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

Deliverable on Task 2.2:

Report on the outcome of Task 2.2
Modal split model development and calibration

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Authors:

Thalis Zis, Postdoc tzis@transport.dtu.dk

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

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

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1 Executive Summary

This document presents the main findings of Task 2.2 (entitled "Modal Split Development and Calibration") of the RoRoSECA project, with a particular focus on the developed methodology to assess the effects of the new SECA limits on modal choice. Task 2.2 belongs to Work Package (WP) 2 (entitled "Enhanced modal split and emissions models"), whose main purpose 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.

There are two main modules associated with Task 2.2 in the maritime mode:

- The modal split module
- The route profitability module

The modal split module takes as input

- the transport volumes for the competing modes (DFDS, other maritime company where competition exists, land-based route where applicable),
- converts these into market shares as %
- The total travel time for each option
- The total cost for each option
- An estimate for the value of cargo transported

The module then calibrates the scale parameter that can be used to replicate the observed market shares. Following this, the model can be re-run to estimate the modal shifts to other modes when a significant alteration in travel times, travel costs, or frequency of service takes place.

Per the outcome of Task 2.1, it was decided 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	Ro-Pax
Klaipeda – Karlshamn	Ro-Pax
CROSS CHANNEL	
Dover – Calais	Ro-Pax

The Harwich-Esbjerg route which was shut down in 2014 will also be used as a benchmarking instance on the criteria to shut down a service, and the Marseille-Tunis route which is outside the European SECA will also be used for comparison purposes.

The modal split module follows a hierarchical (nested) logit structure, where correlation between similar modes is assumed. E.g. the shippers first decide whether they will make use of a maritime mode or not (first split), and then select one of the available alternatives within this nest. For cases where only one alternative option is available, the model collapses into a binary form. As the required data are of disaggregate form and thus extremely difficult to attain, software code has been developed which performs simulation and sensitivity analysis for wide ranges of critical parameters. Initial results show that the freight rates offered by each mode are the basic determining factor in the mode choice and the probability of observing modal shifts.

The profitability module for each route has also been finalized during the last three months. The model estimates the operating costs of each route, given the deployment of vessels. Fuel consumption modules have been developed based on the actual bunker consumption of each engine type at each vessel. Other costs (including scrubber repayment) are incorporated in the model. The profitability is then calculated based on the revenue generated per lm and passenger (for Ro-Pax vessels) transported. The profitability of each route is then compared between 2014 and 2015 (what actually happened), and subsequently for what-if fuel price scenarios, as will be explained below. For the various fuel price scenarios examined, the Bunker Adjustment Factor (BAF) is changing and as a result the freight rates per lm are also changing, prompting a change in actual transport demand.

In parallel, a road network model has been developed which links with the modal split model. Once an origin has been selected, the model is capable of calculating costs to all destinations. As a result, ‘heat maps’ can be plotted that show the impacts of having a Ro-Ro link in place. The model has been run for the selected scenarios.

The enhanced modal split model developed in Task 2.2 has the following features, not encountered in previous models:

- It can capture fact that if a route becomes unprofitable it will shut down and its traffic will be diverted to the road mode.
- It can capture the effects of possible speed reduction on transit time and modal shares.
- It can capture the effects of Ro/Ro freight rate surcharge on (a) increase of revenue for the cargo carried, and (b) decrease of quantity of cargo carried due to the surcharge.
- In the scrubber option, it can capture effects of both capital and operational costs, including increased fuel consumption due to the scrubber.
- It can capture the impact of different values of the cargo on generalized cost and modal shares.
- It can capture the effects of reducing the number of vessels and/or the frequency of service on the route. These include (a) increasing utilization of the fleet and hence profitability, (b) lost cargo (and hence revenue) due to reduced throughput capacity and (c) increased waiting time at port and hence increased total transport time and reduced share.

By far the least anticipated outcome of the sulphur problem and one that has to a great extent masked the impact of the new sulphur regulations has been the unprecedented drop in bunker fuel prices after mid-2014. In fact, in 2015 the MGO price was lower than the HFO price in 2014. This means that despite the new regulation, fuel cost was actually lower for ship operators compared to the year before the limit. This would in turn allow ship operators to offer similar (and in some cases lower) freight rates as in 2014, but operate on lower overall costs which may explain the record revenues recorded in 2015. It has to be noted though that in the first quarter of 2016 the fuel prices have started increasing again, a trend which if continued could have major implications on modal shifts to land based options.

Given such a drop in fuel prices, the question is if one can still pick out and dissect the effect of the new sulphur regulation from the effect of the fuel price drop. The answer turns out to be yes, and the analyses performed in the context of Task 2.2 can help address this issue.

To do so, the benchmark period for all route scenarios was chosen to be the situation during year 2014, the last year before the introduction of the new limit. The fuel prices scenarios are considering the average price of fuel during 2014 as the benchmark, and the simulation was performed for various scenarios of fuel prices in 2015. The three scenarios are:

- Fuel Case 1 - for MGO 2015 prices
- Fuel Case 2 – for HFO (1% sulphur) 2015 prices
- Fuel Case 3 - for MGO 2014 prices

Essentially, Fuel Case 1 is referring to the actual fuel price difference that the ship operators faced, and thus the change in freight rates that the shippers experienced. This allowed to compare the findings of the model, with the actual change in demand due to the fuel prices in 2015 and thus conclude whether the modal split methodology used is a reasonable approach.

Fuel Case 2 is a hypothetical scenario of what would have happened if the sulphur limit had remained at 1% and thus the only difference in operating costs would be the change in fuel prices as a result of the market. It has to be noted that in this case, the investments in scrubber systems would have not taken place, and thus the fuel consumption of the vessels must be adjusted to account for this. Scrubber systems increase the fuel consumption of the vessel between 1.5 and 3.0% to cover their energy requirements.

Finally, Fuel Case 3 is a hypothetical scenario to illustrate what the impacts of the regulation would have been, if the prices had not unexpectedly dropped to the point that it was actually cheaper to use MGO in 2015 as compared to HFO in 2014. For this reason, the MGO fuel prices in 2014 are used to simulate the effects of the regulation as anticipated in the ex-post market and research reports.

Based in the above scenarios, and even allowing for differences due to the particularities of the different routes examined (these can be found in Sections 10.1 to 10.8 of the report), we believe that the analysis of Task 2.2 supports the following general conclusions:

The first conclusion is that indeed most services were not affected by the new sulphur limits, and actually improved their performance. In the DFDS case studies, it is evident that the actual volumes of transported goods increased for most routes. At the same time, even for some routes that lost some cargoes (due to marginally fewer sailings), the utilized capacity has increased, possibly indicating a better management of the assets. However, the main reason the Ro-Ro operators seem to be coping with the new limits is the very low prices of fuel experienced throughout 2015, even though fuel prices dropped for the road option as well. These lower prices may actually give the impression that the investments in scrubbers the years before the new limits may not have been the optimal decision. However, such decisions had by no means anticipated the significant fuel price drop, and should be judged on the projected fuel prices at the time they were made.

At the same time, this is a two edged sword and the models have identified a clear risk. Should fuel prices increase (as the trends in the first months of 2016 suggest) this situation may very well reverse. The what-if scenarios using higher MGO prices (as in 2014 levels) reveal that the Ro-Ro sector would be shrinking and losing cargoes to land based modes in case fuel prices rise toward 2014 levels. In that sense, the need to examine measures and policies that would mitigate and reverse such an outcome is still very clear, and this was recognized by key industry stakeholders at the June 2016 workshop. Such measures and policies are the objective of Work Package 3, in Year 2 of the project.

A final conclusion regards the hypothetical situation if the new sulphur regulation were not in place. In this case fuel prices would be much lower as ships would still use HFO. The what-if analysis on using HFO prices in the 2015 levels showed that the market share of the maritime mode would have increased even further, vis a vis the current situation.

So given these general results of Task 2.2, and also the results of Task 2.3 ("Emissions and External Cost Calculator") described separately, the project is well poised to enter Year 2 with the analysis of WP3. Such analysis would first examine measures from the Ro-Ro operator, including

- Speed reduction
- Service frequency and schedule reconfiguration
- Fleet and network reconfiguration
- Alternative fuels such as LNG
- Other technical measures such as scrubbers

It would also examine potential measures that come under the 'policy' category. These include:

- Full or partial internalization of external costs, all modes (input from Task 2.3 will be used here)
- Easing of port dues/fairway dues/ ice dues for relevant shipping
- European-wide ECO bonus system based on the Italian system (no longer in operation) where freight haulers could get a refund for shipping cost. The level of such refund would depend on the specific route taken
- Public funding or subsidies from which shipping companies could get grants for environmental investments such as LNG conversions, scrubbers, and/or others.
- Any potential policy measure recommended by the ESSF[2] and its subgroups.

[2] European Sustainable Shipping Forum. H. N. Psaraftis is a member of the ESSF subgroup on competitiveness.

2 Introduction: scope of this document

This document presents the main findings of Task 2.2 (entitled "Modal Split Development and Calibration") of the RoRoSECA project, with a particular focus on the developed methodology to assess the effects of the new SECA limits on modal choice. As of the 1st of January 2015, a maximum of 0.1% sulphur content is allowed in marine fuels consumed within SECAs, or alternatively vessel operators must invest in abatement technologies that result in a similar reduction of sulphur emissions. Both options will increase operating costs in comparison to the situation before where no additional action was required. It was heavily anticipated that these new limits could lead to modal shifts towards landbased modes, and in certain cases even lead to closures of existing services. This risk was even more evident on the Ro-Ro sector, as it competes more directly with landbased modes, and the regulation was affecting a larger part of or even the entire voyage.

