Project No. 2014-122: Mitigating and reversing the side-effects of environmental legislation on Ro-Ro shipping in Northern Europe

Deliverable on Task 2.1:

Report on the outcome of Task 2.1 Scenarios defined and data collected in the context of Task 2.1

Due date of deliverable: Month 7 **(**15 January 2016)

Actual submission date: 15 January 2016

Document status: Public[1]

Authors:

Thalis Zis, Postdoc, DTU Transport tzis@transport.dtu.dk

Harilaos N. Psaraftis, Professor, DTU Transport hnpsar@transport.dtu.dk

Jacob Kronbak, Associate Professor, DTU Transport jakro@transport.dtu.dk

[1] Original status of document was confidential. Document was declassified on 26 July 2017. Confidential data in the document are shown as "xx".

Acknowledgments

We would like to thank Poul Woodall of DFDS for his overall assistance in this project, including his comments on a previous version of this document. Also we would like to thank the other members of the project's Advisory Committee, Mogens Schrøder Bech of the Danish Maritime Authority, Tom Elmer Christensen of Danske Havne, and Maria Bruun Skipper of the Danish Shipowners Association, for their constructive engagement and advice as regards the project. Last but not least, we thank George Panagakos, PhD student at DTU Transport, for his comments on a previous version of this document.

DISCLAIMER

The photographs of vessels in this report are originating from the DFDS company websites where the fleet is presented.

Table of Contents

1 Executive Summary

Task 2.1 (entitled "Scenario definition and data collection") of the project comprises of two main objectives:

- the definition of the main routes to be examined, and
- the data collection process for the subsequent analyses.

The project's first Advisory Committee (AC) meeting took place on 28/9/2015 and the DTU team's proposal for the scenario definition was presented. The proposal was to examine the following seven existing DFDS routes:

NORTH SEA	
Gothenburg – Ghent	Ro-Ro
Esbjerg – Immingham	Ro-Ro
Rotterdam – Felixstowe	Ro-Ro
Copenhagen – Oslo	Cruise
BALTIC SEA	
Klaipeda – Kiel	RoPax
Klaipeda – Karlshamn	RoPax
CROSS CHANNEL	
Dover – Calais	RoPax

The DTU team also proposed to examine one of the recently shut down routes of DFDS as DFDS confirmed that the new sulphur limits contributed to the shutting down decision. Following a short discussion, it was suggested that this route would be Esbjerg- Harwich.

It was noted that it might be useful to also consider a what-if analysis on routes not affected by the ECA regulations. To address this, DTU will also examine the Marseille-Tunis route served by DFDS.

This choice of routes respects the selection criteria as defined in the project description (geographical coverage, diverse mixture of vessel and network characteristics, significant portion of total capacity, different levels of alternative land-based competition).

Data collection on Task 2.1 was performed with a specific focus on the selected routes. The key data collected so far include the vessel deployment for the last years, a snapshot of fuel consumption of specific vessels for all port to port journeys, and the network specification information (frequency of service, distances, voyage duration, berth residence time). With regards to data on cargo origin and destination, as well as cargo values, it appears that disaggregate level data are not currently available. At this stage, disaggregate level data include information on cargo types carried on each route (e.g. timber, paper, engines) and estimations on the capacity utilization for one vessel during some of its previous journeys. Information on capacity utilization is anticipated to be received in conjunction with the fuel consumption information for the examined fleet. Other sources that have been used in the primary data collection phase, include aggregate level statistics available from Eurostat that indicate the transport performance by mode in each EU-28 member. Additional information is being collected from national statistical services that provide information on the volume of cargo passing (import-export) through each port of the country. Finally, information on cargo and passenger transportation for certain routes in the Baltic, the North Sea, and the cross-channel routes is being collected from magazines such as the ShippaxCFI publication that provides estimates for ferry, Ro-Ro and cruise ships transport activity in Europe. With regards to competitive ferry services (P&O Ferries, CLdN, Sol, etc.), information on their schedules has been retrieved from their respective websites, as well as other online sources (e.g. Baltic Transport Journal).

The degree of data availability (and at what level of aggregation) is expected to have implications on how the models developed in Task 2.2 will be calibrated.

Whereas Task 2.1 was designed to have a duration of 6 months, it is expected that further data collection will continue during the model calibration process of Task 2.2 (Jan. to June 2016), as more refined data will become available for the case studies considered.

2 Introduction: Purpose of this document

The main objective of this project is to identify and assess possible technical, operational, regulatory and financial measures for the mitigation and reversal of the negative repercussions of environmental legislation to the market shares of Ro-Ro shipping in Northern Europe. As of 1/1/2015, IMO's MARPOL Annex VI and EU Directive 2012/33/EU (amending Council Directive 1999/32/EC) stipulate, among other things, a 0.1% limit in the sulphur content of marine fuels, or invest in abatement technologies that result in the same reductions of sulphur emissions, such as the use of scrubber systems (IMO, 2008). Both options will lead to increased operating costs in comparison with the situation prior to the new limits. While in theory the increased costs could be absorbed by the affected ship operators, most operators may pass the additional financial burden to their customers through surcharges on sea freight rates. These increased transportation costs may therefore affect the modal choice of affected shippers, and result in loss of cargo for the shipping company and increased road or rail transport with effects in the environmental balance of the overall supply chain. Some operators have already shut down some of their routes. The fact that fuel prices have dropped precipitously since the summer of 2014 has somehow alleviated the repercussions of the new regulations, however this was also the case for the road mode and the risk of route closure still exists, particularly if fuel prices rise again in the future.

The objective of Work Package (WP) 2 (entitled "Enhanced modal split and emissions models") is to develop and calibrate a model that can evaluate possible modal shifts resulting from the application of SECA regulations, including their impact on shipping routes profitability and repercussions on land-based modes. The main testing scenarios will come from the Ro-Ro short sea sector in the Baltic, the North Sea, and the English Channel where land-based alternatives are a real option. In these scenarios, sulphur regulations would impact the competitiveness of maritime transport and might also ultimately increase CO_2 elsewhere in the supply chain (even though as already mentioned this may be scenario-dependent and is to be investigated anyway). It should be noted that routes profitability can be an unstable variable as even small shifts of traffic away from the maritime mode can make a route unprofitable and subsequently shut it down. Traditional modal split models (logit or others) do not capture this fact so they will have to be appropriately enhanced. The network of DFDS Seaways will be used as a test case. An investigation of the road mode will be part of this work package, as this constitutes an essential part of the model's input. In addition, a separate module will take care of emissions and external costs calculations.

In a sense, WP2 forms the backbone of the project's methodology and will develop the main tools for the project's anticipated outputs. The WP is divided into three main tasks, and will then feed as input for the objectives of WP3 (entitled "Measures to mitigate and reverse modal shifts"). In order to assess the implications of the increased operating costs on mode choice, it is necessary to construct a model that captures the baseline case using the key variables that are affected by the new limits.

Task 2.1 (entitled "Scenario definition and data collection") is the first of the three tasks of WP2, and as per project plan was scheduled to last from Month 1 to Month 6. It basically had the following two objectives:

- the definition of the main routes to be examined, and
- the data collection process for the subsequent analyses.

The purpose of this document is to report on the outcome of Task 2.1 and is the first deliverable of the project.

As there is a vast number of shipping services using ships sailing within SECAs that may be affected by the increased costs, the first important task is to identify representative case studies that can be analyzed to capture the immediate repercussions of these changes. The first important step in such studies is to analyze the markets affected and identify the scenarios to be further explored. Task 2.1 is concerned with the collection of the necessary data on the DFDS network and the proposal of the main scenarios to be examined within this network. Data include information on the sailing schedules of the company for the affected routes, the main cargoes onboard these vessels and the alternative maritime or land-based transportation options that the shippers of such cargoes have. These data are the key to the development and calibration of a modal split model (Task 2.2) that can reproduce the traffic flows for each mode for the examined scenarios. At the same time, Task 2.3 is dealing with the estimation of emissions generation for each mode, and is an extension of the SHIP DESMO previously developed for tankers and containerships. Figure 1 shows schematically the relationships between each Task in the context of WP2, and how these will be used as input to the tasks of WP3.

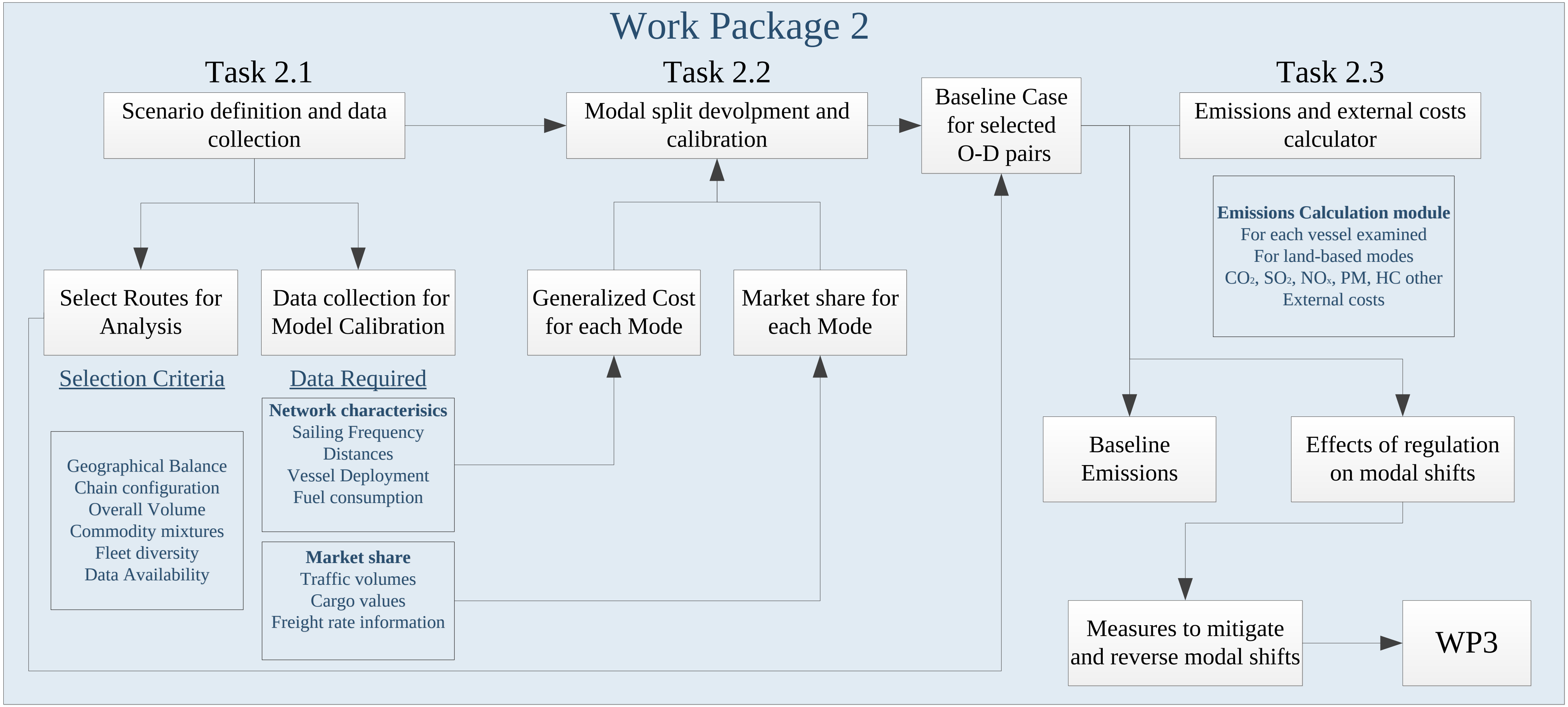


Figure 1: The main objectives of WP2 and the links between its associated Tasks

Task 2.1 is split into two main activities; the selection of routes for further analysis and the data collection for the model calibration. The selection criteria of routes within the DFDS network are such to ensure a representative sample of the affected flows in terms of geographical balance, competition, cargo types, and vessel characteristics. The criteria will be discussed further in section 0 of this report and during the presentation of the network. The required data presented in **Error! Reference source not found.** will feed into the modal split model of Task 2.2 in order to construct the baseline scenarios for the selected routes. These will also be used as input for the model constructed in Task 2.3 that predicts emissions generation based on transport activity for all transport modes available to cargoes for the selected case studies. Finally, **Error! Reference source not found.** shows that the effects of the new regulation limits (higher fuel costs) will be examined according to their influence to mode selection, and operational, market, regulatory, and financial measures will be explored as counterweights in the context of WP3.

The rest of the report is organized as follows. Section 3 provides some background. Section 4 discusses the DFDS network, fleet and abatement technology. Section 5 covers route selection criteria. Sections 6, 7 and 8 describe routes in the North Sea, the Baltic and across the Channel respectively. Section 9 describes routes in the Mediterranean and shut down routes. Section 10 describes the data collection effort for the major categories of data to be used. Finally Section 11 makes some concluding remarks. Appendix I shows some tables.

3 Background

3.1 Freight Transport in Europe

Maritime transportation of freight has had a traditional important role in Europe. The European Union has a coastline of total length around 66 thousand kilometers (CIA, 2009) and a navigable inland waterways network of approximately 41 thousand kilometers. The external trade of the EU-27 members in 2010 (import and export) was seaborne by 50.8% and 74.6% in terms of value and weight respectively (European Commission, 2012). The respective numbers for the maritime sector's transportation of the global trade were about 90 and 73% in 2013 (UNCTAD, 2013). In absolute terms the world merchandise trade keeps on increasing by 2.6 and 2.3% in 2013 and 2014 respectively (UNCTAD, 2015), while in the European Union only in 2014 there was recovery in the volume of merchandise (2.8%) following a recession of -0.9% in 2013.

In the intra-EU trade, sea is the major mode in terms of ton-kilometers and accounted for approximately 37% during the 1995-2010 period (European Commission, 2012). Eurostat (2015) provides an updated figure for 2013 where 32.8% of the tonne-kilometers performed were seaborne, excluding extra-EU transport, placing road transport in the top mode by distance (50.3%) as seen in Figure 2.

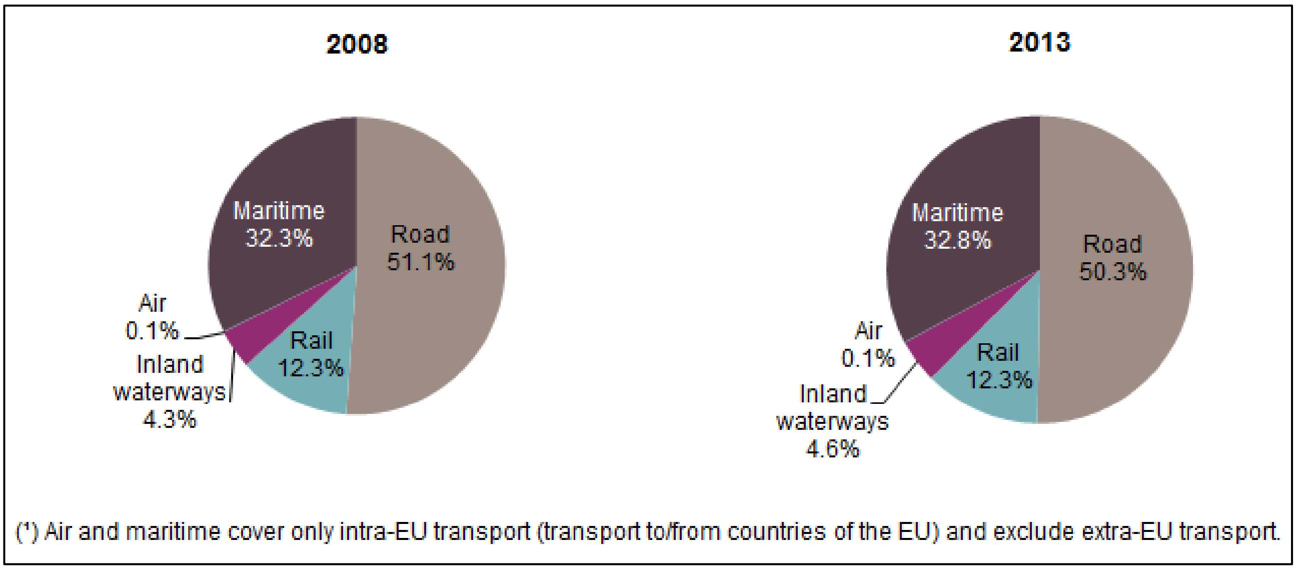


Figure 2: Freight transport in the EU-28 modal split. Source: Eurostat (2015)

The above aggregate statistics indicate that the maritime sector plays an important role in freight transportation within Europe. Data on the European Ro-Ro sector are revealing a mixed picture on the levels of seaborne European traffic volumes in the last two years (see Section 10.2.4) with an overall increasing trend in absolute numbers.

3.2 The environmental impact of maritime transport

In environmental terms, transport was estimated to account for 22% of the world CO_2 emissions in 2010 (IEA, 2012), while the maritime sector alone was responsible for 2.7% in 2007 (IMO, 2009) and 2.2% in 2012 (IMO, 2014). In Europe, the transport sector has a very similar share on greenhouse gas emissions at 21.9% in 2012, a figure which has increased compared to the 15% levels during 1990 (Eurostat, 2015). Greenhouse gas emissions from maritime shipping are estimated to account for 4% of the European contribution (European Commission, 2013). The previous estimates for the European and the global carbon footprint are indicating that maritime shipping is an important contributor to air pollution and emissions. While relatively low if compared with other transport modes, its expected growth in absolute numbers has called for policy actions to reduce its contribution. In response, the European Commission has set out a strategy to progressively integrate maritime emissions into the EU policy on reducing domestic greenhouse gas emissions.

