (Option A2)

Ship	Type	Company	Voyages
Hanko-Rostock			
Vasaland	Ro-Ro	Oy Victor Ek Ab, Hanko	99
Vikingland	Ro-Ro	Oy Victor Ek Ab, Hanko	100
Subtotal (Hanko-Rostock)			*199*
Hanko-Lübeck			
Express	Ro-Ro	Oy Transfennica Ab	4
Friedrich Russ	Ro-Ro	Oy Transfennica Ab	6
Genca	Ro-Ro	Oy Transfennica Ab	77
Kraftca	Ro-Ro	Oy Transfennica Ab	68
Pauline Russ	Ro-Ro	Oy Transfennica Ab	2
Pulpca	Ro-Ro	Oy Transfennica Ab	55
Stena Forerunner	Ro-Ro	Oy Transfennica Ab	27
Stena Foreteller	Ro-Ro	Oy Transfennica Ab	85
Trica	Ro-Ro	Oy Transfennica Ab	31
Subtotal (Hanko-Lübeck)			*355*
TOTAL A2			**554**

(Source: Own compilation based on Finnish Transport Agency, 2017)

Table 4. Voyages performed in 2014 on the Helsinki-Gdynia/Tallinn routes (Options B1 & B2)

Ship	Type	Company	Voyages
Helsinki-Gdynia			
Baltica	Ro-Ro	Finnlines Oyj	87
Sailor	Ro-Pax	Finnlines Oyj	12
Subtotal (Helsinki-Gdynia)			*99*
TOTAL B1			**99**
Helsinki-Tallinn			
Baltic Queen	Ro-Pax	Tallink Silja Oy	149
Finlandia	Ro-Pax	Eckerö Line Ab Oy	726
Gabriella	Ro-Pax	Viking Line Abp / Helsinki	45
Mariella	Ro-Pax	Viking Line Abp / Helsinki	42
Silja Europa	Ro-Pax	Tallink Silja Oy	214
Star	Ro-Pax	Tallink Silja Oy	1009
Superstar	Ro-Pax	Tallink Silja Oy	1042
Victoria I	Ro-Pax	Tallink Silja Oy	3
Viking Cinderella	Ro-Pax	Viking Line Abp / Helsinki	3
Viking XPRS	Ro-Pax	Viking Line Abp / Helsinki	702
Subtotal (Helsinki-Tallinn)			*3935*
TOTAL B2			**3935**

(Source: Own compilation based on Finnish Transport Agency, 2017)

Freight costs of sea transport were calculated on the basis of Finnlines rates. In the absence of information from the other Ro-Ro operators, the Finnlines rates were also used for the other connections after adjustment for distance differences. Land-based transport costs were calculated on the basis of an average figure of 0.4 €/km, which refers to an Eastern European driver.

Land distances were taken from Google maps, while the Marine Traffic Voyage Planner (https://www.marinetraffic.com/en/voyage-planner) was used to estimate port-to-port distances. Vessel speeds were calculated based on published schedules. Two additional hours prior to departure and after arrival were added as port delays to vehicles using the Ro-Ro services. An average speed of 90 km/h was used for road vehicles while running. A driving cycle of 4.5 h driving – 1 h break – 4.5 h driving – 11 break was taken into consideration. According to EU regulations, the time on-board a Ro-Ro vessel is considered as a break.

According to Finnish Customs (https://tulli.fi/en/statistics/international-trade-transports), the commodity of highest volume exported from Finland by ship in 2014 was general cargo. An average value of 70,000 €/lm was assumed for this manufactured cargo in conjunction with an average annual opportunity cost of capital of 4.5%.