Task 2.2 belongs to Work Package (WP) 2 (entitled "Enhanced modal split and emissions models"), whose main purpose 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). 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 (2.1, 2.2 and 2.3), 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") has been completed and was 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 outcome of Task 2.1 can be found in a separate report, delivered in Month 7. It was essentially decided to base the analysis of Task 2.2 on the following DFDS routes:

NORTH SEA

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

In addition, the Harwich-Esbjerg route which was shut down in 2014 will also be used as a benchmarking instance on the criteria to shut down a service, and the Marseille-Tunis route which is outside the European SECA will also be used for comparison purposes.

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 in Year 2.

There are two main modules associated with Task 2.2:

- The modal split module
- The route profitability module

The modal split module takes as input

- the transport volumes for the competing modes (DFDS, other maritime company where competition exists, land-based route where applicable),
- converts these into market shares as %
- The total travel time for each option
- An estimate for the value of cargo transported

The module then calibrates the scale parameter that can be used to replicate the observed market shares. Following this, the model can be re-run to estimate the modal shifts to other modes when a significant alteration in travel times, travel costs, or frequency of service takes place.

The route profitability module takes as input the revenues of the shipping company, considering freight rates, freight utilization, passenger revenue (on-board and fares). It then compares this with the estimated fuel costs based on the planned sailing schedules at each of the examined routes, with the deployed vessels. The route profitability module will be used to conduct sensitivity analyses on fuel prices that could render a service unprofitable. The Harwich-Esbjerg route which was shut down in 2014 will be used as a benchmarking instance on the criteria to shut down a service.

With regards to land-based modes, the network model that calculates transport time and cost is set up and will be used for the main O-D pairs at each route, as well as for hypothetical distances (e.g. from port to port).

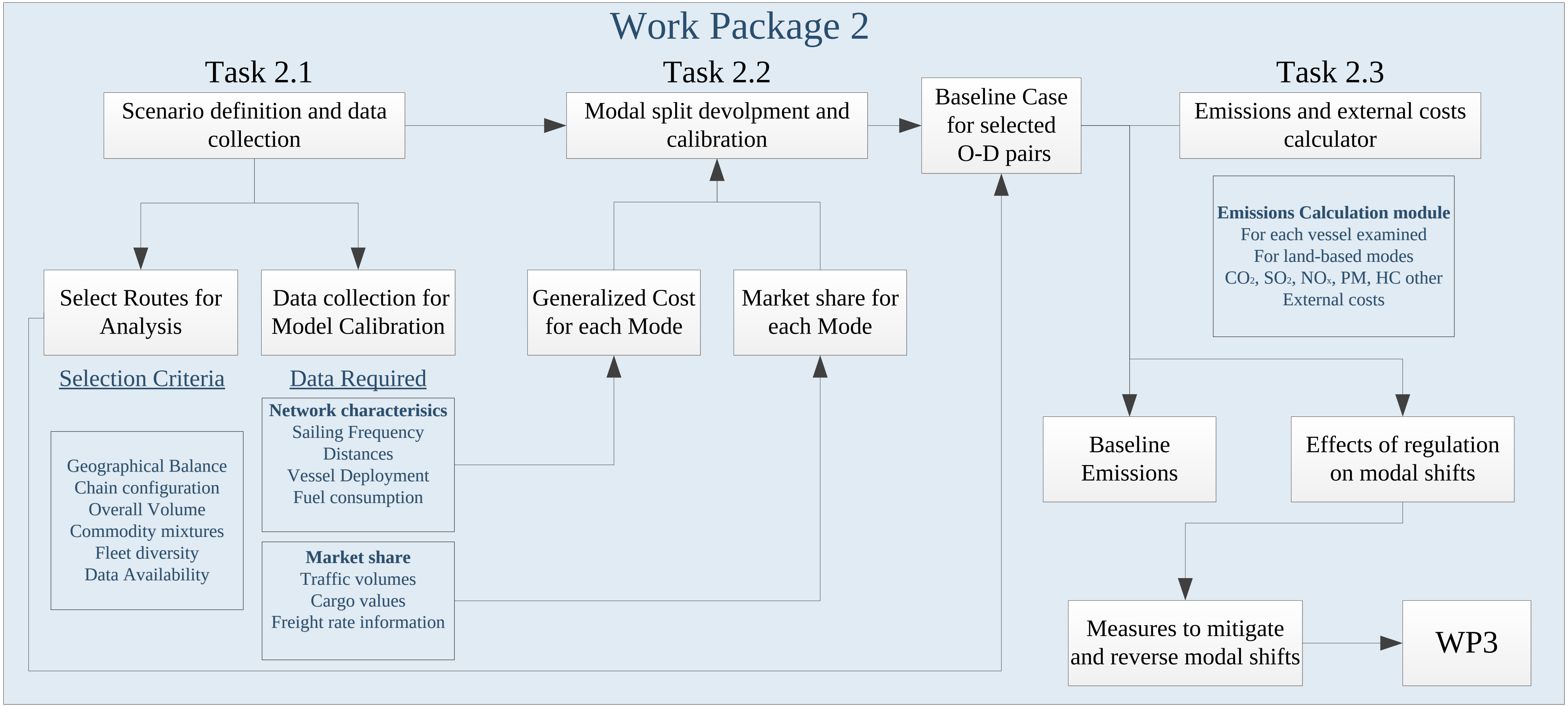


Figure 1: The main objectives of WP2 and the links between its associated Tasks

The data collected in the context of Task 2.1 will feed into the modal split module of Task 2.2 in order to construct the baseline scenarios for the selected routes. Data was also collected as input for the model constructed in Task 2.3 that predicts emissions generation and external costs. . The outcome of Task 2.3 is reported separately. Finally, Figure 1 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 in Year 2 of the project.

The rest of this report is organized as follows. Section 3 presents some general background, including the ex-ante and ex-post situation in the maritime sector in the affected areas by the lower limit of the SECA regulation. Section 4 summarizes the main findings from Task 2.1 of the project which was concerned with the Scenario selection and the data collection for WP2. Section 5 presents an overview of the modelling framework, and describes the links between the different computational modules developed for Task 2.2, and how these will also be used in the second year of the project. Section 6 presents the underlying discrete choice modelling theory used in the project, and how it has been adapted to match the requirements of the project. Section 7 is presenting the model calibration modules developed to apply the theory presented in section 6. Section 8 presents the simulation modules used for the estimation of modal shifts. Section 8 is also concerned with the Route profitability module that examines for a variety of scenarios, how a specific service is operating, and can be used to assess the risk of a service shutting down due to a large market share loss, or a significant increase in operating costs due to increase fuel prices. In the same section the environmental analysis module is also discussed. Section 9 presents in detail the development and use of the RoRoSECA Network model. Section 10 then presents the results of the use of the model for each of the selected Routes of Task 2.1, for a variety of scenarios. Finally, section 11 summarizes the findings of Task 2.2, and how these will be used in the development of mitigating and reversing strategies in the context of WP3 and the second year of the RoRoSECA project.

3 General background

3.1 The anticipated ex-ante impacts of the new limit

This section presents the views of the industry before the introduction of the new sulphur limits, and the handful of technical and academic reports that examined the implications of the regulation. Figure 2 shows a collection of press releases between 2013 and 2014, where it was reported that leading Ro-Ro operators were considering shutting down routes.

DFDS closes Sassnitz-Klaipeda connection

Publication date: 2013-08-30
Tags: maritime, germany, denmark, lithuania

DFDS Seaways has decided to close the ferry service between Sassnitz, Germany and Klaipeda, Lithuania with effect from the end of September.

Previously a busy connection, the route has over the years become economically unviable. As Vice President of DFDS, Anders Refsgaard, stated: "We have fought hard to get new customers and improve revenue and profit, but unfortunately without success". He added, that with the outlook on continued decline in profits, and in light of the new sulphur regulations to be introduced from 1 January 2015, the company does not believe that it will be possible to turn the tide on the crossing.

SECA requirements lead to new European rail link

CARRIERS: Railway company ERS is opening a new route in Europe in light of rising customer demand following the implementation of new sulphur regulations. Many customers and countries are willing to change their mode of transport in order to save money.

SECA SHUTS DOWN TRANSFENNICA IBERIAN SERVICE

The Dutch-owned short-sea shipping line Transfennica (part of the Spliethoff Group) has announced that it is to cease its "Motorways of the Sea" ro-ro service between Bilbao, Portsmouth and Zeebrugge at the end of this month (December).

The decision is a direct result of the introduction of stricter new low-sulphur emission controls from 1 January 2015 in the Baltic Sea, the Kattegat, the North Sea and English Channel. A further SECA extends in a 200 nautical miles wide belt along the coasts of the USA and Canada.

Figure 2: Press releases prior to the new SECA limit.

Sources: www.baltictransportjournal.com, http://www.themeditelegraph.com, www.shippingwatch.com.

Some ship operators started investing in scrubber systems some years before the new limit, so as to be prepared for the new regulation. DFDS Seaways invested in one of the largest scrubber equipped fleets amongst Ro-Ro operators, reaching a total of 17 vessels by 2015. At the same time, the European Commission provided subsidies to help with the capital investment costs, reaching up to 20% of the total system installation costs[3].