At the same time, a major environmental issue that is associated with maritime transport is the generation of air pollutants with effects on human health. Ships are a major source of sulphur oxides, nitrogen oxides, and particulate matter emissions among others. Due to the high sulphur content of marine bunker fuel, the shipping sector was responsible for between 5 and 8% of the global anthropogenic SO2 emissions (Eyring et al., 2005). The relevant figure for NO_x emissions was estimated at around 15% (Corbett et al., 2007), while there is also an increasing concern on ship-related Particulate Matter emissions near coastal areas. To address some of these issues, the revised MARPOL Annex VI introduced limits on the maximum sulphur content allowed in bunker oil, and also designated emission control areas (ECAs) where higher limits applied. Figure 3 presents the progression of the maximum sulphur content in fuel used by vessels sailing inside and outside ECA zones. The global limit of 0.5% may be postponed to 2025 if there is a relevant recommendation following the outcome of a commissioned review on fuel availability in 2018.

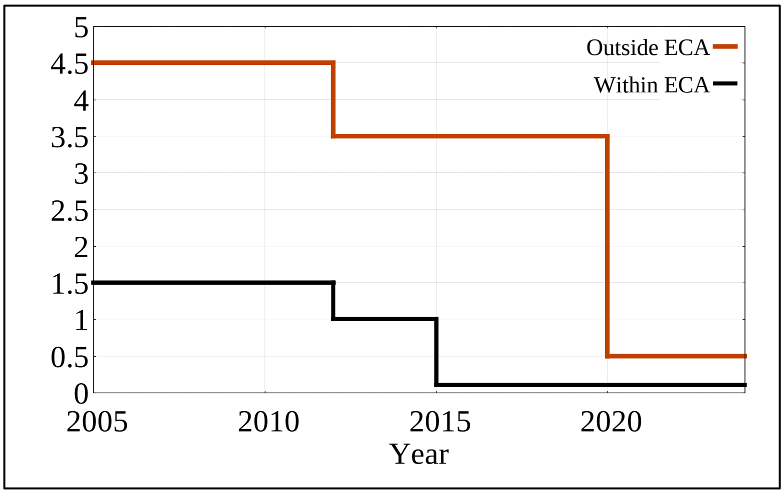


Figure 3: The maximum allowed sulphur content within and outside ECAs

Within Europe, the implications of sulphur in fuel had been considered earlier through the Directive 93/12/EEC of March 1993 which regulated the sulphur content of certain liquid fuels. The Directive would prohibit marketing of fuel up to 0.2% and 0.05% sulphur content (by weight) for fuel in all transport modes by October 1994 and October 1996 respectively. Vessels sailing between a Member State and a third country were excluded from this regulation. In 1999 the EU amended this directive through the Council Directive 1999/33/EC which essentially changed the limit of sulphur to 0.1% by the year 2008 down from the previous limit of 0.2%. The amended Directive required for the first time that from January 2003 heavy fuel oil with sulphur content exceeding 1% would be banned from use within the territory of a Member State. The Directive would provide a period of no more than six months with a higher limit of sulphur for certain Member States. These are the ones that could not apply the limits due to complications in the supply chain of crude oil and petroleum products.

The first effort of the EU to specifically address sulphur emissions from maritime transport came through Directive 2005/33/EC. It acknowledged the importance of the SO_x ECAs designated by the IMO and placed a limit of a maximum of 0.1% sulphur by weight fuel used by inland waterway vessels and ships at berth in Community ports for stays longer than 2 hours. Furthermore, it banned the use of heavy fuel oils exceeding 3% sulphur content in the territorial seas of each Member state.

The use of proper fuel is ensured through the requirement to record all fuel switching operations in ships' logbooks. In addition, the Directive allowed the use of either shore-side electricity while at berth or alternative emission reduction technologies (e.g. scrubber systems) that would result in at least equivalent reductions to those achieved with the use of low-sulphur fuel.

3.3 Abatement technologies, market response, and fuel availability

Placing sulphur limits within inland waterways and on vessel activity at berth signifies how important the EU considers the sulphur dioxide emissions to be near residential areas. Shipowners operating vessels within ECAs had to select whether to use low-sulphur fuel or invest in scrubber systems that would allow them the use of heavy fuel oil with higher sulphur contents. The previous summary of the sulphur related environmental legislation shows that shipping companies operating in the North Sea and the Baltic were affected most. The response of the market to increasing bunker prices due to the regulation was to apply the Bunker Adjustment Factor (BAF) which essentially transferred part of the additional cost to the shipper through higher transport costs.

3.3.1 Fuels with low-sulphur content

This section will present the main available options for ships that meet the legislation requirements.

3.3.1.1 Low-sulphur Marine Gas Oil (LSMGO, or MGO)

This is pure distillate oil that contains less than 0.1% sulphur and can be used in conventional marine engines within ECAs and other sulphur regulated areas (e.g. EU ports). This fuel can be used without major modifications, but one drawback is that it has to be stored at a different tank for vessels that use fuel switching. In the examined scenarios, this is currently not the case but in previous years (before January 1st 2015) some of the vessels of DFDS would use HFO of sulphur content of less than 1% while sailing, switching to LSMGO while at berth. MGO in general has a lower viscosity than HFO, and as a result additional lubrication must be used to avoid damage in the engine's pumps (MAN, 2014). Another major issue here is also that HFO must be heated to 130 centigrade, which is not required for MGO.

Historically, fuel with lower sulphur content is more expensive than regular bunker oil. Low-sulphur fuel requires additional refining which can also result in additional transportation (from production facility to refinery) with environmental and economic implications. In previous years low-sulphur fuel was also expected to increase its price at a faster rate than HFO due to the anticipated increased demand with the coming regulation (Jiang et al., 2014). However, the price differential among different fuel types is not constant and as all fuel prices it is also characterized by significant volatility.

3.3.1.2 Marine Diesel Oil (MDO) and Ultra-Low Sulphur Fuel Oils (ULSFO)

MDO is very similar to MGO: a fuel with low viscosity that can have very low-sulphur content that abides by the regulation. There are similar problems with MGO for operators that use fuel switching when sailing in and out of regulated waters, as due to the different properties between HFO and MDO, the change may lead to operational problems including a potential engine shut down due to incompatibilities with fuel viscosities. A relatively new option is the use of the so-advertised hybrid fuels or hybrid ULSFO products. These offer the advantage of having a higher viscosity and better lubricity than MGO, and same temperature requirements to HFO, thus facilitating the switch over procedure. However, there are currently no ISO 1827 specifications for these products and their use is expected to rise in the near future when these are available.

3.3.1.3 Liquefied natural gas (LNG)

Natural Gas is an alternative option that complies with the low-sulphur mandates. Dual fuel engines have been designed that can use LNG for ship propulsion. In the past, only LNG carriers would use part of their cargo as fuel, in order to maintain the cargo tank pressure. The LNG carrier fleet has increased significantly over the last decade, and many ports are now offering or plan LNG bunkering facilities. LNG has significant advantages as it results in lower emissions generation, and a higher fuel efficiency and lower fuel costs than both MGO and HFO. LNG as marine fuel is expected to play a significant role in the future years, especially for new vessels as the fuel economy and compliance with regulation can outweigh the higher building costs. The main challenge associated with LNG is the limited number of bunkering ports at this stage.

LNG also reduces PM and NO_x emissions significantly. In addition, it has a lower CO_2 emission factor (in terms of tons of CO_2 per ton of fuel) compared to bunker fuels and can also lead to lower greenhouse gas emissions. However, in terms of tons of CO_2 per unit of energy this may not be the case. One major concern with the use of LNG as marine fuel is a potential leakage of methane (CH_4) during distribution and also use (this is the so called “methane slip”), as methane has a much stronger impact on global warming in comparison to CO_2.

There are also significant capital costs associated with the use of LNG in maritime transport, both for ships and for ports. Installing LNG engines is more expensive than conventional diesel engines. In addition, there is a requirement for more space on the vessel for LNG tanks, and thus capacity may be reduced. The additional costs of purchase for LNG engines is expected to decrease as technology matures and the market grows. Another option involves the retrofitting of an engine to a dual fuel engine that allows fuel switching between LNG and conventional fuel. This option is more suitable for routes where the LNG bunkering system is not fully developed (Egea, 2015). In the Baltic and North Sea area, bunkering stations were in 2014 still in the planned phase, and while ferries and high speed vessels are considered suitable for this technology, this option is only going to be considered in this project on a theoretical (what if) basis.

3.3.1.4 Cold ironing

Cold ironing is a term used to describe the process of covering the energy demands of vessels at berth with power from the grid. Vessels that rely on shore power, may switch off their auxiliary engines and the only source of emissions during berth are the ship boilers that are used to maintain fuel temperatures. In the European Union, cold ironing has been used as an emission abatement option for vessels at berth that need to comply with the low sulphur content requirement. While cold ironing is an attractive solution to reduce emissions at the port, there are important economic and environmental considerations.

Cold ironing has the potential of significantly reducing the emissions generation in the port proximity; however there are induced emissions generated at the power source. These will depend on the energy mixture powering the cold ironing facility. The main challenges with cold ironing is the necessary retrofitting costs for the vessel that range between $300,000 and 2M$, and the fact that not all ports are offering this option. Cold ironing would be particularly attractive for ships calling at ports that have low-sulphur requirements. However, the current low fuel prices may constitute shorepower more expensive than low-sulphur fuel. Following the new sulphur limits within ECA, all vessels must now emit less SOx emissions in all activity phases (not only at berth), and must now carry MGO or ultra-low sulphur HFO at all times (unless using scrubber systems).

3.3.1.5 Biofuels, methanol, hydrogen and nuclear fuel

Other options that respect the low-sulphur requirements are the use of biofuels, methanol, hydrogen or even relying on nuclear power. These were discussed in the MIDNORDIC study (2013) even though some options are not commercially available at this stage and tests onboard vessels are still underway.

3.3.2 Scrubber systems

Scrubber systems are neutralizing sulphur oxides by filtering the exhaust gases through water which results in sulphates containing waste water that is recirculated into the sea. Three main types of scrubber systems are currently used depending on the water use to wash out the sulphur oxides. These are:

- Seawater systems (open-loop)
- Freshwater systems (closed-loop)
- Hybrid systems

The first type can use seawater for the scrubbing process so long as the alkalinity of the water is sufficient (Henriksson, 2007). In other cases (notable examples are the waters in the Baltic Sea and near Alaska) it is necessary to use freshwater systems. Finally, hybrid systems allow the change of water depending on where the vessel is operating. All types of scrubber systems can be installed on both new builds and older vessels (retrofitted). The latter is more costly, and there are additional considerations on the space capacity available to install the system and where necessary the freshwater tanks (Danish Environmental Protection Agency, 2014). In terms of environmental performance, freshwater scrubber systems are reported to reduce SO_x by up to 97% and PM emissions by an estimated 30 to 60% when HFO of up to 2.5% sulphur is used (EMSA, 2010). However, these emissions reductions do not take into account the increase in the overall fuel consumption that is associated with the scrubber systems' energy requirements.

The total capital cost required to install a scrubber system depends on the type (open or closed loop) and size of the installation. Rough estimates include a cost range of between 100 and 200 Euros per kW of installed power on new builds, and 200-400 Euros for retrofitting installations. Some cost estimates of the EMSA study are provided in Table 1.

Table 1: Capital cost investments for different scrubber systems (Data source: EMSA, 2010)

Scrubber system	Vessel	Cruise ferry (~40MW)	Cargo ship (~20 MW)
Seawater system	New build	3 M€	2.1 M€
	Retrofit	3.5 M€	2.4 M€
Freshwater system	New build	2.4 M€	1.9 M€
	Retrofit	3.4 M€	2.4 M€
Hybrid system	New build	3.8 M€	2.6 M€
	Retrofit	4.3 M€	3M€

Additionally, there are operating and maintenance costs associated with the use of scrubbers. A very important extra cost stems from the increased fuel consumption to cover the energy requirements of the scrubbers. This varies per technology type, and is estimated at approximately 1-3% for seawater systems, and 0.5-1.5% for freshwater scrubbers. In addition, there are costs associated with the disposal of sludge from the scrubbers that are ranging from €1600 to €13300 per year (Egea, 2015).

3.3.3 Market response

A survey of Lloyd's List (2015) regarding the preferred sulphur emissions abatement method showed that most shipowners were considering using distillate fuel until 2020. Following that period and subject to the review on postponing the global limit of 0.5% until after 2025, the survey showed that most ship operators would switch to LNG for new builds, or rely on scrubber systems. Shipping companies that predominantly operate within ECAs have started installing scrubber systems in part of their fleet. The decision to retrofit part of the fleet and using low-sulphur products for the remaining vessels can reduce the capital costs for a full fleet retrofit. However, the unexpected decline in fuel prices that started in 2014 may have changed which option is more profitable for the ship operator.

A critical issue is the availability of low-sulphur fuel to meet the increasing demand due to the regulation. On this matter, several technical studies have been conducted for the whole European Union, and also for individually affected countries. The European Maritime Safety Agency (EMSA, 2010) provided a review of relevant studies, and notes that while the general consensus was that there would be sufficient quantities of low-sulphur fuel to meet with the 0.1% tier in 2015, the same does not hold true for the next tier for the global limit of 0.5%. Therefore, the oil industry will have to increase the capacity of existing refineries to meet the increased demand for light fuel grades. This may also result in new refineries focusing on ultra-low sulphur fuel production to meet the demand in North American and European countries, and shipping the residual oil in the non-regulated countries, with significant economic and environmental repercussions.

With regards to this project, the partner company DFDS has responded to the ECA requirements with an early decision to invest in scrubber systems and installing the first large scrubber on a Ro-Ro freight back in 2009. The company has retrofitted 17 vessels with scrubber systems and is planning on increasing the number of vessels with scrubber systems in the near future. Section 4.2.1will discuss the implications of such investments in more detail. The vessel deployment shows that there is some correlation between voyage length and sulphur abatement option, most notably in the cross-channel routes where the deployed vessels were running on MGO. The next section presents some aggregate level statistics as an introduction to the company's operating network.

3.3.4 The ECSA survey in the context of the ESSF

To respond to pressure from industry, the European Commission has set up the ESSF, the European Sustainable Shipping Forum. The mandate of ESSF is to examine sustainability and competitiveness of maritime transport in the EU. The mandate of the ESSF subgroup on competitiveness is to assist the ESSF to assess the critical success factors for a competitive EU maritime transport sector and propose recommendations to increase its competitiveness. The specific issue of impact of the sulphur regulations on the short sea sector of Northern Europe has been the focus of the subgroup, the Ro-Ro sector being one of the critical industry sectors[2].

In the context of the ESSF, ECSA, the European Community Shipowners Association, has prepared a survey that was circulated to shipping lines to gather on a confidential basis information about the economic impact of the low sulphur limits effective 1/1/2015. ECSA used a two-phased approach, an initial monitoring phase (autumn 2014- early 2015), followed by a comprehensive analysis in 2015. We have only seen the results of the first phase but we were informed that those of the second phase are quite similar.

The survey (Verhoeven, 2015) has four main sections:

- Information on company, incl. trades and routes covered
- Compliance methods chosen / problems encountered
- Economic impact: freight rates, behaviour customers, level of service (frequency / number of vessels)
- Experiences on enforcement

Some statistics:

- 39 shipping companies completed the survey
- Mostly Danish (28.2%), Dutch (23.1%) and German companies replied (15.4%)

[2] Prof. H. Psaraftis (DTU) and Mr. P. Woodall (DFDS) are members of the ESSF subgroup on competitiveness.

- Types of trades: mostly conventional general cargo, liquid bulk and dry bulk received the biggest share (28.2% each)
- Mainly active in tramp shipping (53.8%), in liner shipping (35.9%) or other(10.3%), ie both liner and tramp shipping / semi liner
- Majority of respondents (59 %) operating up to 20 ships while 20.5% is operating more than 50 ships
- 42.9% active exclusively in European SECAs.

In terms of compliance, the results were as follows.

- Compliant fuel of 0.1% sulphur content (94.8%): Most rank financial, technical and regulatory problems. 48.6% encountered no problems
- Scrubbing technology (12.8%): 60.0% hybrid system, 40.0% open loop, 20.0% closed loop: compliance method chosen more for newbuilds than retrofit. Most rank technical, regulatory, financial problems. One out of five (20%) did not encounter any problem
- LNG as alternative fuel (10%): Only for new builds / financial, technical and regulatory problems equally high. One-fifth (20%) did not encounter any problem
- Methanol (0%)

In terms of economic impact and impact on the level of service, the results were as follows.

- 53.8% respondents increased freight rates (varies between 1-10%) –see also Figure 4.
- 38% respondents estimate that the volume loss is between 1-15% but generally too early to estimate
- 38% respondents said it is too early to describe and even quantify the behavior of customers on the basis of the short period since the entry into force of Directive
- 19% respondents indicated a modal shift to road and 14% to rail, no modal shift to air noticed
- 66.7% respondents see a direct effect of compliant fuel price to freight rates & behavior of customers / MGO still more expensive than HFO even though fuel prices decreased
- 15.4% of the respondents has noticed impact on frequency, number of vessels deployed
- In liner shipping, routes closed already from EU Countries not bordering European SECAs to countries within European SECAs and vice versa (due to shift to road)
- In tramp shipping, voyages inside the European SECAs mostly affected.