This set of assumptions produce the calibration results shown in Figure 19. With 52.48% of the cargoes, ScanMed had in 2014 a slight precedence over the NSB corridor. A λ-value of 0.0328 is estimated for this first-stage selection. Furthermore, more than 2 out of 3 vehicles (68.14%) that followed ScanMed took the Finnlines ships that connect Helsinki to the German ports of Travemünde and Rostock. A λ_A-value of 0.5351 governs this part of the selection process. The shares of the two alternatives of Option

B were even more unbalanced. The vast majority (87.71%) of the vehicles that used the NSB corridor selected the almost exclusively land-based Option B2, producing a λ_B-value of 0.6853.

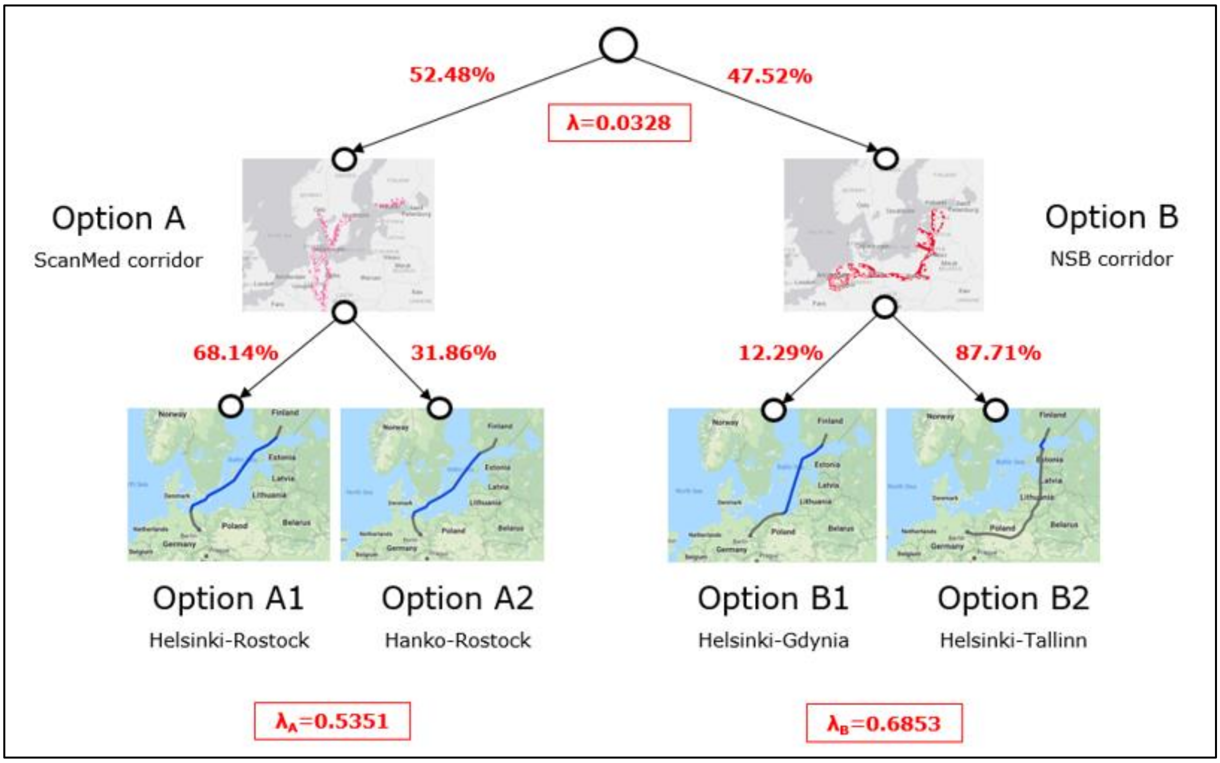


Figure 19. Model calibration results for Year 2014
(Source: Own compilation)

6.3 Model predictions

The calibrated model of the previous section can now be used for estimating the new modal shares of the four available options, as they developed in 2015 after the application of the stricter SECA sulphur limits in the beginning of that year. The case is built on the assumption that in the short run the ship operators had no feasible compliance option but to switch fuel to the more expensive qualities.