A cost-benefit analysis (CBA) study by Jiang et al. (2014) compared investment in scrubber systems vs the use of low-sulphur fuel to comply with the regulation. They concluded that scrubber systems are more beneficial when installed in new builds than retrofit, but for the latter they note that if the lifespan of the vessel is more than four years then it is worth considering. These conclusions agree with the overall view in the industry that scrubber systems were the way forward ahead of the new limits. However, these conclusions were drawn based on the high fuel prices at the time, and the important price differential between the different fuels. In a more recent study which was inspired from the RoRoSECA project, Zis et al. (2016) argued that with the current low fuel prices for both

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

MGO and HFO, the payback period of an investment in scrubber systems (retrofit) has in some cases more than doubled, reaching 10 years for small vessels operating most of their time within SECA. Therefore in retrospect, the current low fuel prices may support the argument that investments in scrubber systems were not the best option. This can be further supported by the fact that in 2020 the global cap of sulphur content will be lowered to 0.5% (certainly in European waters regardless of the outcome of the IMO review on postponing the limit to 2025), and thus the fuel price differential will be lower once the limit kicks in.

A number of studies were conducted the years before the new limits were introduced with a research focus on the implications of the regulation in the maritime sector. In 2010 the Institute of Shipping and Logistics (ISL, 2010) modelled the modal shifts due to the new limit of 0.1% after 2015, and estimated that this could reach on average 22% (considering container and Ro-Ro shipping). The ISL study anticipated an increase in sea transport costs for all fuel scenarios (high and low prices), however even the low fuel price scenarios were actually much higher than the recorded fuel prices in the last two years. In 2013, a study from the North Sea Consultation Group (NSCG, 2013) examined the potential modal shifts following the establishment of NECA and SECA in the North Sea and the Baltic. The study reports an anticipated increase in sea transportation costs ranging between 8 and 16%, reduced to 5-13% when the road haulage is included. The study anticipates only minor modal shifts towards landbased options due to this increase in costs.

3.2 The ex-post market picture in the first year after the launch of the new limit

Despite the concerns of the Ro-Ro sector that certain routes would be closed as a consequence of the new limit, most operators saw a very positive year in 2015. In fact, some of the larger Ro-Ro operators reported record revenues over the year. Figure 3 shows a few press releases in the aftermath of the first year with the new sulphur limit.

Stena Line records 16% yearly growth on North Sea route

Stena Britannica sails between the UK port of Harwich and the Hook of Holland in the Netherlands

P&O breaks Channel freight record in 2015

By Charlie Bartlett from London

P&O Ferries transported more freight between Dover and Calais in 2015 than any other year in its "modern history," amounting to 1,340,317 trucks.

The result is a 22% year-on-year increase over 2014, and is due in part to disruptions at the channel tunnel, which caused a 172% year-on-year increase in HGVs on is separate Teesport to Zeebrugge route throughout the month of July. The group pressed a sixth ship back into service on the English Channel that month in order to increase capacity.

DFDS Wraps Up Record Year, Expects Higher Revenue in 2016

Image Courtesy: DFDS

Danish shipping and logistics company DFDS posted a profit of DKK 1.07bn (USD 151m), up by 89pct when compared to last year's DKK 571 million.

For the full-year 2015, the group reported revenue increase of 5% to DKK 13.5bn. Organic revenue growth, adjusted for route closures and acquisitions, was 7% mainly driven by 7% higher freight shipping volumes and 8% more passengers. In the fourth quarter, organic revenue growth was 10%.

Figure 3: Press releases after the new limit was launched

Sources: http://maritime-executive.com, http://worldmaritimenews.com

These reports contradict the anticipated bleak picture drawn by preliminary reports prior to the launch of the new limit. However, these records may very well be attributed to the very low fuel prices observed in the last two years following the oil crisis. The fuel prices for MGO and HFO are shown in Figure 4.

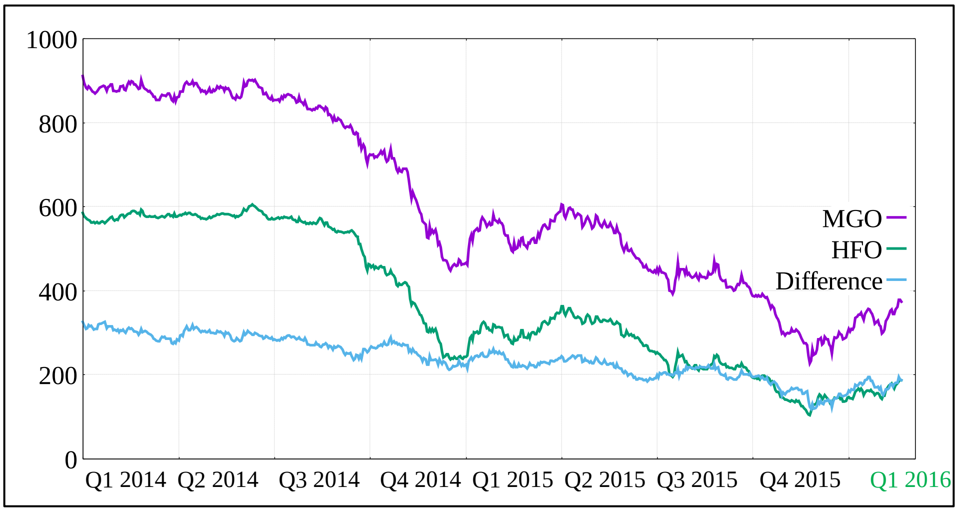


Figure 4: Fuel prices 2014 to first quarter of 2016. Data source: www.bunkerworld.com

The blue line shows the price differential between the two types of fuel, which can be seen to gradually decline in absolute terms. One can actually observe that in 2015 the MGO price was lower than the HFO price in 2014. This means that despite the stricter regulation, the fuel cost was actually lower for ship operators compared to the year before the limit. This would in turn allow ship operators to offer similar (and in some cases lower) freight rates as in 2014, but operate on lower overall costs which may explain the record revenues recorded. It has to be noted though that in the first quarter of 2016 the fuel prices have started increasing again, a trend which if continued could have major implications on modal shifts to land based options. Figure 5 shows how much more expensive MGO is in percentage terms as compared to low sulphur fuel.

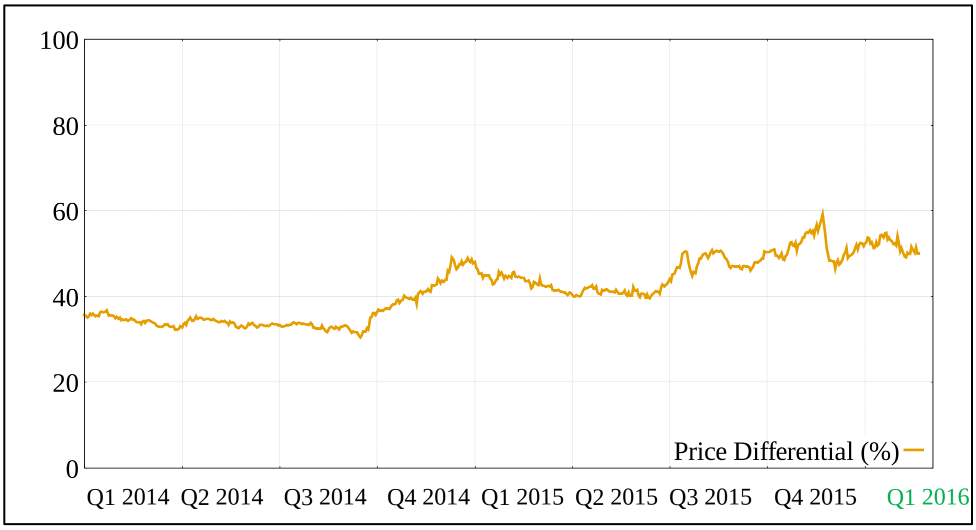


Figure 5: Fuel Price Differential between HFO-MGO in % terms . Data source: Bunkerworld

Figure 5 shows that despite the overall lower fuel prices observed, MGO is becoming more expensive in % terms as compared to HFO. This shows that despite the low fuel prices observed, the regulation is certainly increasing operating costs to ship operators compared to what they would pay if HFO were still allowed.

Currently, with the exception of the ongoing work within the context of the RoRoSECA project, only a handful of press releases have dealt with the post-SECA limit situation in the Ro-Ro sector. There has been one recent study from CE Delft (2016) on the ex-post assessment of the European experience of the new limit. The report's main conclusions are:

- The competitive position of Ro-Ro shipping in comparison with road transport became worse, since the fuel price differential has decreased (note: differential between Road Diesel and marine fuel)
- The first available evidence shows that Ro-Ro shipping has largely been able to cope with the fuel price increases
- Some of the largest Ro-Ro operators report outstanding financial figures over 2015
- The hypothesis that operators would have to shut down routes was not realized

Finally, it is also noteworthy that the ECSA survey in the context of the ESSF platform (2015) revealed that

- No modal shift was reported from the majority of respondents (only 19%)
- 38% of respondents consider it is too early to quantify the behaviour of customers after the new limit
- 94% of the respondents saw no impact on the level of service in terms of frequency and number of vessels deployed

It can be seen that the anticipated negative impacts of the regulation have not been realized yet, following a very positive financial year in 2015 for most operators. However, this is symptomatic and can be mainly attributed to the lowest fuel prices recorded in the last 15 years as seen in Figure 6

Figure 6: Crude oil prices per barrel adjusted for inflation. Source: http://www.macrotrends.net

It is therefore necessary to understand what is the contribution of the low fuel prices to the observed picture, and what would the situation had been if either:

- The regulation was not present and ship operators could still use HFO
- The fuel prices returned to the previous high levels

Particularly the second scenario is not unlikely as the last months in 2016 (see Figure 4) reveal an increasing trend in fuel prices.