Unfortunately, these results are only aggregate and do not differentiate by shipping sector. Thus, no disaggregate results are known for the Ro-Ro sector[3]. In addition, the results do not allow the analyst to pick out the effect of the new regulation vis-à-vis that of other, exogenous events, such as the precipitous drop in fuel prices, which started in mid-2014, and the Russian economic crisis, both of

[3] DFDS was not among the companies who responded to the survey.

which occurred at the same period and have had an impact on Ro-Ro routes profitability (positive and negative, respectively).

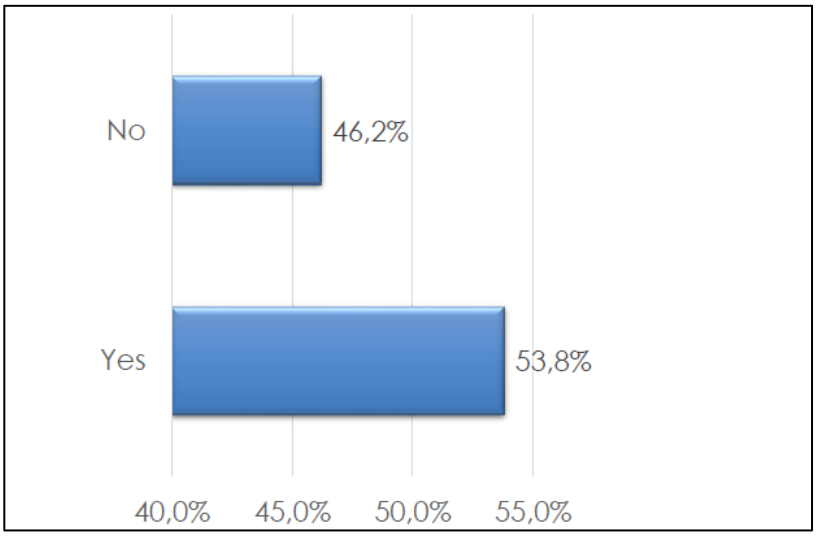


Figure 4: Economic impact on freight rates and effect on customers. Source: ECSA.

4 The DFDS network, fleet, and abatement technology

The DFDS network is comprised of around 25 routes where approximately 55 vessels are deployed to provide a range of passenger, freight, and container transportation. The network is categorized into Ro-Ro, Ro-Pax, Cruise, and container shipping routes. This project deals with ferry services that are affected by the stricter sulphur regulation in Emission Control Areas.

4.1 The DFDS network

There are currently 20 routes operated by ferries with a maximum number of 535 departures per week. The Ro-Ro and Ro-Pax vessels are connecting 30 ports in 13 different countries (Table A - 1 of Appendix I). This is a dynamic network with routes that often change frequency according to seasonal demand. The vessel deployment is also dynamic with different ships serving these routes from time to time. In addition, some routes have been shut down in advance of the new sulphur limits that would constitute these routes unprofitable, and the trade conflicts between the European Union and Russia. The ferry routes of DFDS on which the project is focusing, can be categorized by purpose (Table A - 2 of Appendix I: freight only, freight and passengers, cruise), and by geography (Table A - 3 of Appendix I). Despite the dynamic nature of the network, this section will provide an introductory descriptive statistics analysis of the network before dwelling into more depth on each of the routes.

During a peak week in March 2015, the DFDS fleet was covering a sailing distance of a total of approximately 73,500 NM. As seen in Figure 5 the North Sea routes have the highest share of distance sailed during the peak times. It can also be observed that the three Cross-Channel routes which are the shortest in sailing voyage distance, make up a significant proportion of the overall distance due to the very high frequency of service.

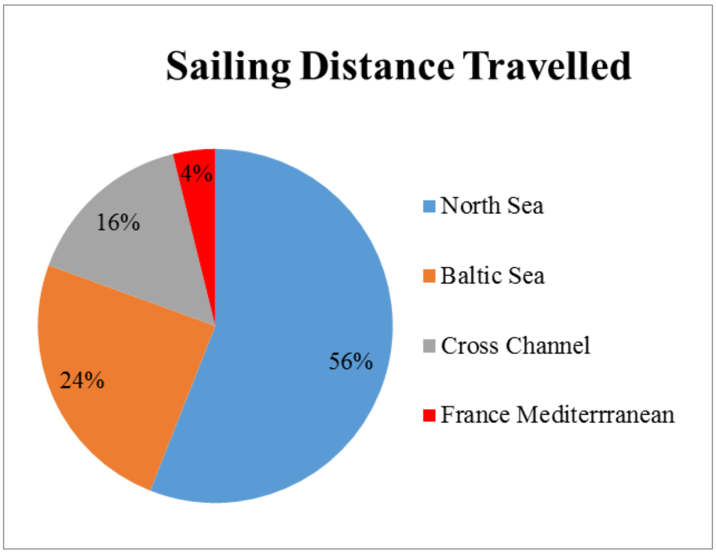


Figure 5: Sailing Distance travelled in each geographical region

The sailing distance of each link varies from some very short links that require less than 2 hours for crossing, to routes that take 48 hours. A snapshot of the sailing distance for each link is presented in Figure 6Figure 6.

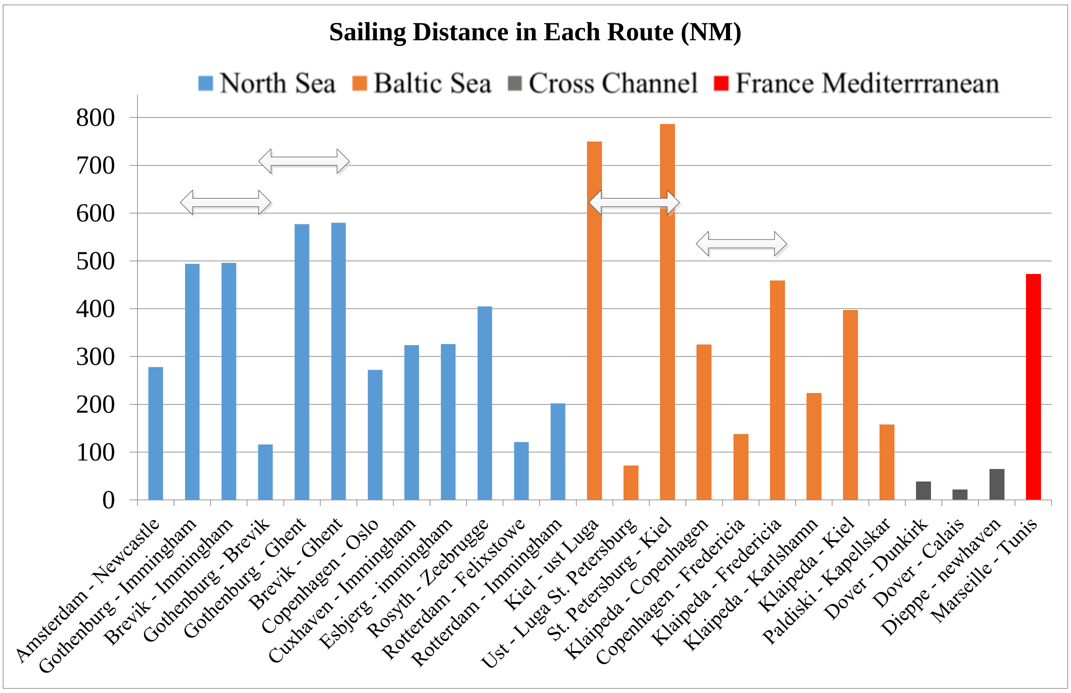


Figure 6: Average Sailing Distance for each DFDS Route

The bar chart is color-coded to present the routes that belong in the different geographical regions that DFDS is operating in. The arrows connecting some routes are indicating that these routes are components (links) of a specific service, with more than two ports of call.

4.2 Vessels deployed and abatement technologies

The DFDS owned fleet comprises of 4 cruise ships, 15 Ro-Pax, and 19 Ro-Ro vessels with an average age of 20.2, 13.6, and 9.9 years at the end of 2012 respectively, as reported by the company. The oldest vessel (cruise) was built in 1986, while the newest (Ro-Ro) were built in 2014. The four cruise ships are deployed traditionally in two main routes on the North Sea, where all other services are freight services using Ro-Ro vessels. DFDS deploys its Ro-Pax vessels in the Baltic Sea and in the Cross-Channel routes. Finally there is one more Ro-Ro service in the Baltic Sea, and the Marseille-Tunis route is served by two Ro-Ro vessels. The vessels vary substantially in terms of cargo capacity which ranges from 1,440 to 4,650 lane meters. The next subsection briefly presents the history of abatement options used by DFDS to comply with the regulations.

4.2.1 Scrubber investments history and associated costs

The recent investments in scrubber systems from DFDS started in 2009 with a test installation in Ficaria seaways (rebuilt in that year). In 2013 an additional 3 vessels were retrofitted with a cost of approximately 4 million euros each. In 2014, DFDS was operating a fleet of 10 ships using scrubber systems, a number which would increase to 17 by the end of 2015. Table 2 presents the recent history of investments in scrubber systems from DFDS Seaways at part of its fleet.

Table 2: The DFDS history of investments in scrubber systems

Year of installment	Ship	Type
2009	Ficaria	Ro-Ro
2013	Petunia	Ro-Ro
	Selandia	Ro-Ro
	Magnolia	Ro-Ro
2014	Victoria	Ro-Pax
	Primula	Ro-Ro
	Britannia	Ro-Ro
	Freesia	Ro-Ro
	Begonia	Ro-Ro
	Suecia	Ro-Ro
2015	Crown	Cruise
	Optima	Ro-Pax
	Sirena	Ro-Pax
	ARK Dania	Ro-Ro
	ARK Germania	Ro-Ro
	Regina	Ro-Pax
	Finlandia	Ro-Ro

This is a very large investment which constitutes the company leading in terms of fleet using scrubbers. For comparison purposes, a relevant UK study in 2009 was anticipating that only 10% of the fleet affected by the new sulphur limits would use scrubber systems (Grebot et al., 2010). The total investment cost for each retrofitting project was ranging between 4 and 7 million Euros. The European Union can assist financially scrubber installations as a part of the Motorways of the Seas programme. In this manner, DFDS secured a subsidy of 6.3 million Euros in 2014 for the installation of five scrubber systems on vessels deployed on Gothenburg-Immingham and Gothenburg-Ghent routes[4]. This represented approximately 20% of the total installation costs.

4.2.2 The bunker adjustment factor

DFDS increases the transport costs for shipping cargo by adding surcharges to cope with increasing fuel prices due to environmental regulation. The company is using the bunker adjustment factor (BAF) which is based on the difference of the average price difference between the low-sulphur fuel (1% content) and MGO used (0.1% content) within ECAs. The exact increase in transport costs is different depending on the length of the route, the speed and type of vessel, and the carrying capacity of the vessel (DFDS, 2014). The surcharge is then broken down based on the number of lane meters of cargo transported per ton of fuel. On average this was 67 lane meters. The expected BAF after the new sulphur limits was raging from 1.25€ (Dover - Dunkirk) to 8.25€ (Rosyth – Zeebrugge) per lane meter. This BAF is then corrected based on the monthly average fuel price. For example, in December 2015 the correction ranged from 0.03€ to 1.14€ per lane meter. The previous additional costs can therefore affect the mode choice for certain shippers.

[4] Source: http://www.cosbc.ca/index.php/international/item/1748-eu-hands-out-scrubber-subsidies

5 Route selection criteria

The first step of the project refers to the selection of representative routes served by DFDS, and analyze the effects of the new sulphur limits on the transport network. The most important route selection criteria for a representative set of case studies to examine the impacts of the stricter sulphur requirements are:

- Geographical balance
- Chain configuration
- Volume
- Commodity mixture
- Vessel types
- Data availability

This section presents how these were taken into account for the route selection.

5.1 Geographical Balance

The DFDS network can be broken down into 4 main categories geographically; North Sea, Baltic Sea, Cross-Channel, and France-Mediterranean. The former three categories are comprised of routes that all belong completely in SECA while for the latter case the only sulphur regulation is concerned with engine operation at berth.

The selected scenarios must therefore exhibit a geographical coverage that reflects the company's network. As seen in Figure 5 the majority of routes were in the North Sea, followed by the Baltic Sea routes, and then the Cross-Channel routes.

For this reason, the selected scenarios of the existing fleet are four in the North Sea, two in the Baltic, and one of the three Cross-Channel routes. In addition, it is envisaged that the Mediterranean route will also be explored for comparison purposes as it is not affected by ECA regulations.

5.2 Chain configuration

The 25 routes have very different characteristics in terms of sailing frequency, number of vessels deployed, sailing distance in each sea leg, and actual deployment time. It is therefore important to select routes that are of varying lengths and sailing frequencies.

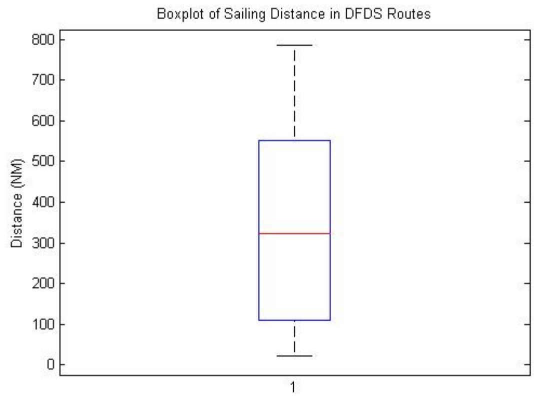
5.2.1 Sailing Distance

The selection of the routes to be analyzed will take into account the sailing distance to create a representative dataset. The sailing distance in each link, as shown in Figure 6, varies from very short (22 NM) in the case of the cross-channel routes to relatively large (750 NM) for short–sea shipping. The quartiles, minimum and maximum distance of the full set are summarized in

Table 3.

Table 3: Descriptive Statistics of DFDS Routes

Statistic	Distance	Route
Minimum	26	Dover-Calais
First Quartile	138	Copenhagen – Fredericia
Median	324	Cuxhaven – Immingham
Third Quartile	472	Marseille – Tunis
Maximum	786	St. Petersburg – Kiel



5.2.2 Frequency of service

In terms of sailing frequency, this varies significantly across the different routes from multiple sailings per day, to one sailing per week. There is also a seasonality effect to some of the services according to demand. Figure 7 presents a bar chart with the maximum sailings per week in each link during the summer of 2015 (both directions).

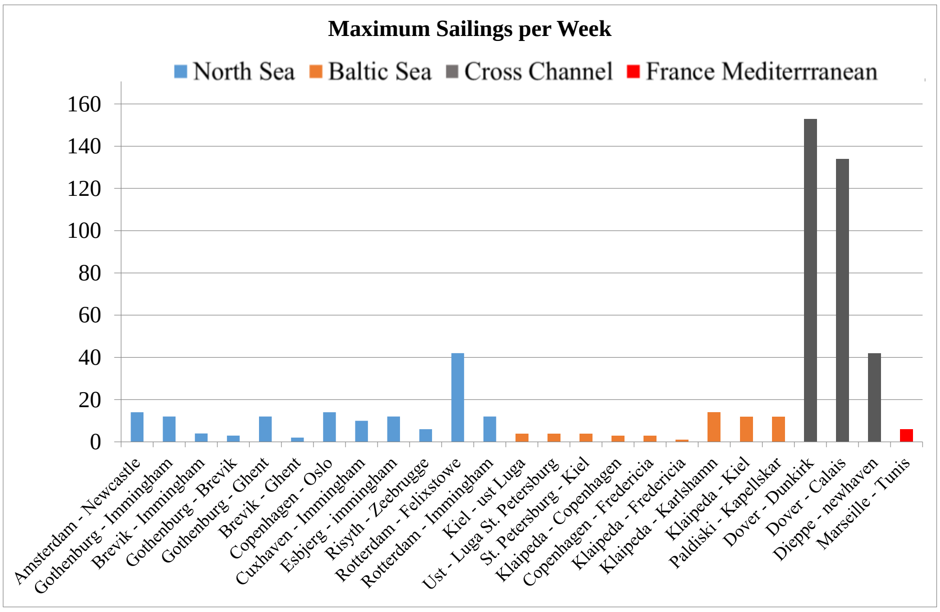


Figure 7: Maximum frequency of each link per Week

It can be seen that there is a significantly higher frequency in the cross-channel routes. With the exception of Rotterdam-Felixstowe, which is one of the shortest routes that connect two important ports, all other routes are limited to 2 daily departures or less. During the peak periods, the total weekly distance travelled in each link is depicted in Figure 8.

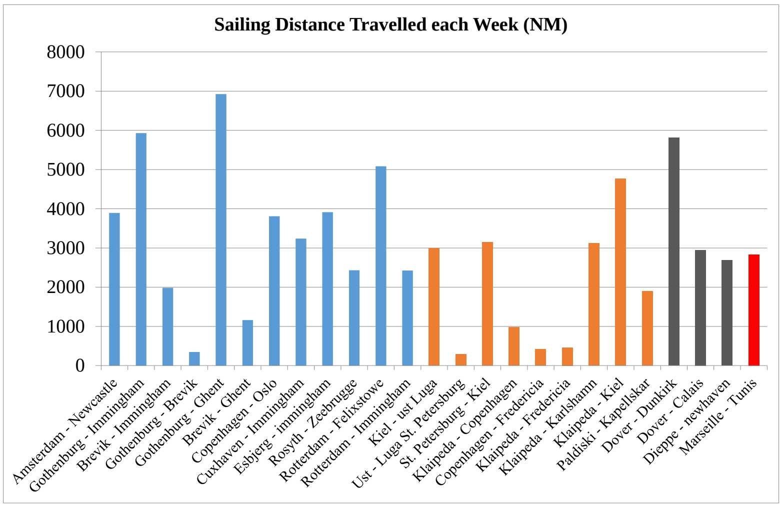


Figure 8: Total sailing distance covered during peak weeks for each route

These variations in the frequency of each service results in some important differences in the actual time the vessels spend cruising. During the weeks with the highest frequency of sailings at each route, the ratio of sailing hours over hours spent at berth (in all calling ports) varies across the different routes. These are summarized in Figure 9, where the darker shaded columns indicate the sailing hours per week in each route.