However, this anticipated change in the business environment coincided with the unexpected drastic reduction of fuel prices shown in . In order to investigate the role of the fuel prices, we examined three different scenarios:

Compliance: The heavy fuel oil (HFO) purchased at 2014 prices is replaced by marine gas oil (MGO) at 2015 prices;

No regulation: Operators continue using HFO, which is now purchased at 2015 prices; and

High prices: Operators comply by using MGO which, however, is now purchased at the 2014 prices (high level).

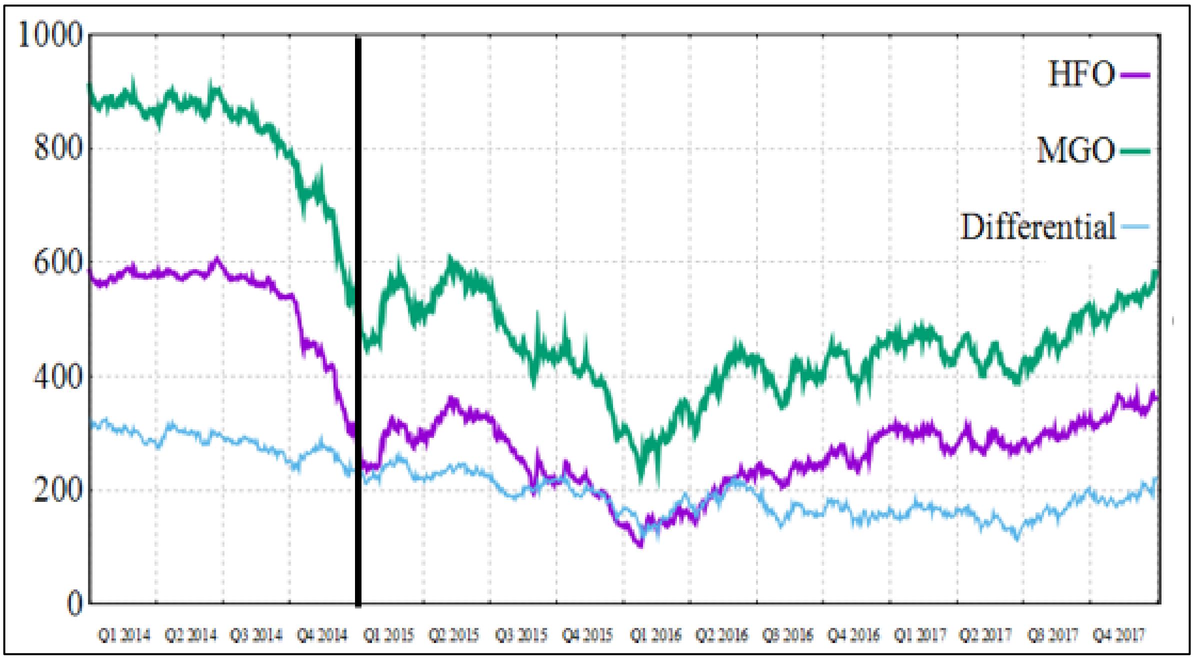


Figure 20. The development of marine fuel prices (2014-2017)
(Source: Bunkerworld)

Table 5. Estimated modal split (Year 2015)

	2014 share (%)	Scenario 1: Compliance HFO (2014) -> MGO (2015) 2015 share (%)	Difference (%)	Scenario 2: No regulation HFO (2014) -> HFO (2015) 2015 share (%)	Difference (%)	Scenario 3: Prices go up again HFO (2014) -> MGO (2014) 2015 share (%)	Difference (%)	Actual case HFO (2014) -> MGO (2015) 2015 share (%)	Difference (%)
A1 (Helsinki-Rostock)	35.76	37.83	2.07	43.99	8.23	27.29	-8.47	32.74	-3.02
A2 (Hanko-Rostock)	16.72	15.80	-0.92	12.28	-4.44	20.04	3.32	15.08	-1.64
A (ScanMed)	***52.48***	***53.63***	***1.15***	***56.27***	***3.79***	***47.33***	***-5.15***	***47.82***	***-4.66***
B1 (Helsinki-Gdynia)	5.84	11.49	5.65	38.25	32.41	0.24	-5.60	5.11	-0.73
B2 (Helsinki-Tallinn)	41.68	34.88	-6.80	5.48	-36.20	52.43	10.75	47.07	5.39
B (NSB)	***47.52***	***46.37***	***-1.15***	***43.73***	***-3.79***	***52.67***	***5.15***	***52.18***	***4.66***