As will be seen, the rest of this report will present the modelling framework used in the context of this project, which is the first attempt to dissect the effects of the low fuel prices from the observed market picture. The developed methodology allows the identification of the negative effects of the new limit on the maritime sector, which are currently masked by the very low fuel prices and the excellent financial figures reported so far. The findings of this report can be used by ship operators and policy makers to propose measures to counter the negative effects of the regulation.

4 Background on route selection and data requirements

This section will first present the main findings of Task 2.1 which was associated with the route selection and the data collection for Task 2.2. Then the selection criteria will be presented and the data requirements for the calibration of the enhanced modal split model will be discussed, along with the necessary contingency plans undertaken for cases where certain data proved intangible.

4.1 Summary of findings of Task 2.1

The first 6 months of the project revolved around the specification of the routes to be examined and the associated data collection, while at the same time the preliminary steps towards the development of the enhanced modal split model (Task 2.2) were taken. Out of the 18 DFDS routes operating in the summer of 2015 (including the unaffected by SECA Marseille-Tunis), seven DFDS routes were selected for additional analysis in Task 2.2 and WP3 which are summarized in Table 1.

Table 1: The selected DFDS routes for further analysis following Task 2.1

Geographical Area		**Total routes in Area**
NORTH SEA		**9**
Gothenburg – Ghent	Ro-Ro	
Esbjerg – Immingham	Ro-Ro	
Rotterdam – Felixstowe	Ro-Ro	
Copenhagen – Oslo	Cruise	
BALTIC SEA		**5**
Klaipeda – Kiel	Ro-Pax	
Klaipeda – Karlshamn	Ro-Pax	
CROSS CHANNEL		**3**
Dover – Calais	Ro-Pax	

The route selection criteria used in the process are summarized in Figure 7, along with the main argument used to satisfy each criterion.

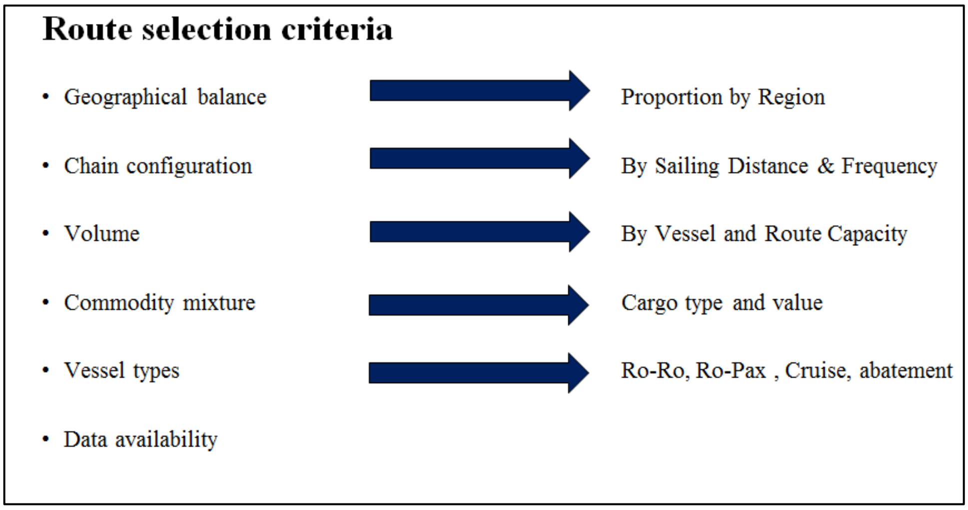


Figure 7: The route selection criteria and the main supporting arguments

In terms of geographical balance, the routes in which DFDS operates were divided into three; North Sea, Baltic Sea, and Cross-Channel Routes. The ratio of routes per region was respected, and therefore more routes were selected in the North Sea were DFDS has more services deployed, followed by the Baltic Sea, and including one Cross-Channel route in the final selection. Out of the three Cross-Channel Routes that DFDS operates, the most important one was selected (Dover – Calais) which is at the same time the only one facing competition (from Eurotunnel and other ferry services).

The following section will discuss the data requirements for the development of the enhanced modal split model, considering that for each route examined a distinct model will be created.

4.2 Data requirements

In order to construct a modal split model that will allow the estimation of modal shifts due to the effects of the SECA regulation or other changes in the market, it is necessary to acquire representative data for the model's calibration. Most discrete choice use revealed preference data to predict aggregate market behaviour (Ben-Akiva et al., 1994), and require information on the key explanatory parameters. Another approach is the use of stated preference data, which revolve around observations on hypothetical choice behaviour, typically collected through surveys, interviews or focus groups. For all cases, the necessary data require the acquisition of information on the market share of each of the available options (e.g. how many select each option) to model the probability of making a selection. Subsequently, the researcher has to decide which type of model to use (see section 6.3) and which are the explanatory variables considered in their model, which will be used in the model calibration stage.

The vast majority of transport research discrete choice models is focusing on passengers/drivers choices between different public transport modes, vehicle use, cycling, and/or walking. This can be attributed to the fact that when the decision makers on mode choice are travellers, they are taking into account more information (cost, travel time, number of transit changes, weather, comfort, etc.). In contrast, for freight transport the shipper usually has to decide based on only the total travel cost and overall time. In the RoRoSECA project the focus is on modelling the mode choice of shippers when one or more short-sea shipping modes are available and compete with one or more landbased modes. It is assumed that the decision is based on information about total travel cost and time, as these are the explanatory variables that are heavily affected by changes in policies (such as the requirement to use low-sulphur fuel since 2015). Therefore, the required data for Task 2.2 can be categorized as shown in Figure 8.

Data on DFDS Routes:	Data on Maritime Competitors:	Data on Landbased Competitors:
Total sailing time (port to port)	Which Service	Is there a fully landbased option?
Frequency of service	Total sailing time (port to port)	Total Distance
Freight rates per lanemeter of cargo	Frequency of service	Total Travel Time
Waiting times at Ports	Freight rates per lanemeter of cargo	Freight Rate
Connecting Road Distance after Sealeg?	Connecting Road Distance after Sealeg?	Tolled Points

Figure 8: The required data for Task 2.2 for each mode

These can be summarized to the following steps:

- Retrieve competing maritime modes to the selected DFDS Route
- Identify competing rail links for certain O-D pairs
- For each option, estimate the total travel time and costs from Origin to Destination, taking into account the waiting times due to frequency of service.

The next section describes in further detail the required data for each step.

Origin – Destination (O – D) pairs

For each DFDS route examined, the first step is to identify the Origin-Destination (O-D) pairs of the cargo carried for each side of the route. To the greatest extent, this data should include information on type of cargo transported (including price, volumes), starting and ending location.

Alternative modes

For these O-D pairs, all alternative transport modes need be identified. These can include maritime competitors that serve the same (or very similar) port-to-port connections, haulers and rail links. For competitive modes, the market share will be explored according to the different commodities transported.

Market Share

For each competing mode during each scenario, it is necessary to identify the transported volumes and express it as the market share of each mode, for the different commodities transported. Some aggregate level data information for the various maritime services was available through the SHIPPAX journal series.

Assumptions on necessary data

The previous assumption that only total travel time and travel cost are taken into consideration simplifies certain aspects of the modelling part. However, discrete choice modelling methodologies consider that a selection is based on maximizing the utility (or minimizing the disutility) associated with each option. As a result, it is necessary to link cost and time in a single function of disutility. This can be the generalized cost of transport which increases at higher transport costs and travel times; both considered as undesirable and thus the preference for using the term disutility.

Travel time and costs can be linked using the value of cargo and its depreciation as a means to convert time into monetary costs, which can also be considered as a representation of the value of time of a certain cargo. As a result, the value of time will vary for different cargoes. Considering that for at least the maritime options the freight rates are a function of the shipment size (costs are given in monetary units per lane-meter transported), it is not only the value of cargo that affects the generalized cost of a shipment but also its physical characteristics. The generalized cost and its formulation will be further discussed in section 6.2, however it can be seen that ideal data would require not only information on volumes of transported goods between all O-D pairs using a DFDS link or its competitive modes, but also information on the cargo values and their depreciation.

4.3 Available data

Following the first year of the project, it has become apparent that cargo flow information is not only extremely difficult to attain from a research team's point of view, but also from the transport operators' perspective as well. The shipping companies were aware of the amounts of cargo transported in terms of lane-meters, and the main cargoes transported on a qualitative basis, but precise information was not available. A similar obstacle was observed with land based modes, as only aggregate estimates from statistical services were available for transported volumes of freight. Therefore, the enhanced modal split model was developed with the objective of being able to estimate changes in the probability of choosing a certain mode, as a function of the following characteristics:

- The initial market share of each option
- The freight rate charged per option
- The total travel time of the option
- The cargo value per lane-meter transported

For the scenarios where data on the aforementioned characteristics were not available, a simulation approach was used, considering a sensitivity analysis around some central values of each characteristic. Figure 9 summarizes the main data retrieved during the first year of the project and the sources.