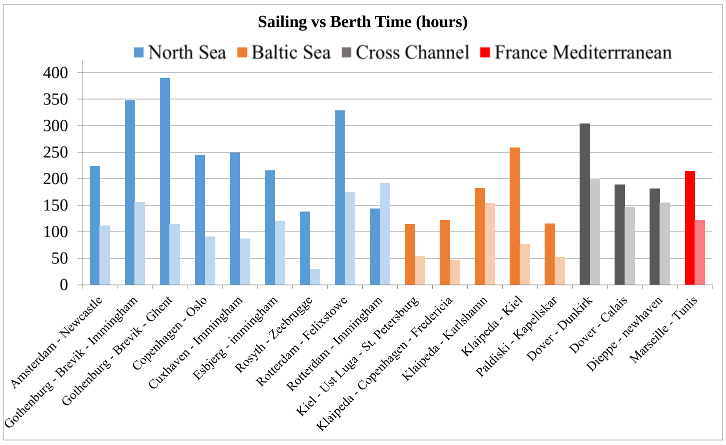


Figure 9: Ratio of hours sailing (dark) vs hours at berth (light shaded)

5.3 Volume

The selected routes need to collectively cover a significant part of the DFDS total traffic. The maximum capacity offered in each DFDS route can be estimated as a function of the maximum capacity in each vessel deployed in the route, and the frequency of the service. Therefore, the selected routes should represent a non-trivial part of the total volume capacity of the company. The capacity for Ro-Ro vessels is usually measured in the maximum number of available lane meters. A lane meter is an area of deck that is one meter long and has the width of one lane (a strip of deck that is 2 meters wide, though for some vessels a lane is wider and for DFDS between 2.8 and 3.0 meters). The capacity of vessels depends on the cargo mix and may vary for different compositions (Styhre, 2010). Liner vessels do not usually have precise information on their maximum capacity (Wu, 2009). Therefore, information for cargo capacity is varying with different estimations given from DFDS and other online sources (www.marinetrafic.com). This section will provide indicative estimates for the capacity in lane meters. Where the information is given into a combination of number of cars, trailers, or lane meters, this will be converted to an estimate number of lane meters. For example, for the two cruise ships deployed on the Amsterdam – Newcastle route, it is given that these can carry 600 cars each. The average passenger car has a length of between 4.2 to 5 meters and typically a length of 6 meters is required onboard a vessel considering the gaps between cars.

Table 4: Vehicle dimensions in Europe

Vehicle	Length (m)	Width (m)
Passenger Car	4.2-5	1.6-2.22
Trailer[1]	12	2.55
Articulated Vehicle[1]	16.6	2.55
Road Train[1]	18.75 (25.25 in Sweden)	2.55
Lorry with two trailers	24	2.55

[1] Maximum allowed dimensions. source: International Transport Forum

For Ro-Pax vessels, the capacity is broken down to two parts: lane meters for cargo, and maximum number of passengers onboard. This can be expressed by the percentage of the total lane meters-kilometers carried from the selected routes over the total network. The selected routes are accounting for approximately 43% of the total lane meters capacity.

5.4 Commodity mixture

This criterion refers to the variety of cargo types carried by the DFDS vessels. The most common commodities are trailers, containers, trucks, and driver-accompanied vehicles. However, more specified information on the exact cargo types and values transported onboard is not easily retrievable. The presentation of each route in sections 6, 7, and 8 will present more detailed information on the cargo types.

5.5 Vessel types

This criterion refers to a selection of a representative set of vessels for the full network. As a result, a mixture of cruise ships, Ro-Ro, and Ro-Pax vessels has been selected. The routes were selected in a manner that ensures a diverse range of vessels deployed in terms of capacity, engine size, age, and type of abatement technology used.

6 North Sea Routes

Excluding the Cross-Channel routes which technically belong in the North Sea, there are currently 12 main routes served by Ro-Pax and Ro-Ro DFDS ships sailing in this area. Of these routes, seven are operating between only two ports, while the other 5 are part of 2 main routes visiting 3 ports each. The routes are connecting Ireland, England, Scotland, France, Belgium, the Netherlands, Denmark, and Sweden. The routes have varying characteristics in terms of distance, frequency, cargo types carried, competition from other modes or other competitors, and technologies used for the abatement of sulphur emissions. Each main route will be presented in this section along with the justification of whether the route will be considered for further examination in the study.

6.1 Amsterdam (Ijmuiden) – Newcastle

This route connects England with the Netherlands via two Cruise ferries and a daily departure from each port. The distance is approximately 273 NM and the crossing time is around 16 hours. The vessels deployed and some key characteristics are shown in Table 5.The vessels are not equipped with scrubbers and are relying on MGO to adhere to the sulphur requirements.

Table 5: The two Cruise ferries serving the Amsterdam-Newcastle Route

Vessel	Year	SO_x abatement	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity			
					Lanemeters	Pax	Cars	Cabins
King Seaways 	1987	Low-sulphur fuel	21	19880	1410	1534	600	522
Princess Seaways 	1986	Low-sulphur fuel	21	19600	1410	1364	600	478

6.1.1 Alternatives

This route is currently unique and does not face direct competition from other maritime modes. A fully land-based alternative through the Channel tunnel is possible, but the overall distance would be approximately 1000 km. A different option is using the Harwich- Hoek van Holland ferry (106 NM) and road links for the remainder of the distance (590 km).

Other options would be getting a ferry from Newcastle to Zeebrugge (maritime leg of 296NM) through the Euro Marine Logistics service. This service is running a roundtrip and for cargo that is destined to the Northern part of England the connecting link is from Emden to Newcastle (327 NM).

6.1.2 Conclusion for selection of route

This is one of the shortest routes of DFDS and it targets mainly cruise passengers with cars. The lack of direct competition from other shipping lines on the same link is not providing significant reasons to focus on this link, as there are similar links in the Baltic Sea that offer the same characteristics. In addition, the fully land based option is much longer in comparison. Therefore, due to the geographical balance requirements for the route selection, and the fact that this link is essentially targeting passengers (with less influence by the regulation; EMSA, 2010) at this stage this link will not be explicitly studied.

6.2 Gothenburg-Brevik-Immingham

This route is linking Sweden, Norway and England via three Ro-Ro vessels that are deployed in the network of the three ports. Of these vessels, two are equipped with scrubbers and one is using MGO. The cargo capacity in lane meters is 4650, 4650 and 3322.

Table 6: The three Ro-Ro ferries serving the Gothenburg-Brevik-Immingham Route

Vessel	SO_x abatement	Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity	
					Lanemeters	Pax
Freesia Seaways 	Scrubbers	2005	22.5	20070	4650	12
Fionia Seaways 	Low-sulphur fuel	2009	20	19200	3322	12
Begonia Seaways 	Scrubbers	2004	22.5	20070	4650	12

As the port visiting sequence is complicated, the network will be broken down into port to port routes, where virtual links will be included. In addition, the Brevik-Gothenburg link is also serviced by vessels deployed in the Gothenburg-Brevik-Ghent route. Table 7 summarizes the distances and average voyage times for each pair. Each individual leg will be presented in more detail.

Table 7: The weekly service of Gothenburg-Brevik-Immingham

Departure	Arrival	Distance in NM (km)	Time (hours)
Gothenburg	Immingham	494 (914.9)	26.5 (36)
Immingham	Gothenburg	494 (914.9)	28 (42)
Gothenburg	Brevik	116 (214.8)	11 (64)
Brevik	Gothenburg	116 (214.8)	14 (107)
Immingham	Brevik	496 (918.6)	29 (43)
Brevik	Immingham	496 (918.6)	25 (46)

Gothenburg – Immingham

This link is normally serviced six time per week with a crossing time of on average 26 hours, with the exception of days where the vessel visits Brevik (departure from Gothenburg on Thursday) where the virtual link requires 36 hours in total. During July, there was a seasonality effect with a less frequent service (4 departures per week of which 1 was via Brevik). The cargo mixture includes paper, steel, new cars, trailers, containers and various types of rolling goods.

Immingham – Gothenburg

This link is also serviced six times a week with a crossing time of 28 hours except on the day where the ship visits Brevik (departure from Immingham on Sunday) where the virtual link takes 42 hours.

6.2.1 Alternatives

There is not currently another direct ferry service between the two ports. The route will be facing competition from other short Ro-Ro links (for example Immingham – Cuxhaven, or Immingham-Rotterdam) followed by road links. A fully land based option through the Channel tunnel and the tolled bridges between Germany Zealand and Zealand with Sweden is possible, but requires a total distance of 1838 km.

Gothenburg – Brevik

This route will be analyzed in more detail in the next section

Immingham – Brevik

This link is serviced two times each week, where the departure on Sunday is a direct trip to Brevik lasting 29 hours, while the departure on Wednesday is stopping at Gothenburg for a total travel time to Brevik of 43 hours. Cargo mixture between the two ports includes trailers, lorries, containers, machinery, trucks and cars.

Brevik – Immingham

This link is also serviced two times each week with one direct trip (25 hours) and one with an intermediate stop at Gothenburg (46 hours in total).

6.2.2 Conclusion for selection of route

Of the three routes within this service, the most interesting is Gothenburg-Immingham. This leg is one of the longest in the DFDS network, with regular frequency and varying travel times due to the intermediate stops at Brevik. In addition, there is competition with other DFDS links that connect the UK with Northern Europe or Scandinavia. The other two routes (Brevik-Immingham and Brevik-Gothenburg) are of very low frequency and will not be explicitly considered. However, it appears more sensible to analyze the Gothenburg-Ghent route instead, as Immingham is also served by other routes of DFDS, whereas the Ghent terminal is only served in the following route.

6.3 Gothenburg-Ghent-Brevik

This route is linking Sweden, Belgium and Norway via three Ro-Ro vessels that are deployed in the network of the three ports. All vessels are equipped with scrubbers.

Table 8: The three Ro-Ro ferries serving the Gothenburg-Ghent-Brevik Route

Vessel	SO_x abatement	Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity	
					Lanemeters	Pax
Petunia Seaways 	Scrubbers	2004	22.5	20070	3831	12
Magnolia Seaways 	Scrubbers	2003	22.5	20070	3831	12
Primula Seaways 	Scrubbers	2004	22.5	20070	3831	12

As the port visiting sequence is complicated, the network will be broken down into port to port routes, where virtual links will be included. Table 9 summarizes the distances and average voyage times for each pair. Each individual leg will be presented in more detail.

Table 9: The weekly service of Gothenburg-Ghent-Brevik

Departure	Arrival	Distance in NM (km)	Time – hours (virtual)
Gothenburg	Ghent	577 (1069)	33
Ghent	Gothenburg	577 (1069)	33 (42)
Gothenburg	Brevik	116 (214.8)	8
Brevik	Gothenburg	116 (214.8)	14, 7
Ghent	Brevik	580 (1074)	(30-48)
Brevik	Ghent	580 (1074)	(34-45)

Gothenburg – Ghent

This link is serviced six times per week with a crossing time of on average 33 hours, with the exception of days where the vessel visits Brevik (departure from Gothenburg on Thursday) where the virtual link requires 36 hours in total. During July, there was a less frequent service (3 departures per week of which 1 was via Brevik). The cargo mixture on this link includes trailers, lorries, containers, new cars, and machinery.

Ghent – Gothenburg

This link is serviced six times per week with a duration of 33 hours on average, except one sailing which is scheduled via Brevik and lasts 42.

6.3.1 Alternatives

The port of Ghent is only connected to Gothenburg via the DFDS route. Competitive Ro-Ro services from Gothenburg to Zeebrugge are offered from CldN (daily departure from each port with a crossing time of on average 36 hours) and SOL Continent Line (four departures from each port per week with two ships) are available. Euro marine Logistics is also offering a car carrier service that calls in 5 ports including a direct link from Zeebrugge to Gothenburg. A land based alternative requires driving a distance of 1239 km that includes a ferry crossing between Puttgarden and Rødby.

Ghent - Brevik

This link is serviced one time each week, with a departure from Ghent on Friday evening and an arrival at Brevik after 30 hours without any stops. Cargo mixture between the two ports includes trailers, containers, factory new cars and trucks, motor homes and caravans and high and heavy project cargoes. The cargo origin may be from Spain, France and Belgium on its way to Norway.

Brevik – Ghent

This link is also serviced one time each week with one trip via Gothenburg that departs from Brevik on Sunday mornings and arrives in ghent on Tuesday morning (45 hours in total).

6.3.2 Alternatives

Brevik is only served by the DFDS routes that connect Sweden with Belgium and Sweden with England. Therefore, the competition the link is facing is with shipments sent on the Gothenburg-Ghent link which is more frequent and relying on a road connection to Brevik on days where the Brevik-Ghent link is not running. This road distance is 333 km and includes a toll and a ferry passage between Moss and Horten for an estimated travel time of 4 to 5 hours. Another option would be driving from Ghent to the northern part of Jutland and taking a ferry from Hirtshals to Larvik (200 NM), for a total distance of 1325 km.

Gothenburg – Brevik

This link is operated one time each week. On Thursdays a departure from Gothenburg towards Immingham via Brevik is planned. The Gothenburg – Brevik leg requires 8 to 11 hours depending on the season and the schedule for the virtual link Gothenburg-Immingham.

Brevik – Gothenburg

This link is operated two times each week. A departure from Brevik towards Ghent with an intermediate stop at Gothenburg is planned every Sunday. The Brevik-Gothenburg leg requires 7 hours to cross. A departure from Brevik towards Immingham is planned each Tuesday (00:00) via Gothenburg (departure at 20:00).

6.3.3 Alternatives

As stated in the previous section, the road alternative would require a minimum distance of 333 km with a ferry passage between Moss and Horten.

6.3.4 Conclusion for selection of route

Similar to the Gothenburg-Immingham-Brevik, the most important leg in this route is the Ghent-Gothenburg route. The relatively long sailing distance in comparison with other DFDS routes and the direct competition with a mostly road mode offers a good potential for analysis. This route is considered for additional analysis. With regards to the Ghent-Brevik link, the very low frequency does not make it an important route to be considered. However, indirect repercussions of that link will be considered due to the added time in the virtual sailings between Ghent and Gothenburg when an intermediate stop at Brevik occurs.

6.4 Copenhagen - Oslo

This route connects Norway with Denmark with two Cruise ferries sailing a distance of 272 NM in approximately 17.5 hours. A vessel departs from Copenhagen at 16:30, and from Oslo at 16:00. Table 10 presents the key characteristics of the two Cruise ferries on this route; Crown Seaways which is the first cruise ferry of DFDS to use scrubber systems, and Pearl Seaways that relies on low-sulphur fuel.

Table 10: The two Cruise ferries serving the Copenhagen-Oslo route

Vessel	Year	SO_x abatement	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity			
					Lanemeters	Pax	Cars	Cabins
Crown Seaways 	1994	Scrubbers	16	19880	1370	1790	450	637
Princess Seaways 	1989	Low-sulphur fuel	16	23370	1482	1989	320	702

6.4.1 Alternatives

There is a fully landbased alternative for this link by using the Oresund Bridge and driving across the west coast of Sweden (via Gothenburg) with a total distance of 603 km. There is not a competitive Ferry service linking the two ports, though another option would be using the Stena Lines ferry from Oslo to Frederikshavn in the northernmost port of Jutland, and then driving to Copenhagen (total distance of 670 km). The crossing time is 9 hours from Denmark to Norway, and 12 hours in the return. This service runs 6 times a week (every day except Monday). Finally, there is also a Ferry connecting Oslo to Kiel with a crossing time of 20 hours to which the added road link would make it unrealistic as an alternative option.

6.4.2 Conclusion for selection of route

This is one of the shortest routes in the North Sea that offers daily services and deploys two vessels of the fleet with high cargo capacity. The route is considered for further analysis as it offers insight on the trade between Norway and Denmark which are not represented in any other selected route. In addition, this route has the advantage of offering a very competitive land mode with very similar distances involved.

6.5 Cuxhaven - Immingham

Two Ro-Ro vessels are connecting Germany and England with a service that departs 5 times each week in each direction, serving only commercial customers. The voyage lasts on average 24 hours but significant variation in scheduled duration is observed, with the longest time being 32 hours on Saturdays from Germany to UK. The sailing distance is around 324 NM (600 km). Table 11 presents some key technical characteristics of the two Ro-Ro ships; Britannia and Hafnia Seaways.

Table 11: The two Ro-Ro ferries serving the Cuxhaven-Immingham route

Vessel	SO_x abatement	Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity	
					Lanemeters	**Pax**
Britannia Seaways 	Scrubbers	2000	21.1	21600	2772	12
Hafnia Seaways 	Low-sulphur Fuel	2008	20	18900	3322	12

The vessels are carrying a mix of commodities, including paper in reel or palletized form, steel, coil in various forms, trailers, containers, automotive cargo, machinery and driver accompanied vehicles. Both ports are linked with national roads, with Immingham being well connected to the Midlands and their industrial regions, and Cuxhaven in good connection with Bremen and Hamburg.