(Source: Own compilation)

Table 5 presents the modal shares that each of the three scenarios produces together with the associated differences to the 2014 shares, which appear in the second column of the table. For comparison purposes, the last two columns present the 2015 shares as they actually materialised and the corresponding differences to the previous year. Losses of shares appear in red.

The lower 2015 prices of the ‘compliance’ scenario (even if they concern MGO) favour the longer sea legs of ScanMed which, collectively, gain shares (1.15%) against the shorter maritime connections of the NSB corridor. The gains are higher for the longer Helsinki-Rostock connection, which now becomes the most popular option capturing 37.83% of the cargoes. The shorter Hanko-Rostock alternative of the ScanMed corridor experiences a limited loss, as its shares drop to 15.80% from 16.72% the year before. Between the two options of the NSB corridor, the lower marine fuel prices favour the longer Helsinki-Gdynia link, which also doubles its shares from 5.84% to 11.49%. On the contrary, the shortest Helsinki-

Tallinn link sees its shares dropping 6.80 percentage points to less than 35%, which brings it to the second place overall.

The trends identified in the 'compliance' scenario are intensified under Scenario 2 ('no regulation'), where ship operators would continue using the low quality HFO at even lower prices. The gains of the ScanMed corridor against NSB would now jump to 3.79%, and the routes involving the longer maritime leg in each corridor would be the big winners of market shares. The developments would be more impressive in the NSB corridor, where the two options almost swap roles in comparison to one year before.

As expected, the situation reverses when fuel prices return to their 2014 level (Scenario 3) and the expensive MGO penalizes the longer Ro-Ro connections. In this case, NSB wins 5.15% shares from ScanMed. The shorter alternatives in each corridor are now the winners, with the Helsinki-Tallinn option capturing 52.43% of the entire traffic.

In fact, Scenario 3 lies closer to the actual case than any other scenario. It seems that in 2015 the NSB corridor gained 4.66% shares from ScanMed. All options lost traffic to the Helsinki-Tallinn connection, which gained 5.39 percentage points capturing 47.07% of the overall traffic. In view of the actual drop of fuel prices in 2015, this is a rather surprising development. Possible explanations include:

(i) the expectations of higher fuel prices led to capacity increases along the short Helsinki-Tallinn services, which then turned into higher traffic volumes along this route,
(ii) the longer-term agreements that the larger Finnish shippers conclude with Ro-Ro operators in order to secure stable freight prices and flows,
(iii) the assumption that freight rates fully reflect the fuel cost might be an exaggeration of reality as there are many other concerns that enter a company's pricing policies, and
(iv) the numerous other assumptions that enter the model calibration of Section 6.2.

In any event, the methodology presented above comprises a valuable tool when it comes to decision-making at enterprise level.

6.4 Mitigating measures

A number of measures have been proposed in the literature for mitigating the adverse effects of the stricter SECA regulation on the competitiveness of the Ro-Ro industry. The RoRoSECA project distinguishes measures decided directly by the operator from those taken at a higher policy-making level.

Three of the operating measures that Zis and Psaraftis (2018) propose are of particular interest for the Ro-Ro operators along the Scandria® corridor. The first one concerns **speed reduction**. The exponential relationship between fuel consumption and the speed of a ship is well known (Kontovas and Psaraftis, 2011; Psaraftis and Kontovas, 2016). Even a small reduction in sailing speed can lead to significant savings in fuel consumption, a fact that gains importance as the fuel price goes up. However, unlike other shipping sectors, Ro-Ro ships sail on scheduled services. This places stiff limits to the delays due to slower sailing that usually have to be made up by faster turn-around times in ports. Another limiting factor stems from the common practice of scheduling ship departure times at sharp or half-past times for planning and marketing purposes.