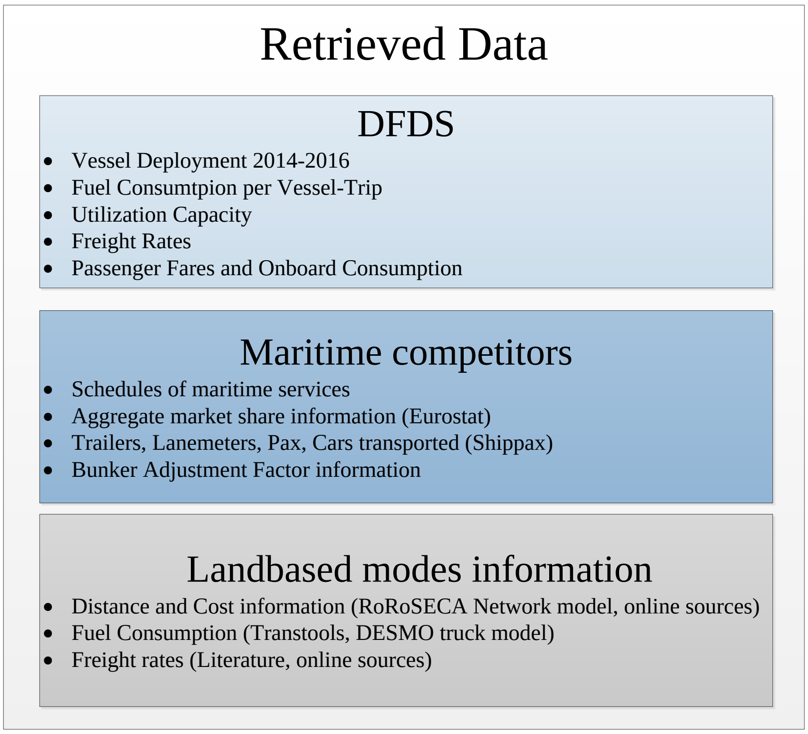


Figure 9: Summery of retrieved data and relevant sources

4.4 Summary

This section briefly summarizes the main findings of Task 2.1, and the route selection criteria. The data requirements for the calibration of the modal split model were presented, and contrasted with the actual data availability constraints for this project. Important data were retrieved in cooperation with DFDS, particularly for the volumes transported from DFDS ships and information on the costs and benefits associated with the trips. However, information on market shares of other modes was based on very aggregate estimates from statistical services, press releases of maritime competitors, and publications on the Shippax CFI journal. As a result, for the case studies examined in the context of Task 2.2, simulation of data and sensitivity analyses will be conducted to make up for lack of relevant data. The next section presents an overview of the modelling framework developed for Task 2.2.

5 Model overview

This section presents the enhanced modal split model and the underlying methodology used in the context of Task 2.2. The model focuses on the repercussions of the new sulphur limits from the perspectives of the shippers and of the main transport operators serving the examined routes. As mentioned earlier, the main objective of Task 2.2 is the calibration of the model, and its setup in a way that will enable the identification of the potentially negative effects of the regulation. This will then be used in Year 2 in the context of WP3 so as to assess the efficacy of certain policy and operating measures in addressing these negative effects.

5.1 Data confidentiality

The necessary data used in the model, are colour coded in Figure 10 to reflect the different confidentiality levels. As such, in red background colour are data that were provided by DFDS Seaways and are strictly confidential. Such data will not be part of the report version that will be published online in the RoRoSECA webpage. As seen in Figure 10 these data revolve around the revenue per route (passenger fares, cargo freight rates, on-board spending), and the fuel costs per trip (mainly the fuel consumption, as fuel prices are, in general, available).

The yellow colour code stands for information that is accessible via certain registered services, or was provided by DFDS Seaways but is not confidential. For example, certain information on market shares was retrieved from the Shippax CFI publications. Bunker fuel prices for HFO and MGO is also available through online services for registered users. Cost information on scrubber systems and other capital investments (including the subsidies provided by the EU where applicable) was retrieved through online articles and was subsequently confirmed by DFDS, but in terms of correct order of magnitude and not with exact financial figures.

Finally, the green colour indicates information that is publicly available, and it mainly comprises of information for schedule of DFDS and other maritime services (planned services, capacity for passengers and cargo, total sailing times (including waiting times for check in), information on aggregate level market shares (e.g. from Eurostat), existing landbased alternatives (road/rail) and their total trip times, and finally which vessels are equipped with scrubber systems and which have to rely on low-sulphur fuel. Figure 10 presents the overview of the models developed in the context of Task 2.2, and the ensuing sections will describe the various modules and their interrelations.

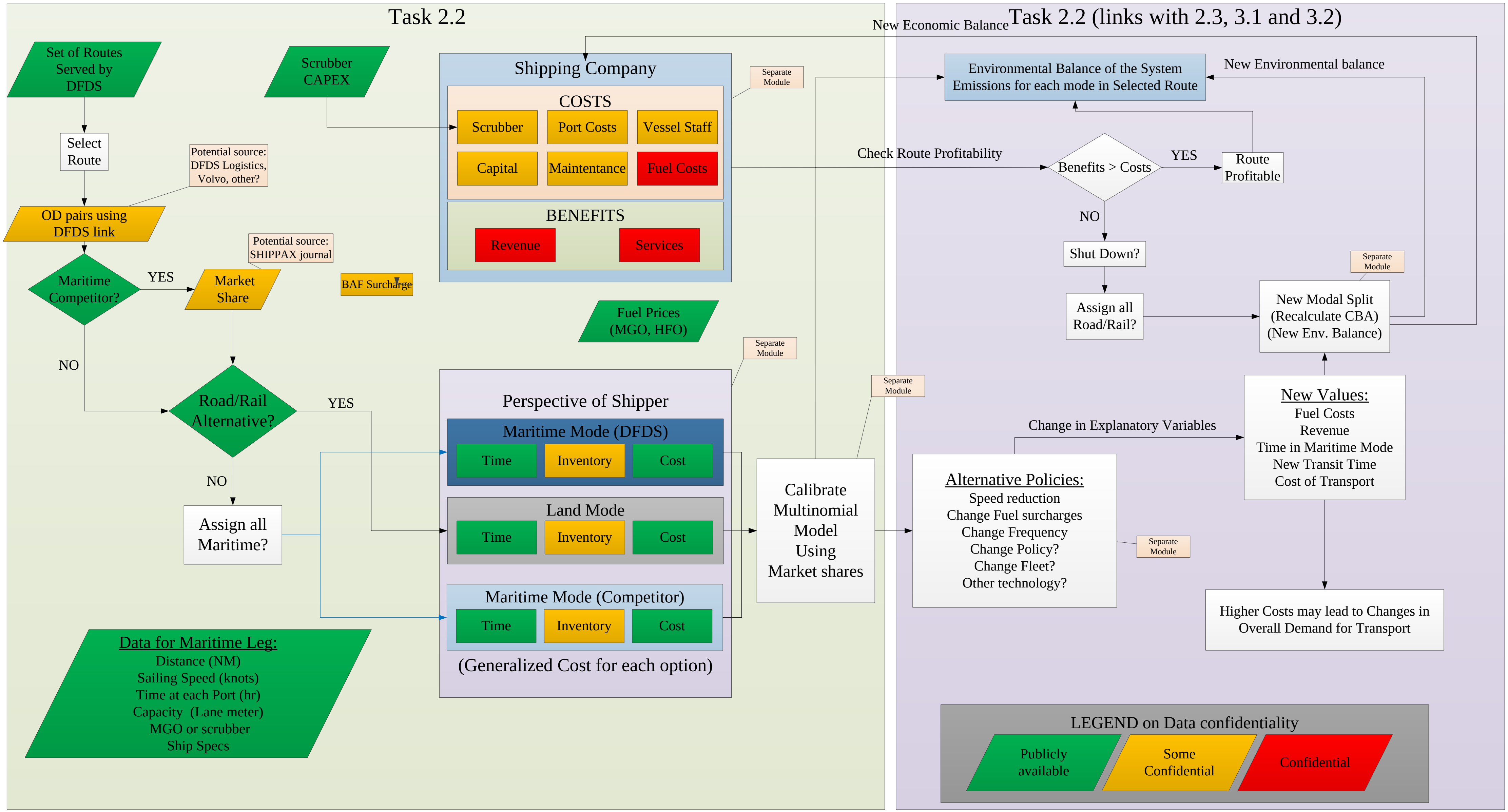


Figure 10: The overview of the model in the context of Task 2.2

5.2 Data input for selected routes

The first step was to make a selection of the DFDS routes to be examined which was part of Task 2.1. For these 7 routes selected, the most important maritime and land based alternatives for cargoes were retrieved. As the enhanced modal split model is based on the theory behind discrete choice, it is necessary to establish a limit of how many different choices are allowed. While the model is developed in a manner that allows the examination of as many different options as necessary, due to time constraints and lack of reliable data for certain routes, only a few very competitive modes were considered for each scenario.