6.5.1 Alternatives

A fully landbased option exists by driving through M11 and crossing the Channel tunnel to Calais, driving through Antwerp to Cuxhaven with a total distance of 1165 km. There is not a competitive service that links the two ports directly. A car-carrier service from UFCC is linking the ports in a roundtrip that visits 8 ports in total. Cuxhaven is also connected with the following UK ports: Southampton (direct link through two car-carrier services from UFCC), Sheerness (indirect link in a Ro-Ro service from Wagenborg Shipping Sweden), Harwich (direct link in a Ro-Ro service from Mann lines). Other options would include driving from Cuxhaven to Netherlands or France and using other services to cross over to the UK, including other DFDS services (Imminghamg-Ghent, Immingham Esbjerg).

6.5.2 Conclusion for selection of route

This route will not be considered for further analysis at this stage, as the existing alternatives are not directly competitive with this link. In addition, the land based alternative has a considerable increase in travelling distance (almost 100%). Finally, from routes within the North Sea that connect the UK with central Europe there are other links that are more promising in terms of alternatives offered and commodity mixtures.

6.6 Esbjerg - Immingham

This route connects Jutland of Denmark with England via two Ro-Ro vessels that depart six times per week in each direction (evening departures daily except Sunday). The sailing distance is approximately 326 NM (604 km) and the voyage lasts 18 hours.

Table 12: The two Ro-Ro ferries serving the Esbjerg-Immingham route

Vessel	SO_x abatement	Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity		
					Lanemeters	TEU	Pax
Ark Dania 	Scrubbers	2014	20.5	19540	3000	342	12
Ark Germania 	Scrubbers	2014	20.5	19540	3000	342	12

The cargo mix comprises of trailers, lorries, tank-containers, machinery and cars, while a limited number of drivers can be transported (amenities for 12 passengers).

6.6.1 Alternatives

A fully landbased option is offered by driving through M11 and crossing the Channel tunnel to Calais, driving through Brussels and Hamburg to Esbjerg in a total distance of 1466 km. A directly competitive service is offered by Stena Lines with the same departure times as the DFDS route. The port of Esbjerg is serviced by a Euro Marine Logistics car-carrier service in a roundtrip that links 7 ports (Newcastle being the UK port), and a Ro-Ro service that connects Jutland with Zeebrugge. Links from Immingham to Cuxhaven, Antwerp or Ghent could be used followed by road connections to Esbjerg.

6.6.2 Conclusion for selection of route

This route will be considered for further analysis as it may offer some insights. It is a medium length service that has a direct maritime competitor, the main land-based mode is significantly bigger and other options that use a combination of road and water modes are available. In addition, this is one route that deploys Ro-Ro vessels that offer diversion to the selection.

6.7 Rosyth - Zeebrugge

This DFDS route connects Scotland and Belgium with a Ro-Ro vessel that departs three times every week in each direction. The sailing distance is approximately 405 NM (750 km) and the voyage lasts 23 hours in the eastbound and 22 in the westbound direction. Table 13 presents the technical characteristics of the Ro-Ro vessel on this route, Finlandia Seaways. Apart from these vehicles, the vessel carries unaccompanied trailers, trade cars, vans, and machinery.

Table 13: The Ro-Ro ferry serving the Rosyth-Zeebrugge route

Vessel	SO_x abatement	Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity		
					Lanemeters	TEU	Pax
Finlandia Seaways 	Scrubbers	2000	20	12600	1899	300	12

6.7.1 Alternatives

The main competition that this route faces is from land based modes. One option is driving through M74, M6, M40, M25, M20 and then crossing the Eurotunnel to Calais and driving to Zeebrugge (distance of 1018 km). The other option is to drive via M74, A1 and M11 to Harwich, use a ferry service to Hoek van Holland and then drive to Zeebrugge through Antwerp (total distance of 1144 km). Other DFDS links connecting the UK with Europe could be used (Amsterdam-Newcastle, Rotterdam-Immingham, Rotterdam-Felixstowe, cross-channel routes from Dover), and in general there are various options connecting the two ports. However, the only direct maritime link between the two ports is offered by DFDS.

6.7.2 Conclusion for selection of route

This route has some unique characteristics that would make it interesting as a case study. The landbased options are very competitive due to the very small difference in the total distance travelled. As a result, a fully land based mode can be significantly faster compared to the maritime option. In addition, the service is medium frequency, and the only DFDS route that connects with Scotland. However, following discussions in the AC meeting it was suggested that the Immingham-Esbjerg route will be considered instead, and the Rosyth-Zeebrugge route was a runner-up.

6.8 Rotterdam - Felixstowe

This DFDS route connects England and the Netherlands with three Ro-Ro vessels that depart three times daily in each direction. This service was actually expanded in July 2015, when a third service on Fridays was added to meet the increased transport demand. The new vessel is Anglia Seaways, which was previously deployed in the Klaipeda-Travemünde. The sailing distance is approximately 121 NM (224 km) and the voyage lasts between 7.5 and 8.5 hours. Table 14 shows the technical characteristics of the current vessels deployed in this route.

Table 14: The three Ro-Ro ferries serving the Rotterdam-Felixstowe route

Vessel	SO_x abatement	Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity		
					Lanemeters	TEU	Pax
Suecia Seaways 	Scrubbers	1999	21.5	21600	2772	180	12
Selandia Seaways 	Scrubbers	1999	21.1	21600	2772	-	12
Anglia Seaways 	Low-sulphur fuel	2000	18.6	10950	1692	-	12

The route targets time sensitive goods (fresh foods, car components), and clients include manufacturers, distributors and other transport companies.

6.8.1 Alternatives

A similar competitive service is offered by Stena Lines that connects Rotterdam with Harwich on a service with 10 departures per week and takes a crossing time of around 8 hours (two departures per day between Tuesday-Friday, one on Mondays and Sundays). Stena lines also connects Harwich with Hoek van Holland 2 times daily in a crossing that requires 7 hours on average. There are additional options that use the Channel tunnel and include driving from Calais to Antwerp and then Rotterdam (total distance of 575 km).

6.8.2 Conclusion for selection of route

This route will be considered for further analysis as it is one of the shortest routes offered by DFDS and deploys a very frequent service with three Ro-Ro vessels. The route may offer important insight due to the nature of the commodities transported that require a fast and reliable service. As a result, potential mitigation measures that affect travel time or frequency could impact the transport demand heavily. Finally, the route has already seen an increase in demand (demonstrated by the increased frequency) and is therefore an interesting option with a significant portion of the total volumes transported by DFDS.

6.9 Rotterdam - Immingham

This is another service that connects the Netherlands with the UK. Two Ro-Ro vessels are deployed in this route with six departures per week from each direction (1 per day except on Sundays).The sailing distance is approximately 202 NM (374 km) and the duration of the voyage is approximately 11.5 hours on weekdays and between 13 and 14.5 hours on weekends. Table 15 presents the two Ro-Ro vessels currently deployed in this route.

Table 15: The two Ro-Ro ferries serving the Rotterdam-Immingham route

Vessel	SO_x abatement	Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity	
					Lanemeters	Pax
Jutlandia Seaways 	Low-sulphur fuel	2010	20	18900	3322	12
Ficaria Seaways 	Scrubbers	2006	22.5	20070	4650	12

6.9.1 Alternatives

There is not a competitive maritime service connecting the two ports directly. Freight ferry alternative services of similar length include the Harwich- Hook of Holland and Harwich - Rotterdam ferry services of Stena Lines, the Hull- Rotterdam and Hull-Zeebrugge (P&O Ferries). A landbased option through the Channel Tunnel is 759 km long.

6.9.2 Conclusion for selection of route

This route will not be considered for further analysis as there many similarities with the Rotterdam-Felixstowe DFDS link, and fewer unique representative characteristics in comparison with other routes. Comparing the two routes, the latter is offering a more frequent service and a more interesting commodity mixture due to the time-sensitive goods carried.

6.10 Summary of North Sea Routes

The selected routes of the North Sea are summarized in Table 16 along with the current vessel deployment serving these routes.

Table 16: The selected DFDS routes in the North Sea

Route	Vessel	Type	Abatement technology	Vessel Capacity	
				Lanemeters	Passengers
Gothenburg – Ghent	Petunia	Ro-Ro	Scrubbers	3831	12
	Magnolia	Ro-Ro	Scrubbers	3831	12
	Primula	Ro-Ro	Scrubbers	3831	12
Copenhagen Oslo	Crown	Cruise	Scrubbers	(450 cars)	1790
	Pearl	Cruise	Low-sulphur fuel	(320 cars)	1989
Esbjerg – Immingham	ARK Dania	Ro-Ro	Scrubbers	3000	12
	ARK Germania	Ro-Ro	Low-sulphur fuel	3000	12
Rotterdam – Felixstowe	Suecia	Ro-Ro	Scrubbers	2772	12
	Selandia	Ro-Ro	Scrubbers	2772	12
	Anglia	Ro-Ro	Low-sulphur fuel	1680	12

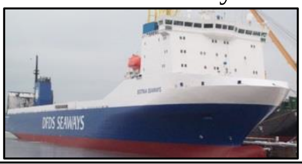
7 BALTIC SEA ROUTES

There are currently 5 main routes served by DFDS in the Baltic Sea, and a sixth that was shut down in August 2014. These routes are connecting Denmark, Germany, Lithuania, Estonia, Russia and Sweden. These routes have several differences in terms of sailing distance, frequency of service, cargo carried, and competition. This section briefly presents each route in order to establish arguments for the selection of the routes to be examined from the Baltic Sea cohort.

7.1 Kiel-Ust Luga – St. Petersburg

This route connects Germany with Russia via a Ro-Ro vessel that runs a weekly service visiting each port once. The round trip distance is approximately 1607 NM which comprises of 2 long distance sea legs and one short (Ust Luga - St. Petersburg at 72 NM). The sailing distance is approximately 405 NM (750 km). Table 17 presents the technical characteristics of the Ro-Ro vessel on this route, Botnia Seaways.

Table 17: The Ro-Ro ferry serving the Kiel-Ust Luga-St. Petersburg route

Vessel	SO_x abatement	Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity	
					Lanemeters	Pax
Botnia Seaways 	Scrubbers	2000	20	12600	1899	12

The short leg is also served by Euro-Marine Logistics in their Newcastle-Ust Luga- St. Petersburg route that is dedicated to a car-carrier service with a weekly service, and Finnlines through a Ro-Ro service. However, this particular leg would heavily compete with 2 road alternatives of distances of 163 or 175 km. As of October 2015, DFDS decided to move Botnia Seaways to other duties in the network, and would instead acquire space from Finnlines to cover the capacity needs. The new voyage times are slower, with the Kiel-Ust. Luga leg requiring 35 hours, and the St. Petersburg-Kiel link taking 99 hours.

7.1.1 Alternatives

The long distance legs (Kiel to Ust Luga and St.Petersburg to Kiel) are not serviced by other shipping companies. Therefore, the only significant competition is land based. There are two main road alternatives that are fully land-based; through Poland-Lithuania-Latvia (2078 km) or through Poland-Belarus (2263 km) and therefore the distance travelled is comparable to the maritime route (1441 km). There is an additional option of going through Sweden using 3 ferry services.

7.1.2 Conclusion for selection of route

As this service is weekly and it only covers a trivial fraction of DFDS ro-ro traffic, the route will not be further considered at this stage.

7.2 Klaipeda-Copenhagen-Frederecia

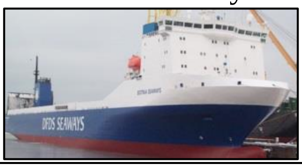
This route connects Denmark with Lithuania via a Ro-Ro vessel in a service that runs twice a week with a roundtrip distance of 1848 NM. The commodity mix in this route is comprised of accompanied trailers, trailers, containers on mafi’s, tractors, excavators, and machinery. The different sea legs are short and medium distance and there are multiple visits at each port during each roundtrip as summarized in Table 18. Each sea leg will be presented in more detail in a separate section.

Table 18: The weekly service of *Klaipeda-Copenhagen-Frederecia*

Departure	Arrival	Distance in NM (km)	Time (hours)
Copenhagen	Fredericia	138 (255.6)	9
Fredericia	Copenhagen	138 (255.6)	9.25
Copenhagen	Klaipeda	325 (601.9)	21
Klaipeda	Fredericia	459 (850.1)	31.5
Fredericia	Copenhagen	138 (255.6)	9
Copenhagen	Klaipeda	325 (601.9)	21
Klaipeda	Copenhagen	325 (601.9)	21

Table 19 presents the technical characteristics of Corona Seaways that is deployed on this route.

Table 19: The Ro-Ro ferry serving the Klaipeda-Copenhagen-Fredericia route

Vessel	SO_x abatement	Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity	
					Lanemeters	Passengers
Corona Seaways 	Low-sulphur fuel	2008	20	18900	3322	12

Copenhagen – Fredericia

This link is served two times per week, where once it is a direct sealeg, and the other time is essentially a virtual link with an intermediate vessel call at Klaipeda. Departure on Monday from Copenhagen requires 9 hours to reach Fredericia, while cargo loaded in Copenhagen on Wednesday will require 58.5 hours to reach its destination in Fredericia.

Fredericia – Copenhagen

This link is served two times per week through direct sea legs and a voyage time of 9 hours.

7.2.1 Alternatives

The road alternative requires passage through E20 using the Great Belt Fixed Link that is tolled, while the total distance stands at 216 km which is shorter than the maritime route and much faster.

Copenhagen – Klaipeda

This link is also served twice per week, but with two direct sailings between the two ports and a voyage time of 21 hours.

Klaipeda – Copenhagen

This link is served twice a week where the first connection is direct (Sunday 21:00 to Tuesday 06:00) requiring 21 hours, while the second connection is a virtual link that requires 48.5 hours (Thursday 11:00 to Saturday 11:30).

7.2.2 Alternatives

Alternative routes include taking the ferry from Gelder to Rostock and then driving through Poland for a total distance of 1572 km, or driving to Sweden and Karlshamn and taking a direct ferry to Klaipeda (also served by DFDS) with a shorter overall time, which makes the latter link more interesting for examination. The port of Klaipeda is only connected through DFDS to other destinations.

Fredericia – Klaipeda

This is a virtual link that is served two times a week, with an intermediate stop at Copenhagen and an overall voyage time of 32 to 33.5 hours.

Klaipeda – Fredericia

This link is served twice a week, one direct sailing that requires 31.5 hours and one virtual link that requires 32 hours despite the short call at Copenhagen (3 hours).

7.2.3 Alternatives

There are two fully land based routes going through Germany and Poland (via Berlin and Warsaw or via Rostock and Malbork) with distances of 1538 or 1666 km. There is also a route via driving to Sweden and taking the Karlshamn Klaipeda ferry.

7.2.4 Conclusion for selection of route

While there are some interesting links present in this service, due to low frequency of sailings and the competition part of the sealegs are facing from other DFDS routes, this service will not be examined in detail in this project. However, the analysis of this route will be useful in analyzing the Klaipeda – Karlshamn route that is an alternative for some of the previous legs and runs a daily service.

7.3 Klaipeda-Karlshamn

This route connects Sweden with Lithuania via two Ro-Ro vessels with one departure daily from each side. The sailing distance for each way is approximately 223 NM (413km), and the vessels are commuting in 13 hours each direction. Table 20 presents some key technical characteristics of the two Ro-Pax ships; Athena and Regina Seaways. It should be noted that Regina Seaways was previously deployed on the Klaipeda-Kiel route, and since September it has been swapped with Optima Seaways that is now deployed there.

Table 20: The two Ro-Pax ferries serving the Klaipeda-Karlshamn route

Vessel	SO_x abatement	Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity		
					Lanemeters	Cabins	Pax
Athena Seaways 	Low-sulphur fuel	2007	23.5	24000	2490	113	600
Regina Seaways 	Scrubbers	2010	24	24000	2496	114	600

7.3.1 Alternatives

As mentioned in the previous section, the port of Klaipeda is not served by companies other than DFDS. This route appears geographically unchallenged by road and rail options, however there are two other options that involve long road segments. The first would be to drive north to Nynäshamn and take the ferry to Ventspils in Latvia, with a total distance of 1042km and a maritime leg of 166 NM. The second alternative would be to drive through Denmark (including the tolled Øresund Bridge and the Great Belt Fixed Link) and taking the ferry to Rostock from Gelder for a total distance of 1756 km.

A more realistic alternative for some cargoes would be using the Karlskrona – Gdynia Ro-Pax service of Stena lines to Poland for a maritime leg of 168 NM which is served two to three times daily and has a crossing time ranging between 10 and 12.5 hours.

7.3.2 Conclusion for selection of route

This is one of the shortest routes in the Baltic that offers daily services and deploys two vessels of the fleet with high cargo capacity. In addition, this is one of the links that will be less contested by road and rail options (there is no fully land-based alternative) and in particular the port of Klaipeda is currently not served by other companies. The route therefore presents an excellent opportunity to assess the impacts of the higher fuel costs (as both vessels run on MGO), given that the link is relatively safe from competition apart from a maritime leg connecting Poland with Sweden that could pose an alternative for some cargoes.

7.4 Klaipeda-Kiel

This route connects Germany and Lithuania via two Ro-Pax vessels that offer six departures per week in each direction. Each weekday there is one sailing each way whereas during the weekend there is one departure from Kiel on the late evening of Saturday (23:00) and one departure from Klaipeda on Sunday at 01:00. The duration of each voyage ranges around 22 hours for each direction. The sailing distance is approximately 397 NM (735 km). The cargo capacity and technical specifications of the two vessels currently deployed in the route (Optima and Victoria Seaways) are summarized in Table 21.