The second cost-reduction measure that Ro-Ro operators can consider is lowering **sailing frequency**. This can take the form of either reducing the number of vessels deployed on a specific route or simply reducing the number of weekly sailings. The measure is meaningful only in cases of low utilisation rates of the deployed capacity. Even in these cases, however, caution needs to be taken to the fact that a lower frequency of service might lead to losses of cargo volumes. This can become serious in the case of Ro-Pax vessels, since passengers tend to be more sensitive to service frequency than freight.

Along the same line of thinking, Ro-Ro operators can react to increased fuel costs by **fleet and network reconfiguration**. The term refers to the adjustment of routes served and the assignment of different vessels to those routes so, as to optimise profitability given the technical characteristics of the fleet in terms of capacity, speed, and fuel consumption.

It needs to be clarified here that the Ro-Ro operators always pursue operating measures of the kind mentioned above as part of their effort to achieve better financial results. The argument, however, is that in periods of high fuel prices, this need becomes more pressing and the optimal solutions may be different.

The second family of measures consists of those taken by policy makers at a higher than operational level. Zis et al. (2017) examine five such measures. The first among them and broadest in nature is the full or partial **internalisation of external costs** of transport, that is costs that a transport activity imposes on the society and which are not compensated for by the users of this activity. The main transport related external costs concern congestion, accidents and environmental impacts in terms of climate change, air pollution and noise. Others, more difficult to monetise, include the degradation of nature, landscape and sensitive areas, the pollution of soil and water, and the energy dependency (Maibach et al., 2008). In principle, the internalisation of these costs sends the right price signal to the users of these services, thus, providing an incentive to change their behaviour to the benefit of the society. Although in general the internalisation of external costs of transport will probably lead to lower demand for transport services, it is expected to favour maritime transport against its road-based competitor.

Easing of port dues is another possible measure that involves subsidising part of the port dues that the affected ship operators have to pay during their vessel calls. As most of the shipping-related external costs take place in the urban areas surrounding ports, the measure is founded on the rationale that a certain reduction of the port dues can now be justified because of the lower sulphur emissions during the phases of approach to / departure from a port.

The **Eco-bonus system** is a financial aid mechanism promoting short sea shipping. It was first applied in Italy as a temporary state aid scheme for freight operators moving from road to sea. This first implementation provided a subsidy of 20% of the seaway tariffs of existing services at the time, and up to 30% for new services. A certain minimum number of trips had to be performed by the benefited operator as a prerequisite for the subsidy. Due to limited resources and the ensuing recession, this scheme was operational only for a little bit over two years. More recently, there are new efforts attempting to implement similar schemes such as those in Norway and Sweden.

The **subsidies for environmental investments**, such as for scrubbers or LNG engines, comprise a similar financial aid scheme. The European Commission has provided grands for such purposes under its Motorways of the Sea (MoS) programme.

A **tax on land-based modes** is yet another mitigation measure as it increases the land-based freight rates that a shipper must pay and limits the modal shift loss of Ro-Ro operators triggered by the low sulphur fuel requirement.

What is common in all these policy measures is that they affect the generalised cost of the examined routes and, thus, their modal shares. It has to be mentioned, however, that the generalised cost functions of Section 6.1 reflect the out-of-pocket cost (price) borne by a shipper. As such, all the measures mentioned above will influence the modal split only if the financial consequence of a subsidy or tax reaches the final user of the transport service. Otherwise, it will affect the profitability of the transport operator but not the modal split.