This requires establishing a limit as to what option constitutes a rational alternative. As such, for the main cargoes using an examined DFDS route the main points of origin and the most probable destinations were considered. In terms of landbased modes, the fastest and cheapest routes were considered using the RoRoSECA network model (see section 9). For maritime services, all maritime operators offering the same route were considered (e.g. for Dover Calais), and links where the additional total travel time would not exceed 50% of the DFDS option. For example for cargoes going from Sweden to Belgium, an alternative link could be Gothenburg-Kiel followed by a large road link, but a maritime link between Karlshamn and Klaipeda and then driving is considered as not possible. Finally, as Figure 10 shows, if there are no landbased alternatives that are reasonable, then all cargo is assigned in maritime modes.

For each of these options, certain calculations need to be made in order to provide the necessary input for the Shipper's perspective module as in Figure 10These revolve around the estimation of the total travel time and costs.

For time, the travel times at each different leg, the waiting times at points of intermodal changes, and the inclusion of the sailing frequency is performed. The latter is important as a landbased alternative in theory can depart at any moment of time without waiting times. The sailing frequency can be converted to travel time assuming that on average the waiting time for a service depends on the time between two successive departures from the same port. As departures are fixed (e.g. there is no random process), the waiting time can be assumed to be half of the inter-departure time. It can be argued that for small shipments the shipper can incorporate the maritime option without considering time losses when using a maritime service; the shipper adapts a Just-in-time approach. However, as in year 2 changes in the sailing frequency will be examined as a policy measure to reverse the negative effects of the regulation, the modelling framework in this work is considering waiting times attributed to sailing frequency.

For travel costs, the freight rates for each available option need to be retrieved. DFDS has provided the freight rate per lane meter of cargo. Similar values have been retrieved for competing maritime services, based on published information in the respective webpages of the operators. For road options, information from haulers on an individual cargo basis was not possible to be retrieved due to time constraints. As such, travel cost estimates from the road network model per trailer, and figures used in other studies were used (see section 9.3).

Finally, the depreciation of cargo and the cargo value per lane-meters are also varying heavily across different selected routes, and thus a simulation approach is followed (section 8).

5.3 The shipper's perspective

The shipper is assumed to be the responsible for the decision making process of which mode will be selected. The different options for a given O-D pair are:

- Route using an examined DFDS service
- Route using only land-based options (if available)
- Route using a competing maritime service (if available)

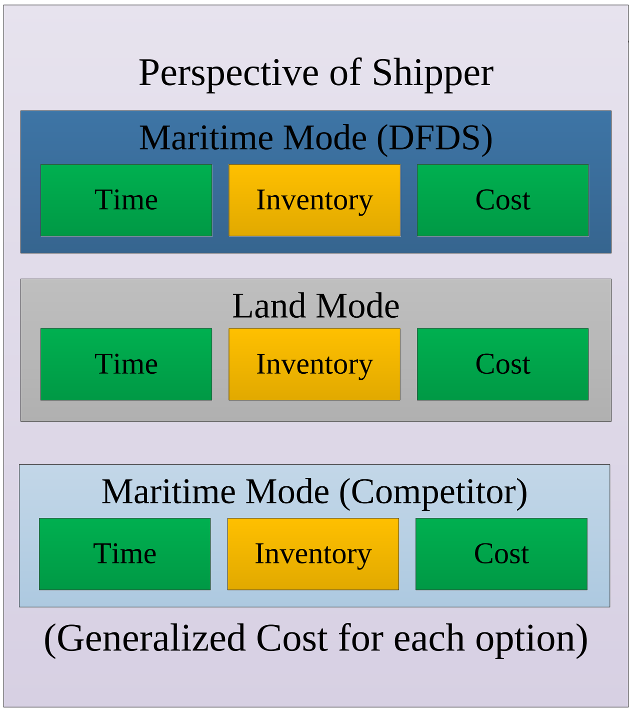


Figure 11: The module for the Shipper's perspective

For maritime options, the travel time and cost for the landbased distances (e.g. from warehouse to port of origin, and from port of destination to client) are also derived from the road network model. The way these three variables are connected into the generalized cost will be presented in section 5.5. It is important to note that the travel cost within a sea-link depends on the cargo volume, and more specifically the lane-meters occupied on-board a ship. In contrast, for road transport options the travel cost may also depend on the weight of the product. Finally, the cargo value is assumed not to affect the freight rates. It has to be noted that for certain cargoes the travel cost may be increased; particularly hazardous cargoes that are not only more expensive to transport, but may also require an earlier check-in time at the port and thus increase overall travel time. However, no such cargoes will be examined in the context of Task 2.2.

5.4 The perspective of the shipping company

This part of the model is concerned with the changes that DFDS would see in the examined routes as a consequence of the new sulphur limits. Due to the liaisons with DFDS and the acquired confidential data, it is possible to consider the before-after economic balance of the examined routes. This is not possible for other maritime operators due to the lack of crucial data, particularly regarding fuel costs, other operating costs, as well as occupancy ratios. However, the developed methodology can readily be applied on other maritime services as well provided the same type of data. The key components in the module examining DFDS's perspective is shown in Figure 12 which is essentially the close-up of the overall modelling framework.

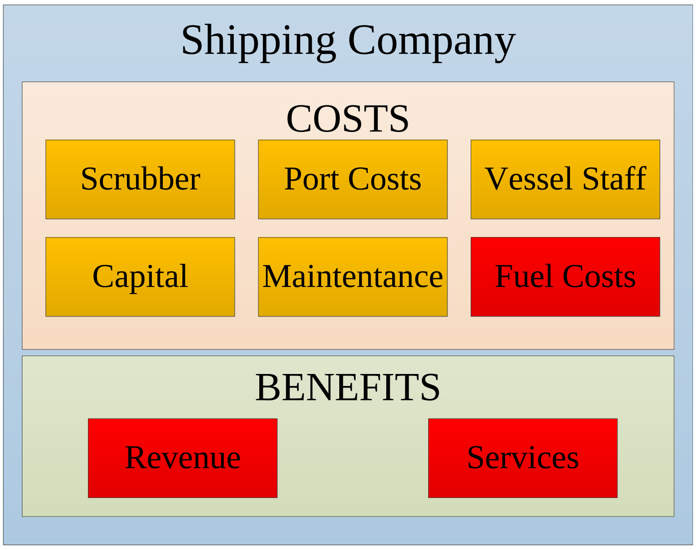


Figure 12: The module for DFDS' perspective

The scrubber costs are relevant for vessels that were retrofitted, and it is assumed that the capital costs are discounted into monthly payments for a period of 20 years from the time of installation. It has to be noted that this period may vary for different vessels depending on the actual age of the vessel. In addition, these vessels were in their majority retrofitted before the 1st of January 2015, and as such the increased operating costs (higher fuel consumption, and discounted capital costs) were applied since the baseline examination period. Information on other operating costs for a voyage (port fees, vessel staff costs, capital depreciation, and maintenance) were not explicitly disclosed by DFDS. But DFDS provided the actual fuel consumption for the vessels requested, and what percentage of the total operating costs the fuel costs were for years 2014 and 2015. Using these, it is possible to differentiate between fuel costs and other operating costs for both years.

Finally, on the benefits calculations the company provided confidential figures on the average utilization capacity for freight and passengers per year, coupled with the information on freight rates and passenger fares (including on-board spending per passenger). This allows the examination of the change in the profitability of a certain route between the examined years. This will be further explored in section 5.4 of the report.

5.5 Flow and links with Task 2.3 and WP3

Following the retrieval of the generalized cost of transport for all available options, and the respective market shares of each option, it will be possible to calibrate the modal split model. This model can then be used to simulate what will happen for different fuel price scenarios, and as a result of the lower sulphur limits. For each route, and for each different scenario examined, the baseline case in terms of economic performance for the DFDS route can be compared with the new predicted economic performance following any modal shift. In addition, using the information on fuel consumption from each vessel, it is possible to construct an emissions inventory for each route examined. These emissions can also be compared with the findings of the SHIP DESMO model in Task 2.3 (reported separately), which can be used to predict emissions for a certain energy demand as a function of transported cargo for each vessel[4].

In the first year of the project, the main objective of Task 2.2 has been the development of an enhanced modal split model that can be used to assess any negative repercussions of the regulation. This has to be taking into account the objectives of year 2. The methodology presented in section 4 of this report is enabling an iterative procedure that is closely linked with the requirements of tasks 3.1 and 3.2 of WP3. For these tasks, the baseline case will be the anticipated modal shifts as a result of the regulation, and this will subsequently be compared with the efficacy of suggested policies and operating practices in reversing these side effects. The next section will present in detail the underlying theory of discrete choice modelling, and how this was adapted in developing the enhanced modal split model for Task 2.2.

[4] As Task 2.3 was being completed the same time as Task 2.2, there has not yet been a direct link between the two tasks. Such a link however will be considered in Year 2 of the project, in the context of WP3, as some of the outputs of Task 3 (emissions, external costs, etc) will be used in WP3.

6 Methodology - Theory

The choice of transport mode can be influenced by several factors as Ortuzar and Willumsen (1990) note. These are classified into:

- Characteristics of the trip maker
- Characteristics of the journey
- Characteristics of the transport facility

This classification is used for modelling mode choice for all types of transport and each category has a number of different attributes that affect the choice. However, as stated in Section 5, an aggregate approach is adapted in this work where the governing criterion for the choice that the shipper is making, is the generalized cost of transport. The enhanced modal split model developed in this section is a two-stage model, where at first the mode choice (maritime vs. road or other competitive mode) is calibrated and the implications of the additional costs (due to the lower sulphur limit requirements) are evaluated for their effect on mode choice. A secondary model is then used to assess the implications of the potential modal shift to the maritime company's profitability on the examined route. The next section summarizes the theoretical background of modal split models, and the main types of structure used.