Table 21: The two Ro-Pax ferries serving the Klaipeda-Kiel route

Vessel	SO_x abatement	Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity		
					Lanemeters	Cabins	Pax
Victoria Seaways 	Scrubbers	2009	23.5	24000	2490	114	600
Optima Seaways 	Scrubbers	1999	21	18900	2115	66	328

7.4.1 Alternatives

This route faces strong competition from road modes as there two fully land based alternatives through Germany and Poland that are similar to the Klaipeda-Fredericia alternatives. The first link is driving near Rostock and Malbork for a total distance of 1351 km. The second link would be to drive through Berlin and Warsaw for a total distance of 1521 km. There is not currently any other ferry operator serving a similar link to Klaipeda - Kiel. The only alternative with a maritime component would be to use the service between Sassnitz (Germany) and Kaliningrad (Russia). However, it appears that following the acquisition of the company from the Russian Railways the vessel will be deployed in a different route, therefore only fully land based alternatives will be considered.

7.4.2 Conclusion for selection of route

Due to its high frequency and medium sailing distance, this route will be considered as it will offer interesting insights given there is strong competition with road modes that may have longer distances (almost double) but offer faster times. In addition, the deployed vessels have considerable capacity and are the only DFDS vessels in the Baltic that are currently equipped with scrubber systems.

7.5 Paldiski - Kapellskär

This route connects Estonia with Sweden via one Ro-Pax vessel with some additional TEU capacity that departs six times each week from each port. The vessel departs midnight of each day (except Thursday) from Paldiski, and at noon from Kapellskar with the exception of Thursday (22:30) and Friday where there is no service. The duration of each voyage is approximately 9.5 hours while the sailing distance is around 158 NM. The vessel currently deployed is Liverpool Seaways, and its main specifications are shown in Table 22.

Table 22: The Ro-Pax ferry serving the Paldiski-Kapellskär route

Vessel	SO_x abatement	Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity		
					Lanemeters	TEU	Pax
Liverpool Seaways 	Low-sulphur fuel	1997	20	15600	2460	357	300

7.5.1 Alternatives

There is no fully land based alternative connecting the two ports. There appeared to be a competitive service from the Tallink Silja Line that was running the same route, but this appears to have discontinued. A different option would be to use three ferry boats (Tallinn-Helsinki, Turku-Ahvenanmaa, Ahvenanmaa- Kapellskär) with a total distance of 526 km, which seems unrealistic due to the many modal changes for such a short port to port distance.

7.5.2 Conclusion for selection of route

This is the shortest route of DFDS within the Baltic Sea in terms of distance. The route has a high frequency service from one vessel that is running on MGO. However, the route is not particularly interesting in terms of repercussions from the additional fuel costs, as it is practically unrivalled from other competitive modes.

7.6 Summary of Baltic Sea routes

From the 5 routes in the Baltic that have deployed 7 DFDS vessels, the study will focus on two routes (Klaipeda- Karlshamn, Klaipeda-Kiel) that are deploying 4 vessels in total (2 vessels per route). Similarities on the two selected routes are limited in their high frequency of service, the significant carrying capacity, and the fact that all vessels are Ro-Pax. In addition, the port of Klaipeda is currently only served by DFDS vessels. Table 23 summarises the selected routes from the Baltic Sea, and the vessels serving these.

Table 23: The selected DFDS routes in the Baltic Sea

Route	Vessel	Type	Abatement technology	Vessel Capacity	
				Lanemeters	**Pax**
Klaipeda – Kiel	Victoria	RoPax	Scrubbers	2115	328
	Optima	RoPax	Scrubbers	2240	328
Klaipeda - Karlshamn	Athena	RoPax	Low-sulphur fuel	2490	600
	Regina	RoPax	Scrubbers	2496	600

There are important differences in the routes. Technologically, both Klaipeda-Kiel vessels have been retrofitted to use scrubbers. In terms of distance, the Lithuania-Sweden link is very short while the Lithuania-Germany link is medium. The former link will offer insight on the effects of the new sulphur limits given that there is strong competition with fully land based alternatives that faster and without a very steep increase in travelling distance. In addition, the recent shut down of the Klaipeda – Travemünde route will shift some cargoes in the same link which may affect the route positively. The latter link is practically unrivalled and allows for interesting analyses on ways to limit the negative effects of the increased fuel prices.

8 Cross Channel Routes

There are currently 3 cross channel routes served by DFDS. These are

- Dover-Calais,
- Dieppe-Newhaven,
- Dover-Dunkirk.

All routes share some common characteristics:

- Multiple sailings per day
- Short sailing distance
- Served by Ro-Pax vessels
- All DFDS vessels use MGO
- Driver accompanied vehicles
- Fast sailing speeds
- Departures span the full day
- Short stays at berth

The deployed vessels spend approximately half of their time sailing between the two ports of each link, and the remaining time at berth. All routes have very short distances, with the shorter corresponding to the Calais-Dover route. All routes face competition from the Eurotunnel which connects Folkestone and Calais via rail. The DFDS routes of Dover-Dunkirk and Newhaven-Dieppe are currently facing no maritime competition, as previous shipping lines serving these routes were either absorbed by DFDS or simply shut down their service.

8.1 Dover-Calais

This route connects the United Kingdom with France with two Ro-Pax vessels in a service that offers a maximum of 134 sailings (both ways) during peak weeks. The sailing distance is approximately 26 NM and average voyage time is 2 hours. There are plans of adding a third vessel in the service.This link has seen competition from other maritime operators. P&O ferries offered 23 sailings each day with an average crossing time of 1.5 hours. LD lines used to run a service but was merged with DFDS. Finally, MyFerryLink was also offering a service on this route, but it ceased operation on the 1st of July 2015. The main technical specifications of the two Ro-Pax DFDS vessels are shown in Table 24.

Table 24: The two Ro-Pax ferries serving the Dover-Calais route

Vessel	SO_x abatement	Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity		
					Lanemeters	Cabins	Pax
Calais Seaways 	Low-sulphur fuel	1990	21	21120	1784	81	2000
Malo Seaways 	Low-sulphur fuel	2000	25	39600	1950	NA	405

8.2 Dover-Dunkirk

This is the second option for connecting Dover with France, and in this case with the port of Dunkirk. The sailing distance is around 38 NM, and there is a maximum of 153 sailings (both ways) weekly.Three Ro-Pax vessels are currently deployed in this route which holds a monopoly from DFDS. Their technical specifications are summarized in Table 25.

Table 25: The three Ro-Pax ferries serving the Dover-Dunkirk route

Vessel	SO_x abatement	Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity		
					Lanemeters	Cars	Pax
Dover Seaways 	Low-sulphur fuel	2006	20.5	38400	2000	250	1000
Delft Seaways 	Low-sulphur fuel	2006	20.5	38400	2000	250	1000
Dunkerque Seaways 	Low-sulphur fuel	2005	20.5	38400	2000	250	1000

8.3 Dieppe-Newhaven

This link with a distance of approximately 64 NM connects France with England. There is a seasonal change in the frequency of service from 28 sailings a week for 29 weeks with one vessel, that increase to 42 (both ways) during peak periods in the summer via 2 Ro-Pax vessels that are run but not owned by DFDS.The route is only serviced by DFDS throughout the year. The two Ro-Pax vessels that are deployed in peak periods are summarized in Table 26.

Table 26: The two Ro-Pax ferries serving the Dieppe-Newhaven route

Vessel	SO_x abatement	Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity		
					Lanemeters	TEU	Pax
Cote d'Albatre 	Low-sulphur fuel	2004	22	16800	1440	52	600
Seven Sisters 	Low-sulphur fuel	2005	22	18900	1440	52	600

8.4 Summary and selection of Dover-Calais

The Cross Channel routes are very similar with each other, and due to their lower share of cargo compared to the full DFDS network, only one route will be examined. This will be the Dover-Calais route as it is the only route that competes directly with other maritime operators (P&O ferries), and is arguably the most affected by the Eurotunnel due to the proximity of the ports with the two sides of the tunnel. In addition, it has the shortest sailing distance and the shortest sailing time, while there is no significant seasonality in the frequency of the routes.

9 Mediterranean and Shut-Down Routes

9.1 French – Mediterranean Route

The Marseille - Tunis route is currently served by two Ro-Ro ferries that run three sailings per week in each direction with a voyage time of around 34 to 36 hours and a distance of 472 NM. The cargo mix includes trailers, containers, used cars, and a maximum of 12 driver accompanied vehicles. The full length of the route does not belong in a SECA and the only sulphur requirement is at berth in Marseille as the hoteling time is always longer than 2 hours, and the vessels would be using MGO at these stays. The technical specifications of the vessels deployed in this route are shown in Table 27.

Table 27: The two Ro-Ro ferries serving the Marseille-Tunis route

Vessel	SO_x abatement	Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity	
					Lanemeters	Pax
Ark Futura 	Low-sulphur fuel at berth in Marseille	1996	18.5	11120	2308	12
Beachy Head 	Low-sulphur fuel at berth in Marseille	2003	21	12600	2606	12

9.2 Harwich – Esbjerg

This was the only Ro-Pax service linking Denmark and England, and it was shut down in September 2014 in anticipation of the increased operating costs following January 2015. This route had been in operation for 140 years, and despite the historical significance to the company, it was struggling financially for a long time. The passenger service alternatives between Scandinavia and the UK are the Newcastle-Amsterdam and Dover-Calais or Dover-Dunkirk services from DFDS. Alternatively, services from Harwich to Hook of Holland and Harwich - Rotterdam ferry services of Stena Lines could be used, but would include additional driving distances.

During the last journeys in this service, Sirena Seaways was deployed offering a capacity of 610 passengers, 423 cars, and a total of 1956 lane meters. The vessel had a service speed of 22 knots, and following the closure of the route was moved to other routes from October 2014. In the end of January 2015 the ship was chartered to Britanny ferries to operate the Portsmouth – Le Havre route to meet the increased demand.

9.3 Portsmouth – Le Havre

This was a short-lived service offered by DFDS that connected England and France with a Ro-Pax service. The Seven Sisters vessel was deployed between June and December 2014, but was later moved to the Dieppe-Newhaven route (Table 26). The alternative options for passengers traveling between the UK and France involve the Britanny ferries offering a daily service in each direction. Other services from Portsmouth to Caen or Cherbourg are offered from Britanny services linking England and France, while the Cross-Channel options of DFDS are also available to passengers.

Finally, the route may also compete with the Eurotunnel. As this link has many options available, and essentially has been taken over by the Britanny ferries service, it will not be further examined for analysis.

9.4 Klaipeda – Travemünde

This was a new service launched by DFDS on the 14th of June 2014 to connect Lithuania and Germany via these terminals. The distance between the two ports is approximately 377 NM, and one vessel was deployed in the service (Botnia Seaways and Anglia Seaways) offering three sailings per week in each direction. The route was shut down from August 23rd 2014 due to the trade dispute between the EU and Russia. Therefore, this route will be considered ex-post to provide insight on the reasons of the route's termination. The fact that this route shuts down, may lead to some cargo being diverted to land based modes. There are three main options, driving through:

- Berlin-Poznan-Warsaw-Kaunas (1479km)
- Szczecin-Gdansk (1313 km)
- Szczecin-Malbork (1278 km)

DFDS is also suggesting the use of its Kiel and Klaipeda route as an alternative option. This is an additional reason why the Kiel-Klaipeda route has been selected. The company states that the route will be shut down until trade volumes have regained a viable level.

9.5 Summary of miscellaneous routes

This section presented routes that were recently shut down in anticipation of either the higher fuel costs due to the new sulphur limits, or due to trade implications. The only DFDS route that is currently not within an ECA was also shown. The Mediterranean route will be further examined for comparison purposes, as it will allow comparisons with the other routes that have increased fuel consumptions. In addition, the Harwich-Esbjerg route will also be examined for further analysis in order to understand the critical cost levels that led to its shut down, despite the long history of DFDS serving this particular route.

10 Data collection summary

10.1 Data sources

The main data collection undertaken so far, focused on the aggregate level of freight transport in Europe using information from Eurostat, and national statistical services. More detail was shown on the network specification, in order to select representative routes with regards to the full DFDS network. This task required a very thorough examination of all available information on the network configuration and the sailing schedules during the last 2 years. Apart from the snapshots of data presented in sections 6-8 for each route, the fleet deployment of all DFDS vessels during the last years has been retrieved. Technical information on all vessels has been retrieved, including installed engine power, main dimensions, capacity for passengers and cargo (lane meters), and abatement technology used (MGO or scrubber systems). Table 28 presents an overview of the necessary data for the subsequent analysis, and the next subsections describe in more detail the current status on each item.

Table 28: Overview of data collection for WP2

Maritime mode	*Road mode*
Shipping network configuration	Road network routes
Distances, speed and schedules	Distances & speeds
Ship & fleet characteristics	Vehicle & fleet characteristics
Traffic volumes	Traffic volumes
Cargo values	Cargo values
Fuel consumption	Fuel consumption
Fuel prices	Fuel prices
Freight rate information	Freight rate information
Other cost information (scrubbers, LNG, etc)	

10.2 Data on maritime mode

This section will present the current status on data collection for the maritime modes, with a more intense search for relevant technical information on vessels sailing the selected routes defined in the previous sections.

10.2.1 Shipping network configuration

Information on the shipping network included the identification of the ports and countries served by DFDS in the four main geographical areas where ferries operate. Full data on the network configuration have been gathered since 2013, which include the vessels assigned to each service throughout this period as well as the vessels that are laid up for maintenance or retrofits.

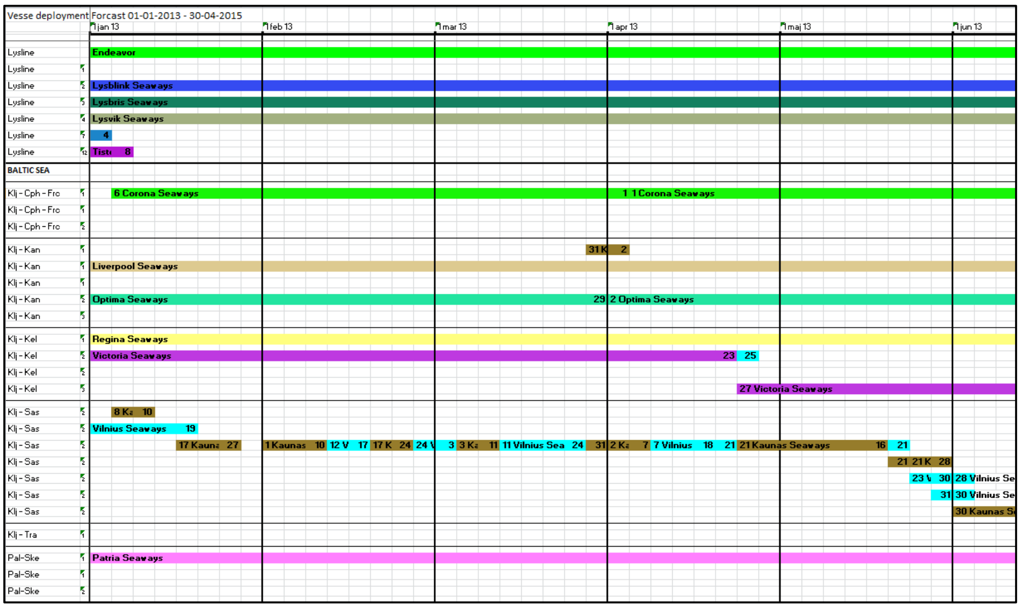


Figure 10: A sample of the vessel deployment in some DFDS routes.

10.2.2 Distances, speeds, and schedules.

The data collected were used to create taxonomy of the existing routes of the company in terms of sailing distance (short, medium, long), frequency of service, and number of vessels assigned. Information was primarily collected through the company's website (http://www.dfds.com/freight-shipping/routes-and-schedules) where the schedule is published and is regularly updated, particularly when there are seasonal changes. Some of the seasonal changes affect the number of vessels deployed, as well as the sailing speed used. For example, during the summer there were 2 Ro-Pax vessels deployed in the Dieppe-Newhaven route offering 3 departures per day in each direction, whereas from October 1st only one vessel is used to offer 2 departures per day.

Additional information was retrieved on some recently shut down routes, whose closure was primarily attributed to the anticipated increased fuel costs following interviews with company staff.

The nominal (planned) sailing speed of each leg was calculated based on the published schedule (planned departure and arrival time for each leg). This information will be cross-checked with the data on vessel trips that are concurrently collected (see section 10.2.6), as well as the technical specifications of the vessels in the DFDS fleet (see section 10.2.3).

10.2.3 Ship and fleet characteristics

The fleet deployment of DFDS vessels during the last 3 years has been collected. For each vessel a set of basic data was collected during the scenario selection stage. These data include information on:

- Dimensions (length, breadth, draft)
- Gross tonnage, net tonnage, deadweight tonnage,
- the age of each vessel including year of rebuilt (where applicable),
- the ownership status (owned by the company or under charter),
- its type (Ro-Pax, Ro-Ro, cruise),

- capacity (passengers, lane meters, and TEU where applicable),
- nominal power installed for each machinery onboard (propulsion engines, auxiliaries, bow and stern thrusters, boilers),number of propellers, shaft generators.