In order to investigate the effectiveness of such measures, we examine below as an example the impact of an Eco-bonus scheme on the modal shares of our Lahti-Berlin routes. This fictional Eco-bonus scheme, which would apply to the entire Baltic Sea region, is based on the mechanism proposed by the Swedish government and which was approved by the EU as recently as in November 2018 (https://www.transportnet.se/article/view/633263/ecobonus_far_godkant_av_eu).

In view of the persistent congestion of Swedish roads and the very low (3%) share of the country's domestic trade transported by sea (unlike in Europe where short sea shipping accounts for 40% of freight transport), the government decided to invest SEK 50 million a year for three years on a new temporary Eco-bonus system that aims to move freight from road to shipping. According to the Swedish Shipowners' Association (http://www.sweship.se/nyhet/svensk-sjofart-valkomnar-regerings-satsning-for-att-fa-mer-gods-pa-sjofart/), the scheme foresees a subsidy (SEK 0.12) to the ship operator for each tonne of goods shifted from road to sea. The ship operator can then select to pass this financial support to the cargo owner (shipper). Thus, the support becomes an aid to the shipper who can benefit from less costly sea freight. Among others, the requirements include:

- The initiative must relate to new or upgraded intermodal routes
- The initiative leads to a transfer from road to shipping
- The initiative must not be financially viable without support
- Economic viability must be reached no later than three years when the support ceases
- The aid may cover a maximum of 30 percent of the operating cost of the shipping route, or up to 10 percent of the cost of investment in transhipment equipment
- At least one Swedish port must be involved.

In order to apply the simple Swedish formulation of a support equal to 30% of a ship's the operating costs, an indication of the cost structure of a Ro-Ro vessel is needed. Delhaye et al. (2010) suggest the cost structure of Figure 21 for a typical Ro-Ro ship with a carrying capacity of 200 trailers.