6.1 Discrete choice and modal splits

In general, modal split models are useful as they can allow the simulation of the travel demand between an O-D pair amongst a set of different transport modes. The underlying theory is based on the assumption that the decision maker (in this case the shipper) seeks to maximize his utility (or minimize his disutility) by selecting the best transport mode. In the context of the RoRoSECA project this is equivalent to minimizing the perceived generalized cost associated with an option. In theory, this would lead to an all or nothing assignment, as a simple enumeration of the total generalized costs could show which option has the minimum. However, in reality each decision maker will have a different perception of what the lower cost would be. In transportation, the majority of modal split models used are falling in the category of logit models, as these are found to fit mode choice behaviour quite well (Panagakos et al., 2014). Logit models are essentially regression models where the dependent variable is categorical; in this case mode choice. The purpose of logit models is to predict the probability of particular outcomes (mode choice) based on one or more predictors (explanatory variables). For the purposes of this project, the main predictor is the generalized cost of transport for each option.

6.1.1 Notation

The model developed comprises of a number of different variables which are necessary to be introduced in the ensuing sections. Table 2 presents the notation with a short description of each variable and parameter.

Table 2: Nomenclature within each Route scenario

Indices	*Denotes*
k	Different leg of the route
i	Commodity type to be shipped
j	Transport option of shipper
n	Transport option among similar transport options (for a nested logit model)
p	Intermodal node where waiting occurs (e.g. port, loading station)
Sets	
K	All legs in a specific route
J	Set of transport options (1,2 for binary), (l,r,m for multinomial top level)
L	Set of transport options within the same level (1,2,3… different similar options)
P	Set of all nodes where waiting occurs
Parameters	
$GC_{i.j}$*(€)*	Generalized cost (or disutility) of option *j* for commodity shipped *i*
t_j *(days)*	Total time needed through transport option *j*
$P_{i,j}$*(€)*	Transport price for commodity *i* via transport option *j*
s_j	Fuel surcharge applied in a maritime leg
I_i *(€/day)*	Inventory cost for commodity i
CV_i	Value of cargo i
R	Opportunity cost of capital
rel_j	Reliability of option *j*
t_{w_p} *(days)*	Waiting time at node *p*
D_k *(km)*	Distance of leg *k*
V_k *(km)*	Speed used in leg *k*
Binary Logit Model	
$x_{i,j}$ *(%)*	Fraction (probability) of product *i* shipped via option *j*, $j \in (1,2)$
λ^{ι}*(number)*	Positive constant found through model calibration
Multinomial Logit Model	
$x_{i,j}$ *(%)*	Fraction (probability) of product i shipped via option j, j $j \in (1,2,\dots n)$
λ^{ι}*(number)*	Positive constant found through model calibration
Nested Logit Model	
$x_{i,n/j}$ *(%)*	Fraction of product *i* shipped via option *n* among similar alternatives *j* $j \in (l,m,r)$, *l:landbased, m:maritime, r: rail*
λ_L^i*(number)*	Positive constant for calibration at level *L* of the multinomial $L \in (1,2,3 \dots)$
$GC_{i.j}$*(€)*	Composite generalized cost of correlated similar alternatives *j*, $j \in (l,m,r)$,
$GC_{i.n/j}$*(€)*	Generalized cost of product *i* shipped via option *n* among similar alternatives *j*

6.2 Generalized Cost formulation and assumptions

The generalized cost $C_{i.j}^{g}$ for each different transport option *j* that each shipper *i* pays is a function of the monetary cost of transport, the required travel time, the inventory costs and the reliability of the service. Shipper i may have a pool of alternative options to transport cargo from a specific origin to the final destination. It is assumed that when comparing the available options, the shipper will decide based on the cost and total travel time that each option presents. How important the time is as compared to cost will depend on the nature of the product transported. As stated in earlier sections, in reality there may be additional factors influencing the choice (for example historical evidence of reliability of service, minimizing the total number of intermodal changes, or a simply strong preference towards a particular mode even if it is more expensive/slow). However, most of these factors could be transformed to represent an additional delay or monetary cost in the form of penalties.

The generalized cost (or disutility) for each mode j and product i is calculated through eq. 1

$$GC_{i.j} = P_{i,j} \cdot (1 + s_j) + I_i \cdot (t_j + rel_j) \tag{1}$$

Where

- $P_{i,j}$ (€) represents the price the shipper is paying to transport commodity *i* through mode *j*.
- s_j denotes any % surcharge imposed by the shipping company due to the increased fuel prices (applicable for maritime modes).
- I_i (€/hour) stands for the inventory costs of commodity *i* estimated by, considering the cost of capital *r* and the working days. This is essentially the value of time, that can be used to combine the total time and the travel costs into the generalized cost. Considering that the unit of time of interest in this work is hours, the inventory cost is given by equation 2.

$$I_i = \frac{CV_i \cdot r}{365 \cdot 24} \tag{2}$$

- t_j (days) is representing the total travel time for shipment I through transport option j. It includes transit times at intermodal nods.
- rel_j (days) stands for the reliability of the service which can either be the standard deviation of transport time or the average overall delay in delivery based on historical data.

This formulation of the generalized cost can facilitate comparisons between different shipping options. In addition, the effects of a change in a specific parameter of the problem (e.g. fuel price, change in the frequency of a service, introduction of an additional tax, etc.) can be compared with respect to their effect on the generalized cost. However, it has to be noted that this formulation is essentially binding the relationship between travel time and monetary cost via the value of time. While this relationship varies for different cargo values and types, a more suitable approach would be to estimate a weight on the travel time based on comprehensive revealed preference data for cargo shipments in each route. This unfortunately is impossible due to data confidentiality and time constraints, and as such the value of time approach is used based on previous research in the field (Psaraftis and Kontovas, 2010). The next section presents the different structures used in the family of logit models, depending on the number of modelled alternatives, always taking into account generalized cost as the main predictor.

6.3 Potential structures (binary, MNM, hierarchical)

There are three main structures of logit models that are relevant in the context of the RoRoSECA project. These are the binary, multinomial, and nested (or hierarchical) structures.

6.3.1 Binary case

In the simpler case, a binary logit model is used when the decision maker is assumed to be able of choosing only one of two alternatives. A binary logit model was used in the work of Panagakos et al. (2014) when modal shifts between an option using a maritime link within the Mediterranean and a fully land based option were modelled. Figure 13 shows the typical structure of a binary model assuming the alternative options are

- a link using a DFDS service, or a link using a competitive maritime service
- a maritime link using a DFDS service (maritime monopoly), or a fully landbased alternative

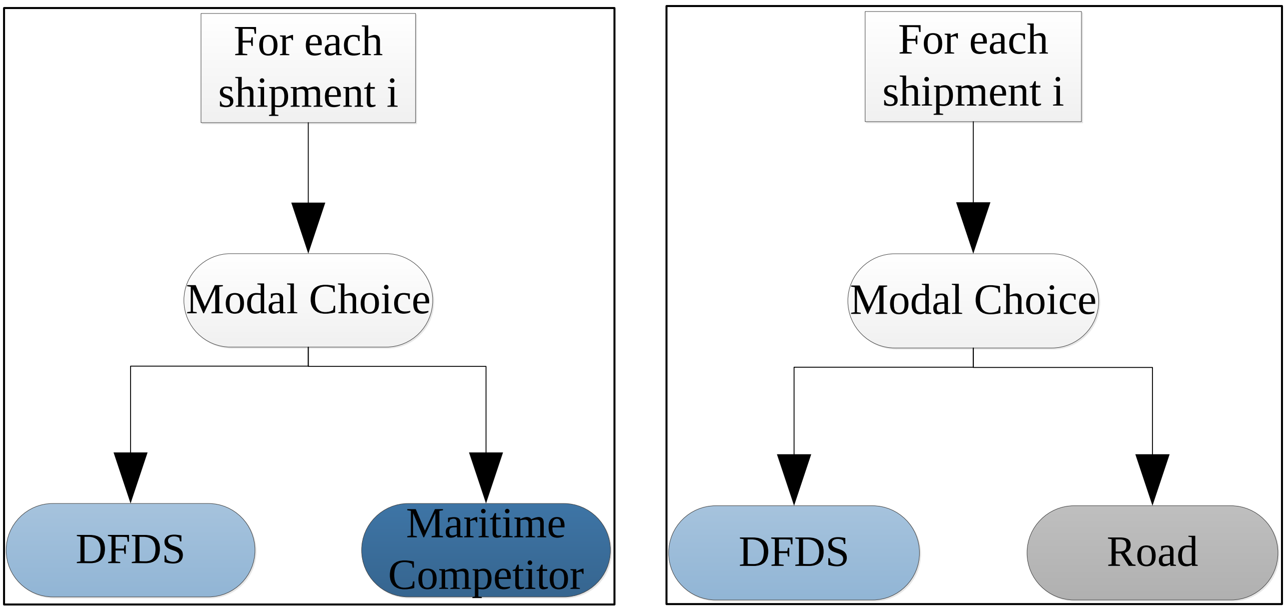


Figure 13: Possible Binary structures

In this case, the probability $p_{i,j}$ of a cargo i being shipped via mode $j \in \{1,2\}$ is given by:

$$p_{i,j} = \frac{e^{-\lambda \cdot GC_{i,j}}}{\sum_{j=1}^{2} e^{-\lambda \cdot C_{i,j}}} \tag{3}$$

Where λ is a positive constant associated with each different cargo type and acts as a dispersion (scale) parameter. The larger the value of λ, the greater the implications of a change in the generalized cost of one of the two options in the shipper's decision.