Figure 11 shows the technical specifications of one of the DFDS

MAIN DETAILS

Built	Signal letters	Flag	IMO No.:	Communication		14 feb 13
2006	**MJYC9**	**UK**	**9293088**	Inmarsat:		
Rebuilt	Port of Registry	Officers	Class	Mobile phone:		
	Dover	**UK**	**LR 100A1**	Fax:		
Owners	Crew	Ice	**RoRo Cargo**	e-mail:		
Norfolkline	**UK**	**No**	**& Pax Ship**			
GT	NT	DWT	Length	Width	Draft	Passengers
35.923	**10.776**	**6.874**	**186,65**	**28,40**	**6,75**	**780**
LDT 13.895,45 ts						

CAPACITIES

	Deck 3	Deck 4	Deck 5		Total	Note
Axle / tonsm2	**22,5 / 3,1**	**22,5 / 3,1**	**1,0 / 0,3**		**0**	
Lanemeters	**1.000**	**1.000**	**900**		**2.900**	
DTL lanemeters	**840**	**840**	**0**		**1.680**	
13,6m trailers	**60**	**60**	**0**		**120**	
Cars			**200**		**200**	
Motor Cycles			**50**		**50**	
Free height	**4,9**	**4,90**	**2,40**			
Comments	**On deck 3 aft of frame 82 a minimum uniform load of 4t / m2 is allowed**					
	Maximum boogie load on deck 3 and 4 is 35mt					

DTL lanemeters = a full load of 14m trailers stowed for ShortSea operation (quick loading/discharging)

RAMPS

From	To	No.	Length	Width	Height	Max.load weight
Deck 3	**Deck 4**	**1**	**48m**	**3,3m**		**PS tiltable**
Deck 4	**Deck 5**	**2**		**2,75m**		**SB Fixed**

LIFTS

From	To	No.	Length	Width	Height	Max.load weight

MACHINERY

Main engine/type	No.	Total kW / BHP	Bow thruster(s)	Stern thruster(s)	Stabilizers	Serv.Speed
MAN B&W 8L48/60B		**38.400 / 52.174**	**3 x 1.800 kW**	**1 x 1.800 kW**	**Finn**	**25,8 knots**
Aux engine/type	No.	Total kW / BHP				Propellers:
MAN B&W 6L32/40-CD		**8.640 / 11.739**				**CPP**
Consumption	Fuel type	per 24 hours	90% MCR	17 knots	15 knots	..... Knots (eco)
Main Engine	IFO 380	mtons	169,5			
Aux. Engine			Shaft generator	2	Total 3.800 kW	

All details believed to be correct, but not guaranteed

Figure 11: Sample data for one of the DFDS vessels. (Name is confidential)

For these ships, estimation on their fuel consumption per 24 hours for a set of different sailing speeds is known. More specific information on fuel consumption is provided in section 10.2.6. Additional basic information for each vessel includes the dimensions of ramps, the number of lifts and their weight limits. Most of these data are confidential, and will be used in order to more accurately model the implications of a change in the service frequency, or voyage characteristics (e.g. sailing speed) to the demand for transport, and consequently on fuel consumption.

10.2.4 Traffic volumes

Obtaining accurate and detailed information on traffic volumes has been one of the main challenges of this project so far. This has not been entirely a surprise, as flow data availability is a difficult issue in EU freight transport. With regard to cargo flows, following a series of interviews with the company representatives and with DFDS Logistics, it is clear that data on disaggregate level regarding cargo types, values, and origin-destinations are hard to retrieve due to the vast number of people involved for each individual shipment. As a result, data collection on traffic volumes is an ongoing procedure that is expected to continue throughout the first months of 2016. Some data on certain of the examined routes are collected through relevant magazines such as the Shippax CFI publication that covers estimates on ferry routes in Europe. This database provides monthly updates on the total number of passengers and cars, buses, and trailers on these routes, including the number of trips undertaken. A snapshot of such data is shown in Figure 12.

European traffic figures for October 2015, compared to the same period in -14

October 2015	Pax		Cars		Buses		Trailers		Trips		Notes
BALTIC											
DENMARK DOMESTIC	2 321 365	6%	989 133	5%	3 646	51%	122 061	-1%	4 751	2%	
Miscellaneous routes (-)	-		-		-		-		-		Quarterly
Bøjden-Fynshav (Faergen AS)	27 380	4%	10 457	5%	33	65%	266	-17%	446	-10%	
Esbjerg-Fanø (Faergen AS)	142 385	5%	29 828	7%	9	-10%	778	-16%	2 608	4%	
Hou-Sælvig (Faergen AS)	-		-		-		-		-		*3
Kalundborg-Ballen (Faergen AS)	12 953	14%	4 077	20%	9	-47%	341	28%	154	12%	
Köge-Rönne (Faergen AS)	3 865	-5%	989	5%	10	11%	2 552	7%	62	0%	
Spodsbjerg-Taars (Faergen AS)	43 227	7%	16 680	8%	118	-6%	3 295	-7%	1 060	-1%	
Aarhus-Sjaellands Odde (Mols-Linien)	-		-		-		-		-		Quarterly
Ebeltoft-Sjaellands Odde (Mols-Linien)	-		-		-		-		-		Quarterly
Hou-Sælvig (Samsø Rederi)	29 666	14%	10 646	41%	10	0%	950	30%	421	14%	
Storebaeltsbroen (Storebaelt)	2 061 889	6%	916 456	5%	3 457	56%	113 879	-1%	-		
DENMARK-GERMANY	635 502	6%	145 120	2%	3 732	15%	1 579	-97%	3 868	-2%	
Rönne-Sassnitz (Faergen AS)	5 511	16%	1 690	17%	6	0%	12	50%	24	9%	
Havneby-List (Romo-Sylt Linien)	31 018	7%	6 772	10%	62	-26%	1 567	15%	416	0%	
Gedser-Rostock (Scandlines)	120 481	11%	22 429	14%	1 014	16%	-		560	0%	*4
Rödby-Puttgarden (Scandlines)	478 492	5%	114 229	0%	2 650	16%	-		2 868	-3%	Railwagons=958; *4
DENMARK-NORWAY	99 977	-2%	4 795	1%	109	8%	-		116	0%	
Hirtshals-Kristiansand (Color Line)	-		-		-		-		-		Quarterly
Hirtshals-Larvik (Color Line)	-		-		-		-		-		Quarterly
Copenhagen-Oslo (DFDS Seaways)	65 462	3%	2 487	7%	96	3%	-		62	0%	
Hirtshals-Kristiansand (Fjord Line)	-		-		-		-		-		Quarterly
Hirtshals-Langesund (Fjord Line)	-		-		-		-		-		Quarterly
Hirtshals-Stavanger-Bergen (Fjord Line)	-		-		-		-		-		Quarterly
Frederikshavn-Oslo (Stena Line)	34 515	-9%	2 308	-5%	13	62%	-		54	0%	*4
DENMARK-SWEDEN	1 507 818	5%	598 162	2%	4 324	33%	40 160	-30%	611	-1%	
Rönne-Ystad (Faergen AS)	96 540	4%	23 395	4%	109	137%	810	5%	210	3%	
Helsingör-Helsingborg (Scandlines Helsingborg-Helsingör)	-		-		-		-		-		
Frederikshavn-Gothenburg (Stena Line)	87 933	5%	14 747	8%	56	22%	-		295	-3%	*4
Grenaa-Varberg (Stena Line)	10 474	-5%	2 651	1%	1	-67%	-		106	-2%	*4
Copenhagen-Malmö (Öresundsbro Konsortiet)	1 312 871	5%	557 369	2%	4 158	32%	39 350	2%	-		

Figure 12: Example of available information of Shippax CFI journal. (December 2015 issue)

This table also provides the relevant percentage change from the same period in the previous year. This information will be used to assess the impacts of the different fuel prices on the demand for transport. It is expected that data on the capacity utilization (in terms of volume and weight) for the deployed vessels will be provided on individual trips.

With regard to the alternative maritime options in the selected routes, information on competitive ferry services is being collected from online sources., This may either be directly from the ferry operator, or from sources that compile information on the full network (for example the Baltic transport journal that covers the Baltic Sea network). The main obstacle with alternative maritime options, is that some of the online databased that provide this information are outdated, and do not reflect the current fleet deployment or cost information accurately.

10.2.5 Cargo values

The values of the cargoes carried will play an important role in the development of the modal split model for Task 2.2, as they will allow a more refined estimation of the generalized cost of transport that the shipper is facing. Pricier cargo have a higher depreciation cost and as a result a shipper may consider a faster and more expensive service as a better option to a cheaper alternative. To identify the cargo values, a list of the clients for products to be considered in the what-if scenarios will be provided, and the relevant information will be retrieved either through online sources, or through interviews.

10.2.6 Fuel consumption

As mentioned in section 10.2.3, DFDS has provided some estimation on the daily fuel consumption for a set of sailing speeds for most vessels. This information is important, but is not enough to extensively examine the implications of changes in the voyage characteristics. More accurate data are being collected, and currently the fuel consumption for each machinery onboard a vessel for all its voyages during the last 4 years has been provided by DFDS. This information is essentially the actual fuel consumption as measured from the tanks, from port arrival to port arrival for each voyage. This will be used in parallel with the SHIP DESMO model of Task 2.3[5].

The SHIP DESMO model allows the estimation of the fuel consumption during cruise for varying scenarios of loading of the vessel (passengers, cargo) and sailing speed chosen. Currently, based on the data on vessels specification (see Section 10.2.3), the SHIP DESMO model is being used as an additional data source as it is being calibrated based on these data to provide fuel consumption information on the cruise mode for each vessel for the scenarios to be examined.

The collected information on fuel consumption in the context of task 2.1 will allow the more accurate modeling of fuel consumption from other activities (namely maneuvering and hoteling), as the contribution of each machinery is known. Coupled with the fact that vessels prior to 2015 were using different fuel types for different activities (e.g. MGO only at berth for auxiliary engines and boilers) allows a better estimation of power requirements for all machinery at the different activity phases. A module is therefore under development that will allow the estimation of the auxiliary engines and boilers fuel consumption demands during each activity, based on the data collected on fuel consumption from DFDS. This is a very important step, as in the relevant literature on ship emissions at berth, most studies assume universal load factors that remain steady throughout the vessel’s operation; something that the acquired data contradict at this stage.

[5] As many as 6 reports on work on Task 2.3 have been produced. These will be submitted in Month 13.

10.2.7 Fuel prices

Fuel costs data are monitored through online sources and will be used for the model calibration stage to assess the profitability of the examined routes, as well as to estimate the fuel cost surcharges applied to transportation costs through the bunker adjustment factor. On a first instance, fuel cost data are retrieved from Bunkerworld for the periods from 2013 onwards for ports in the Baltic and the North Sea. Figure 13 shows the price fluctuation for MGO (left) and HFO380 (right) during 2015 where it is evident that fuel prices are on a steep decline.

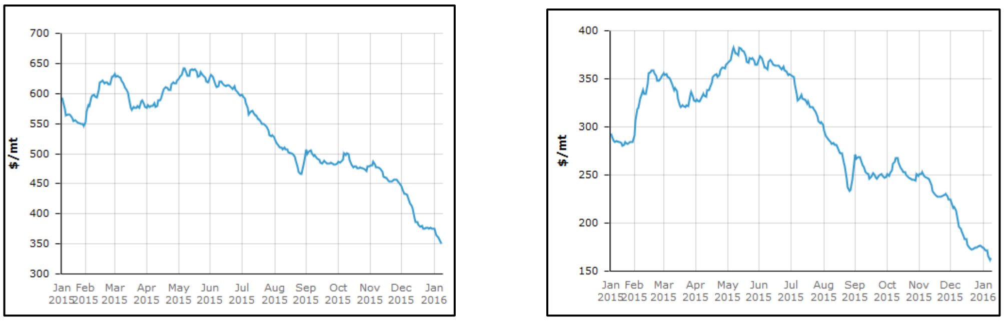


Figure 13: Fuel price fluctation for MGO and HFO in 2015. Source: Bunkeworld

10.2.8 Freight rate information

Information on freight rates is currently being collected from online sources including the company website, and other websites that are comparing prices (for example www.directferries.co.uk) with other operators. This is run in parallel with the BAF estimation from section 10.2.7. Miscellaneous information is also being collected (for example the winter surcharges for certain routes).

10.2.9 Other cost information

As mentioned in sections 3.3.2 and 4.2.1, there are additional costs to the shipping company when scrubber systems have been installed on a vessel. These are not as straight forward as the case of using MGO as fuel to comply with the sulphur regulations. In the aforementioned sections, the main cost elements for scrubber systems have been identified, and through the fuel consumption information collected (section 10.2.6) it is expected that the additional operating costs due to scrubber systems will be retrieved. Finally, the DESMO model is also capable of performing a prediction on the scrubber systems energy requirements, and it will also be used for the identification of any other extraneous cost information relating to a vessel's activity.

The next section presents the current status on land-based mode data, with a particular focus on how the in-house model is estimating road network routes, distances, and speeds. This is information that will be used for the model calibration of Task 2.2., as well as to construct emissions inventories for the land-based modes.

10.3 Other ship data

In the context of the development of the SHIP DESMO models of Task 2.3, the following additional ship data has been collected:

- Data on ships of the entire world fleet of Ro-Ro and Ro-Pax ferries (source: ShipPax). This database contains more than 2,000 individual ship entries. Each entry includes ship information such as main dimensions, service speed, capacity and fuel consumption. This data was used to perform regression analyses.
- General arrangement drawings, capacity plans, trim and stability booklets and loading manuals of DFDS ships.

10.4 Data on road mode and description of the network model

This section focuses on data collection for the land-based modes and provides a preliminary description of the network model used to calculate and assess transport costs in a multimodal transport system. The model itself will be further described in more detail in the context of Task 2.2.

10.4.1 Road network routes

Data on the road network routes are based on the network model used for this project. This model is based on a digital transport network for selected countries in the Northern part of the EU. It allows the estimation of a generalized cost of transport for the entire network, and it can handle both link-based costs, and node-based costs. The latter, is particularly relevant when modal shifts are taking place and therefore an additional cost is experienced within a node. The entire transport system-modelling tool is integrated within the geographical information system (GIS) ArcInfo Workstation. The cost of traversing the multimodal transport system is modelled in two steps. The first step deals with the modelling of the physical performance of the transport system, while the second with the calculation of the associated cost of using the transport system. The way the physical performance of the transport system is modelled, is closely linked to the implementation within the GIS and gives the distance and transport time for traversing space as output. The calculation of costs is based on the physical performance of the transport systems and the costs are divided into:

- Distance-dependent costs
- Time-dependent costs
- Toll and fare costs

The next sub-sections focus on the modelling and calculation of the previous costs.

10.4.2 Transport costs

The main objective of the road network tool is to model the cost of freight transport. A crucial step is therefore the transformation of the physical measurements (transport distances and time) into monetary values, or a generalized cost. The distance and time dependent costs normally apply to road transport, whereas sea transport normally operates with fares. The distance dependent cost components are for road transport typically vehicle operating costs (VOC) covering e.g. fuel consumption, maintenance, tires etc.
The distance dependent cost for each link within the network are defined as in equation 1.

$$DD_{cost} = (DD_{CC1} + \ldots + DD_{CCn}) \times TransportDist \quad (1)$$

Where *DDcost* is the total Distance Dependent cost for the link
DDCC1 … DDCCn are the Cost Components
TransportDist is the length of the link

The time dependent cost components are for road transport typically e.g. wages or depreciation of the material (including e.g. financial costs). The time dependent cost for each road link is defined as in eq. 2.

$$TD_{cost} = (TD_{CC1} + \ldots + TD_{CCn}) \times TransportTime \qquad (2)$$

Where *TDcost* is the total Distance Dependent cost
TDCC1 … TDCCn are the Cost Components
TransportTime is the time used to traverse the link

The fare and toll costs are linked to either the use of a sea link, modal shift or the passage of a physical location like e.g. a toll bridge, a toll tunnel or a toll ring. The fare and toll costs for specific links are added to the cost for traversing the link.

10.4.3 Distances and speeds

The distance and time dependent costs are modelled using a lookup table describing the costs for different link types or specific links. In the same way as for the calculation of the traverse time the calculation of the different costs elements can be made on an arbitrary classification of the transport network based on e.g. country, region, road type, truck type, wages etc.

The modelling of distances and transport time are automatically handled by the GIS. This is similar to car navigations systems and web-based route finding tools. One specific functionality of the Ro-RoSECA tool that constitutes it superior needs to be mentioned. The tool includes an event-manager that allows the placement of specific transfer points in the network at a given location, based on arbitrary conditions. For example, this can allow the introduction of drive-rest regulations in the cost modelling process, by adding an associated cost within the network when the accumulated transport time by road reaches 9 hours. Such events may have implications on the speed of transport.

In addition to the road network calibration discussed in section 10.4.1 and the outputs of the network model, the land-based distances from port to port have been collected through online tools for comparison purposes. These distances were also used as indicators in the selection process of the routes to be further examined.

10.4.4 Vehicle and fleet characteristics

In the context of Task 2.3, a key component is the estimation of emissions from the land based options. However, it would be impossible to collect data for all vehicles used in the landbased options serving the shipments of the case studies. Therefore, the SHIP DESMO truck model will be used to estimate the fuel consumption for each shipment via road. The model calculates the emissions at different weight loads and different distances travelled, as there is a correlation between total distance and fuel consumption rates.

10.4.5 Traffic volumes

As mentioned in section 10.2.4, information on traffic volumes has been difficult to obtain in the early stage of the project. Traffic volumes will depend on the information received from hauliers and shippers, as well as any necessary assumptions or sensitivity analyses performed in the model calibration for Task 2.2.

10.4.6 Cargo values

The relevant information on cargo values from section 10.2.5 also applies here.

10.4.7 Fuel consumption

As discussed in section 10.4.4, the SHIP DESMO model will be used for the fuel consumption information for the selected case studies. This will also be incorporated in the model described in section 10.4.1.