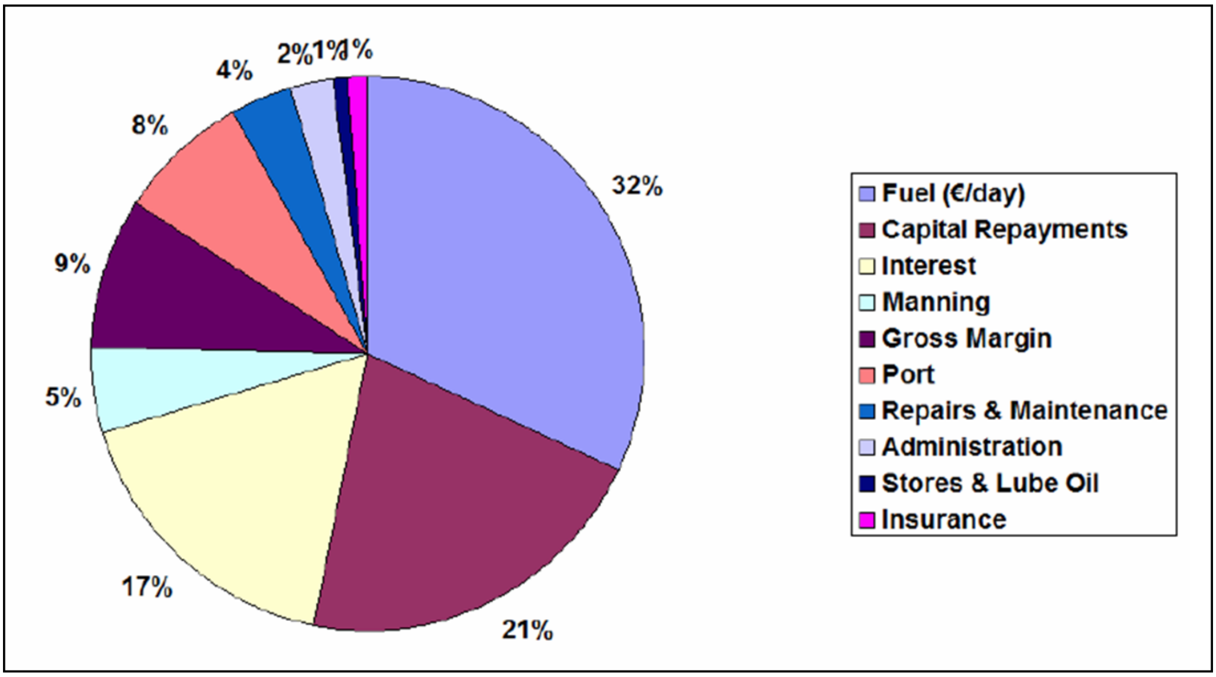


Figure 21. The cost structure of a typical Ro-Ro vessel
(Source: Delhaye et al., 2010)

When the 32% contribution of fuel in the cost structure of a Ro-Ro vessel is taken into consideration, the 30% support of the Eco-bonus system leads to the results of Figure 22. As expected, the routes involving longer maritime legs in the two corridors are favoured against their shorter counterparts. The ScanMed corridor gains 3.31% shares from NSB, and the Helsinki-Gdynia option is the biggest winner in traffic volumes climbing to the second place overall after the Helsinki-Rostock one.

	Without Eco-Bonus (%)	Scenario 4: Eco-Bonus 30% reduction in operating cost	
		Share (%)	Difference (%)
A1 (Helsinki-Rostock)	35.76	42.56	6.80
A2 (Hanko-Rostock)	16.72	13.23	-3.49
A (ScanMed)	***52.48***	***55.79***	***3.31***
B1 (Helsinki-Gdynia)	5.84	33.42	27.58
B2 (Helsinki-Tallinn)	41.68	10.79	-30.89
B (NSB)	***47.52***	***44.21***	***-3.31***

Figure 22. Effect of Eco-bonus on the modal split
(Source: Own compilation)

The effectiveness of such a measure is the reason for its adoption by Sweden and other countries (Norway, Italy, the UK). It is rather unfortunate though that, at about the same time, the Swedish government has raised port dues during the last two years counteracting the benefits of the Eco-bonus system (http://www.sweship.se/nyhet/svensk-sjofart-valkomnar-regerings-satsning-for-att-fa-mer-gods-pa-sjofart/).

7 Conclusions

In view of the more stringent regulations on the sulphur content of marine fuels introduced on 1 January 2015, many expected a rise in costs, a modal backshift from maritime transport to land-based transportation, and the closure of certain services leading to even higher modal shifts. The aim of this report was to investigate the sensitivity of the Ro-Ro services along the Scandria® corridor to fuel cost fluctuations, anticipate the adverse effects of a possible fuel price hike and discuss potential mitigating measures.

The study identified 77 services (operated by 30 different companies) that include at least one direct connection between two Baltic ports. Among them, the routes connecting Finland to Germany were selected for examination because:

- (i) this is where the ScanMed and NSB core network corridors meet, in which case the study would also serve the stakeholders of the sister projects NSB CoRe and TENTacle,
- (ii) provide a wide distance range (from 48 miles of Helsinki-Tallinn to 611 miles of Helsinki-Travemünde),
- (iii) carry all road exports of Finland to Europe, and
- (iv) involve Ro-Pax in addition to Ro-Ro vessels, while almost half of the ships deployed are equipped with scrubbers.

Among the abatement options available to the Ro-Ro operators, the study considers only the switching from Heavy Fuel Oil (HFO) to the compliant but more expensive Marine Gas Oil (MGO), which happens to be the only feasible solution in the short-run that does not require a substantial capital investment.

The study deployed two different approaches in meeting its objectives. The first one looked at the problem from the macro-level perspective and the analysis was based on aggregate annual statistics of the ports serving the Finland-Germany connections. A multiple regression model estimated the sensitivity of cargo flows to fuel price fluctuations. Although most of the cargo volumes exhibit a statistically significant sensitivity to fuel price, in all cases this is below 1.0, indicating a rather inelastic behaviour. The results show that an increase in fuel price penalises the volume of lorries on the long-distance Helsinki-Germany route in favour of the shorter Helsinki-Tallinn and Hanko-Germany options. The trailer (unaccompanied) traffic exhibit a different behaviour that might relate to the pricing policies of the Ro-Ro operators in relation to this market segment.