10.4.8 Fuel prices

Fuel price information is collected from online sources (such as http://www.fuel-prices-europe.info/) and the European Environment agency (http://www.eea.europa.eu/data-and-maps/indicators/fuel-prices-and-taxes/assessment-3) that provides a differentiation between real and nominal fuel prices. Figure 14 shows a snapshot of relevant data (fuel prices without tax) through the European Commission's Oil Bulletin website. An example of such data during the last 10 years is shown in Figure 14.

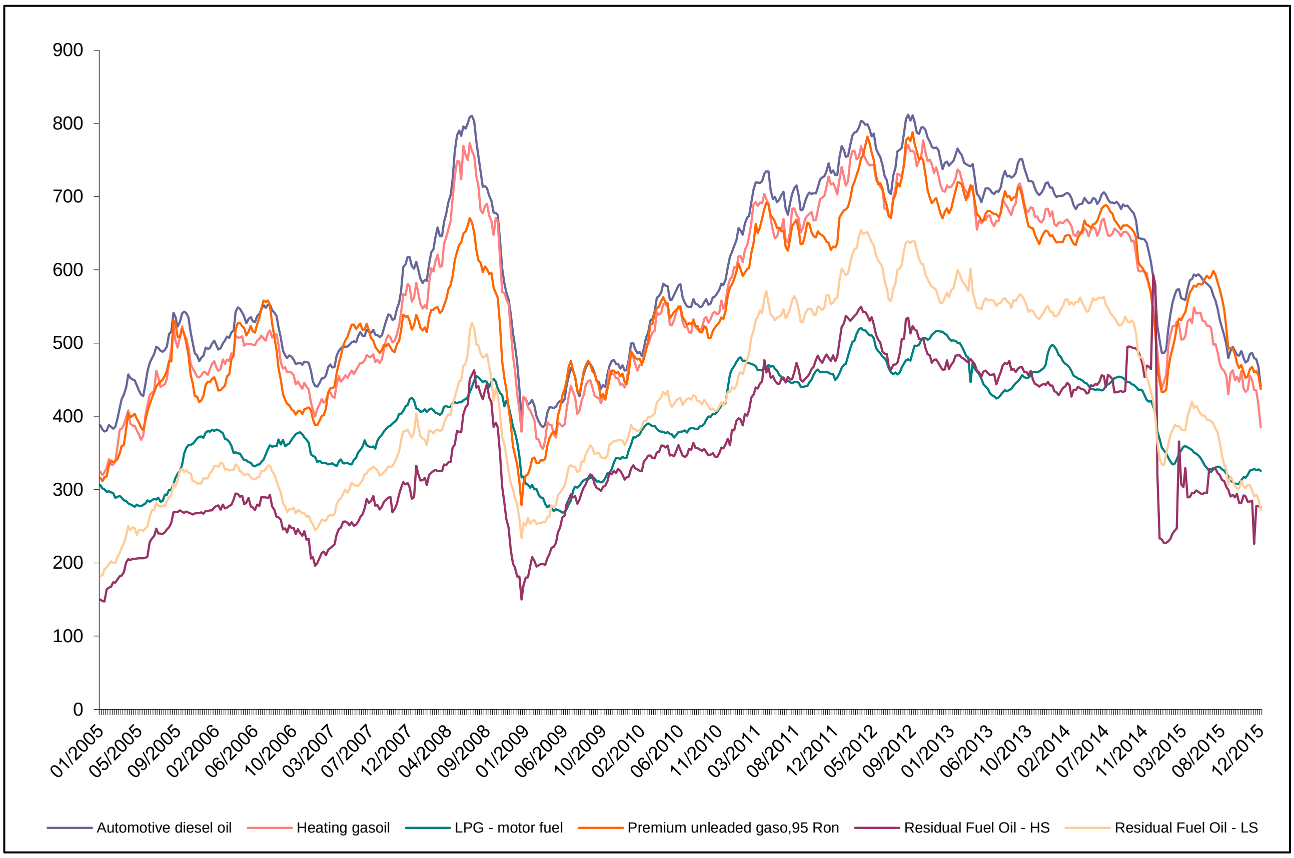


Figure 14: Consumer prices of petroleum products net of duties and taxes - EU weighted average (Source: Oil bulletin, 2015)

10.4.9 Freight rate information

Freight rate information as experienced from shippers has not been collected at this stage, but indicatory prices from hauliers have been collected, along with figures used in the literature (for example Panagakos et al., 2014).

10.4.10 Initial values used in the road network model

One of the main purposes of the network model is to calculate the consequences of changes in the transport system. In order to do that it must be possible to change as many parameters as possible. This calls for a simple but at the same time flexible model for handling the cost of transport. The approach in the RORO SECA tool has been based on the development of a cost model based on a fairly simple functional classification of links and nodes within the digital network. Subsequently, an SQL like approach to calculate the costs of traversing the transport system is used. This means that the demands in terms of information need for the digital network are very limited and at the same time, the possibilities for defining and using different costs are quite flexible. This gives the possibility to use the model for modelling a large variety of different scenarios.

In the initial modelling for the RORO SECA project the focus has been on modelling the cost of freight transport on a Northern European level and the modelling of the traverse speed for roads has to reflect this purpose and level of aggregation. That means that a model for calculating e.g. the road traverse speed that uses parameters like the number of lanes, the gradient of the road etc. will be too advanced (and expensive) for the chosen aggregation level. Instead, a more simple approach is chosen where all road links are classified according to a simple type classification and a country specific lookup table determine the speed for each of the link types. This way of handling road speed still provides the possibility to introduce and use country specific congestion factors. The cost of traversing each link depends as, previously described, upon the valuation of the time use and the valuation of the distance.

In the initial calculation, the value of time (VOT) is modelled as a composite cost composed of several components. As point of departure, the costs originating from the Danish Manual for Economic Evaluation of Transport Investments are used. The unit of the costs are in EUR per hour of operation and the used cost components and the associated values are shown in Table 29.

Table 29: The cost components for the value of time

Component	**Value (EUR/h of operation for 2 TEU)**
Depreciation	11.06
Wages	22.36
Reparation	1.34
Capacity cost	5.43
Duties	1.11
Total time dep. cost (VOT)	**41.30**

The same VOT is used for all countries in the initial calculation but will be differentiated in the next development step. In the same way as the VOT the vehicle operating costs (VOC) is a composite cost composed of several components. Again the initial cost components and costs originate from the Danish Manual for Economic Evaluation of Transport Investments. The used cost components and the associated value are shown in Table 30.

Table 30: The cost components for the vehicle operating cost

Component	**Value (EUR/km for 2 TEU)**
Diesel	0.12
Oil	0.02
Tires	0.05
Reparation	0.08
Duties	0.14
Total distance dep. Cost	**0.41**

The same VOC has been used for all countries with the exception of Germany. For Germany the Maut toll (0.13 EUR/km) has been added to the VOC bringing the total VOC within Germany up to 0.54 EUR/km.

The initial calculations also include modelling of drive-rest restrictions. In this case a fixed cost of 145 EUR has been added for each rest period, approximately corresponding to the additional payment to the driver dictated by the collective agreement in Denmark. It's assumed that the cargo is a low-value commodity so that there is no financial cost associated with the rest period.

It has to be kept in mind that the calculation of costs for road transport heavily depends on the assumed flow speed on each network link. Assuming free flow conditions will certainly improve the performance of road transport but is however not realistic at all on the Trans-European Transport Networks (TEN-T) of Northern Europe. Ideally, the average speed on the congested European road network would be an output from a transport model. Unfortunately – but not surprisingly - no such transport model was available to the project. Instead, calculations are made on a network where the free flow speed on each link has been reduced by an empirically estimated congestion factor. In this case, a simple differentiation of the congestion factors between countries and urban/rural surroundings are chosen. The free flow speed and the congestion factors are multiplied to find the congested speed. Congestion factors used in the initial calculation are shown in Table 31.

Table 31: Congestion factors used in the explorative example

Country	**Urban factor**	**Rural factor**
All	0.8	0.9

The increase in the costs due to congestion can be viewed as a fairly conservative estimate.

11 Concluding remarks

This report presented the main activities undertaken in the context of Task 2.1 during the first six months of the project. The main objective of Task 2.1 was the preparation ahead of the model calibration of Task 2.2 and the subsequent analyses on how to reverse the negative effects of the new stricter sulphur limits following January 1^{st} 2015. The report presented recent trends of freight transportation in Europe, and the current understanding on the implications of the new sulphur limits. The main available options to comply with the regulations are either to invest in scrubber systems that bear significant capital costs, but allow the use of cheaper fuel, or to switch to ultra-low sulphur fuel (usually MGO) which is significantly more expensive. The report presented the existing DFDS network, and briefly discussed the company's response to the regulation, as well as the way the additional operating costs will be passed on to shippers through the BAF.

The main selection criteria for routes to be further investigated were discussed. From the existing DFDS routes there will be further analysis on seven routes (4 in the North Sea, 2 in the Baltic Sea, 1 Cross-Channel route), as these are representing a significant portion of the total DFDS activity within ECAs. This selection was possible after a thorough data collection on the existing network (sailing distances, frequency of service, vessel specifications), and the main maritime competitors that could pose a suitable alternative for shippers. The data collection in the context of Task 2.1 was focused on the necessary elements for the accurate modelling of fuel consumption under different operating scenarios. The next steps of the project involve the model calibration for a set of case studies on the selected routes. This will require additional data collection, on cargo values and information on market shares for different modes.

REFERENCES

BTJ (2015). Baltic Ro-Ro & Ferry Yearbook 2014-15. Available at: http://www.baltic-press.com/ftp2/baltic_ro-ro_ferry_yearbook_2014-15_preview.pdf

Central Intelligence Agency. (2009). *The CIA World Factbook 2010*. Skyhorse Publishing Inc.

Danish Environmental Protection Agency (2014). Reduction of SO2, NOx and Particulate Matter from Ships with Diesel Engines. Environmental Project no.1510, 2014. Copenhagen. Available at: http://www.alfalaval.com/microsites/puresox/documents/978-87-93026-57-5.pdf (accessed November 2015)

DFDS (n.d.). The EU sulphur Directive and DFDS Response. Available at: https://www.dfds.com/Downloadables/THE%20EU%20SULPHUR%20DIRECTIVE%20AND%20DFDS%20RESPONSE.pdf (accessed September 2015)

DFDS (2014). New sulphur ruels will increase fuel costs. Available at: http://www.dfdsgroup.com/About/Responsibility/Documents/A4_New%20Sulphur%20rules_07_2014_low1.pdf (accessed July 2015)

Egea M.M. (2015). Route analysis for capturing the side-effects if stricter Sox emission legislation on Ro-Ro shipping in Northern Europe. M. Sc. Thesis. Technical University of Denmark

European Commission (2012). EU transport in figures. Statistical Pocketbook 2012. Available at: http://ec.europa.eu/transport/facts-fundings/statistics/doc/2012/pocketbook2012.pdf (accessed November 2015)

German Shipowners Association and Association of German Seaport Operators (2010). Reducing the sulphur content of shipping fuels further to 0.1% in the North Sea and Baltic Sea in 2015: Consequences for shipping in this area. Bremen, Germany. Available at: http://www.reederverband.de/fileadmin/vdr/pdf/themen_und_positionen/GermanISLStudyonSECAimpacts.PDF (accessed July 2015).

Grebot, B., Scarbrough, T., Ritchie, A., Mahoney, C., Noden, R., Sobey, M., & Whall, C. (2010). Study to review assessments undertaken of the revised MARPOL Annex VI regulations. *Entec UK Limited, London*.

Henriksson, T. (2007). SO_x scrubbing of marine exhaust gases. Wärtsilä Technical Journal. February 2007.

IMO, 2008. Revised MARPOL Annex VI: Regulations for the prevention of air pollution from ships and NO_x technical code London: IMO Marine Environmental Protection Committee (MEPC)

International Transport Forum (2015). Permissible Maximum Dimenisons of Lorries in Europe. Available at: http://www.internationaltransportforum.org/IntOrg/road/pdf/dimensions.pdf (accessed August 2015)

Jiang, L., Kronbak, J., & Christensen, L. P. (2014). The costs and benefits of sulphur reduction measures: Sulphur scrubbers versus marine gas oil. *Transportation Research Part D: Transport and Environment*, *28*, 19-27.

Lloyd's List (2015). Lloyd's List Sulphur Survey: Distillate fuels seen as best solution for meeting sulphur rules. Available at: http://www.lloydslist.com/ll/sector/ship-operations/article460072.ece (accessed June 2015)

MAN Diesel & Turbo (2014). Guidelines for operation on fuels with less than 0.1% Sulphur. Copenhagen, Denmark. Available at: http://marine.man.eu/docs/librariesprovider6/test/guidelines-for-operation-on-fuels-with-less-than-0-1-sulphur.pdf?sfvrsn=5 (accessed September 2015).

MIDNORDIC (2013). Sulphur Regulation in the Baltic Sea–Scenarios for the Mid Nordic Region–Threats and Opportunities. *North East Cargo Link II Project, Municipality of Sundsvall, Sundsvall*.

Ministry of Transport and Communications (2009). Sulphir content in ships bunker fuel in 2015. A study on the impacts of the new IMO regulations on transportation costs. Helsinki, Finland. Available at: http://www.lvm.fi/documents/20181/817543/Julkaisuja+31-2009/cfb920d0-d1c5-4c4f-94e2-7a92e58adc9d?version=1.0 (accessed July 2015)

Panagakos, G. P., Stamatopoulou, E. V., & Psaraftis, H. N. (2014). The possible designation of the Mediterranean Sea as a SECA: A case study. *Transportation Research Part D: Transport and Environment*, *28*, 74-90.

Styhre, L. (2010). *Capacity utilisation in short sea shipping*. Chalmers University of Technology.

Verhoeven, P. (2015). Report on online survey of ship operators. ECSA, 24 March 2015.

Wu, W.-M. (2009) An approach for measuring the optimal fleet capacity: Evidence from the container shipping lines in Taiwan. International Journal of Production Economics, 122: 118-126

Appendix I

Miscellaneous tables

Table A - 1: Ports served by DFDS group

Port	**Port**	**Country**
Ro-Ro and Ro-Pax Routes	Ghent	Belgium
	Zeebrugge	Belgium
	Copenhagen	Denmark
	Esbjerg	Denmark
	Fredericia	Denmark
	Paldiski	Estonia
	Calais	France
	Dunkirk	France
	Dieppe	France
	Marseille	France
	Cuxhaven	Germany
	Kiel	Germany
	Klaipeda	Lithuania
	Brevik	Norway
	Oslo	Norway
	Ust. Luga	Russia
	St. Petersburg	Russia
	Gothenburg	Sweden
	Karlshamn	Sweden
	Kapellskär	Sweden
	Amsterdam (Ijmuiden terminal)	The Netherlands
	Rotterdam	The Netherlands
	Tunis	Tunisia
	Newcastle	United Kingdom
	Immingham	United Kingdom
	Felixstowe	United Kingdom
	Dover	United Kingdom
	Newhaven	United Kingdom
	Rosyth	United Kingdom (Scotland)
	Port	**Country**
Container Routes (DFDS	Antwerp	Belgium
	Rotterdam	The Netherlands
	Belfast	(United Kingdom) Northern Ireland
	Cork	Ireland
	Dublin	Ireland
	Waterford	Ireland

Table A - 2: Taxonomy of routes according to purpose

Route	Purpose
Amsterdam (Ijmuiden) – Newcastle	Cruise
Oslo – Copenhagen	Cruise
Calais – Dover	Ro-Pax
Dover – Dunkirk	Ro-Pax
Karlshamn – Klaipeda	Ro-Pax
Klaipeda – Kiel	Ro-Pax
Newhaven – Dieppe	Ro-Pax
Paldiski - Kapellskär	Ro-Pax
Brevik – Ghent	Ro-Ro
Brevik – Immingham	Ro-Ro
Copenhagen – Fredericia	Ro-Ro
Cuxhaven – Immingham	Ro-Ro
Esbjerg – Immingham	Ro-Ro
Fredericia – Klaipeda	Ro-Ro
Gothenburg – Brevik	Ro-Ro
Gothenburg – Ghent	Ro-Ro
Gothenburg – Immingham	Ro-Ro
Kiel – Ust. Luga	Ro-Ro
Klaipeda – Copenhagen	Ro-Ro
Marseille – Tunis	Ro-Ro
Rosyth – Zeebrugge	Ro-Ro
Rotterdam (Vlaardigen) – Felixstowe	Ro-Ro
Rotterdam (Vlaardigen) – Immingham	Ro-Ro
St. Petersburg - Kiel	Ro-Ro
Ust. Luga – St. Petersburg	Ro-Ro

Table A - 3: Geographical breakdown of routes

Route	Geographical Area
Amsterdam (Ijmuiden) – Newcastle	North Sea
Brevik – Ghent	
Brevik – Immingham	
Oslo – Copenhagen	
Cuxhaven – Immingham	
Esbjerg – Immingham	
Gothenburg – Brevik	
Gothenburg – Ghent	
Gothenburg – Immingham	
Rosyth – Zeebrugge	
Rotterdam (Vlaardigen) – Felixstowe	
Rotterdam (Vlaardigen) – Immingham	
Calais – Dover	Cross Channel
Dover – Dunkirk	
Newhaven – Dieppe	
Marseille – Tunis	Mediterranean
Kiel – Ust. Luga	Baltic Sea
Ust. Luga – St. Petersburg	
St. Petersburg - Kiel	
Klaipeda – Copenhagen	
Copenhagen – Fredericia	
Fredericia – Klaipeda	
Karlshamn – Klaipeda	
Klaipeda – Kiel	
Paldiski - Kapellskär	