The second approach looked into the route selection problem from the perspective of a cargo owner/shipper and it was based on detailed information pertaining to a specific company. A logit model was used to describe route selection on the basis of the generalised cost associated with each alternative route, which in this case was a function of price, transit time and frequency of service. The selection process was modelled as a 2-stage hierarchical decision. The first stage concerns the selection among the alternative ScanMed and NSB corridors, while one of the two alternative options that correspond to each of the above corridors is selected at the second stage. The model was calibrated on the 2014 data and was used to predict the 2015 modal shares.

A brief reference was also made to the main measures have been proposed in the literature for mitigating the adverse effects of the stricter sulphur regulation on the competitiveness of the Ro-Ro industry. Speed reduction, lowering sailing frequency, and fleet and network reconfiguration are among those controlled by the Ro-Ro operator. Measures decided at a higher policy level include the full or partial internalisation of external costs of transport, the easing of port dues, the Eco-bonus system, subsidies for environmental investments, and a tax on land-based modes. The micro-level model was used to assess the effectiveness of an Eco-bonus system following the Swedish formulation. The results indicate that a 30% subsidy on the vessel's operating cost would favour routes involving the longer maritime legs in the two corridors and that the ScanMed corridor would gain 3.31% shares from NSB.

The use of two different approaches enables the comparison between them. Figure 23 below shows that in this case the macro-level approach has been much more effective in forecasting the developments of 2015. It captured the gains of NSB over the ScanMed corridor, as well as the fact that the Helsinki-Tallinn option won shares from all other alternatives. This is probably due to the fact that:

(iii) the actual case reflects the aggregate port statistics of 2015, which is in line with the logic of the macro-level perspective, and
(iv) the micro-level analysis has been based on a number of assumptions that limit the accuracy of the results.

		MICRO		MACRO		Actual case	
		HFO (2014) -> MGO (2015)		HFO (2014) -> MGO (2015)		HFO (2014) -> MGO (2015)	
	2014 share (%)	**2015 share (%)**	**Difference (%)**	**2015 share (%)**	**Difference (%)**	**2015 share (%)**	**Difference (%)**
A1 (Helsinki-Rostock)	35,76	37,83	2,07	32,30	-3,46	32,74	-3,02
A2 (Hanko-Rostock)	16,72	15,80	-0,92	14,14	-2,58	15,08	-1,64
A (ScanMed)	***52,48***	***53,63***	***1,15***	***46,44***	***-6,04***	***47,82***	***-4,66***
B1 (Helsinki-Gdynia)	5,84	11,49	5,65	3,21	-2,63	5,11	-0,73
B2 (Helsinki-Tallinn)	41,68	34,88	-6,80	50,36	8,68	47,07	5,39
B (NSB)	***47,52***	***46,37***	***-1,15***	***53,56***	***6,04***	***52,18***	***4,66***

Figure 23. Comparison between the micro and macro approach
(Source: Own compilation)

Nevertheless, the validity of the micro-level methodology is not questioned when it comes to decision making at the enterprise level.

Furthermore, it is worth noting that the drop of market shares of the Helsinki - Gdynia route has resulted in the withdrawal of this service in 2016, showing the sensitivity of the Ro-Ro connections to even moderate changes in demand.

In conclusion, it seems that the Ro-Ro flows have not been affected much by the stricter sulphur regulations. This can be attributed to:

(i) the large drop of fuel prices that coincided with the introduction of the stricter sulphur regulation and resulted in a reduction rather than an increase in costs,
(ii) the ‘systematic’ nature and long term contracts of Ro-Ro-traffic, and
(iii) the fact that Ro-Ro services pertain to a combination of sea and road transport that is affected by external influences other than the cost of marine fuel.

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