6.3.2 Multimodal Split structures

In cases where more than two alternatives exist, it is necessary to reformulate the model to include the additional options. This formulation allows the addition of more services even after the calibration. That would be equivalent to an opening of a new service (e.g. a rail link) due to increases in freight rates of maritime operators. In that case, the new option would absorb some shipments and take its own market share. Similarly, the adapted methodology allows the elimination of an alternative (e.g. the closure of a service due to poor economic performance). This would of course require the redistribution of the market shares of the shut-down option to the remaining modes. There are two main structures for logit models that simulate more than two alternatives.

6.3.2.1 N-way structure

The first structure is the N-way, where it is assumed that the shipper will select any option of the n>2 alternatives bearing in mind only the disutility (generalized cost) of each option. This structure is depicted in Figure 14, where there are assumed to be three available choices to cross the sea (e.g. there is no fully landbased alternative).

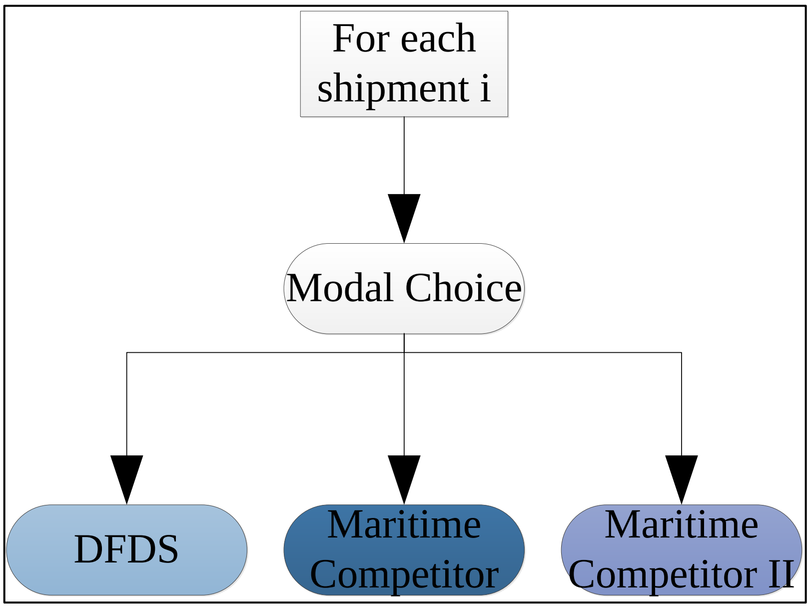


Figure 14: An N-way structure with three options

The model in the N-way structure is very similar to the binary case. Assuming there are M available options in total, then the probability $p_{i,j}$ of a cargo i being shipped via mode $j \in \{1,2,\ldots M\}$ is given by:

$$p_{i,j} = \frac{e^{-\lambda \cdot GC_{i,j}}}{\sum_{j=1}^{M} e^{-\lambda \cdot GC_{i,j}}} \tag{4}$$

The N-way structure is the simplest possible structure for cases with more than 2 options. Ortuzar and Williamsen (1994) note that this structure can lead to problems as it assumes that all alternatives have equal weights, which can lead to problems when some options are correlated. This could lead to problems when a new mode is introduced to the model. When there is strong evidence that some of the available options are correlated, it is best to use the hierarchical (or nested) structure.

6.3.2.2 Hierarchical structure

The second structure is the hierarchical or nested structure. This considers a primary split where the similar options are grouped together, and have been separated from the uncorrelated options. This is depicted schematically in Figure 15.

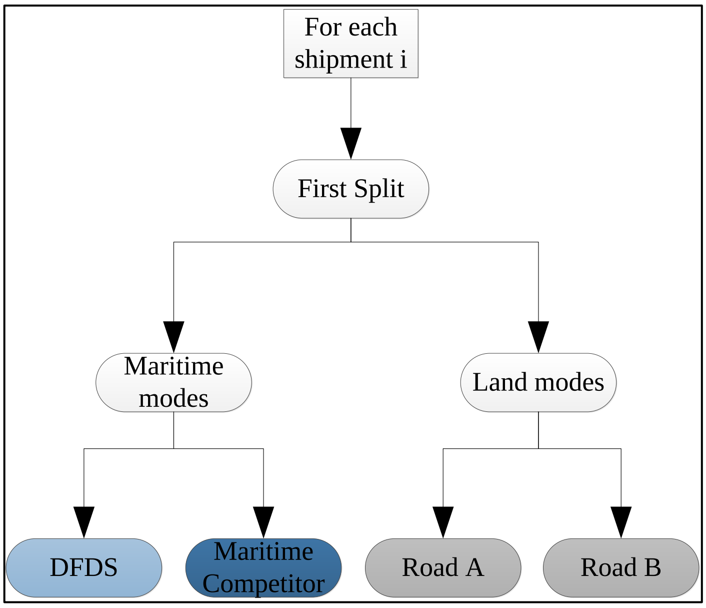


Figure 15: A hierarchical structure with 4 options and 2 splits

In this case, a first split between the maritime (*M*) and land (*L*) modes is assumed. The options within each nest (maritime or land) are for this paradigm considered correlated. The first split has to do with deciding which of the two general modes to use; a mode containing a maritime leg at some point, or a fully landbased option. The probability p_n of choosing a maritime mode M is given by equation 5.

$$p_n = \frac{e^{-\lambda_1^i \cdot GC_M}}{\sum_{n=M,L} e^{-\lambda_1^i \cdot GC_N}} \tag{5}$$

Where λ_1^i is the dispersion parameter between the two nests. GC_N represents the composite generalized cost for nest N, and is a function of the generalized cost of all *j* alternatives in nest N.

Assuming that the first decision revolves around which type of mode is selected (*M* or *L*), and that the decision is a maritime mode $j \in M$, the shipper must now decide which of the available *j* maritime options to use. The hierarchical structure is then assuming that the conditional probability $P_{j/i}$ of choosing mode j when type *i* is selected:

$$p_{j/M} = \frac{e^{-\lambda_M \cdot GC_{j/M}}}{\sum_{j \in i} e^{-\lambda_M \cdot GC_{j/M}}} \quad (6)$$

And

$$p_{1/M} + p_{2/M} = 1 \quad (7)$$

Where λ_M is a dispersion parameter for the secondary split amongst the maritime modes. A similar λ_L dispersion parameter for the secondary split among the landbased modes is also defined. Equation 7 shows that if there are only two alternatives in the maritime nest, then all commodities selecting a maritime mode will be transported via maritime option 1 or 2. At this level, it is possible to have more options of a similar type (e.g. a third maritime option) which is assumed to follow an N-way structure (within the maritime nest) and thus share the same secondary dispersion parameter λ_M.

These secondary dispersion parameters can be calibrated as in the binary or N-way structure if the generalized cost of each option within the nest, and its associated market share are known. Having estimated the secondary dispersion parameters, it is possible to estimate the so called composite generalized cost GC_N seen in equation 5. This composite cost GC_N for nest N is calculated through equation 7.

$$GC_N = \frac{-1}{\lambda_i} \log\left(\sum_{j \in i} e^{-\lambda_i \cdot GC_{j/i}}\right) \quad (8)$$

According to eq. 8, if there is only one alternative j between a similar mode of type i, then the composite cost collapses into the generalized cost GC_j of that mode. In a similar manner, if there are only two modes of type i (for example L and M for landbased and maritime), and for each type there is only one alternative, then the hierarchical model collapses into a binary logit model of only two options. Therefore, the described structure can be readily applied to all types of case studies affected by the SECA regulation. These can be:

- Routes that face no competition from land-based modes, but more than one shipping operators are serving
- Routes with a unique shipping operator and one landbased alternative
- A combination of the previous

It has to be noted that there could be a hierarchical structure with more than 2 nests (for example a maritime, a road, and a rail nest) but this is not considered in the RoRoSECA project based on the nature of the selected routes. However, the developed models in the context of Task 2.2 can be readily reformulated to take this into account as a theoretical exercise. Section 6.6 presents the selected routes as an outcome of Task 2.1, and under which structure each falls.

6.4 Effects of the value of the dispersion parameter λ

In the previous sections the importance of the scale parameters was noted, and the identification of its value is the main objective of the model calibration. It has been noted that a large value of the dispersion parameter shows an increased sensitivity in the modal choice. In other words, even a small change in the generalized cost of one option will lead to a significant modal shift for large λ. Using the binary structure to illustrate this in a conceptual approach, let us assume that there are two options 1 and 2, with equal generalized costs of 5 units each; $CG_1=CG_2=5$. The theory states that the probability of choosing either mode should be equal. Substituting the generalized costs on equation 3 and considering that $p_1=p_2=0.5$ it is not possible to estimate the scale parameter. However, the interesting question is what would the modal shift be, if there are changes introduced to the GC_2 value. Conducting a sensitivity analysis for the dispersion parameter, the plot of Figure 16 can be produced where the share of option 1 is presented as a function of the new GC_2.

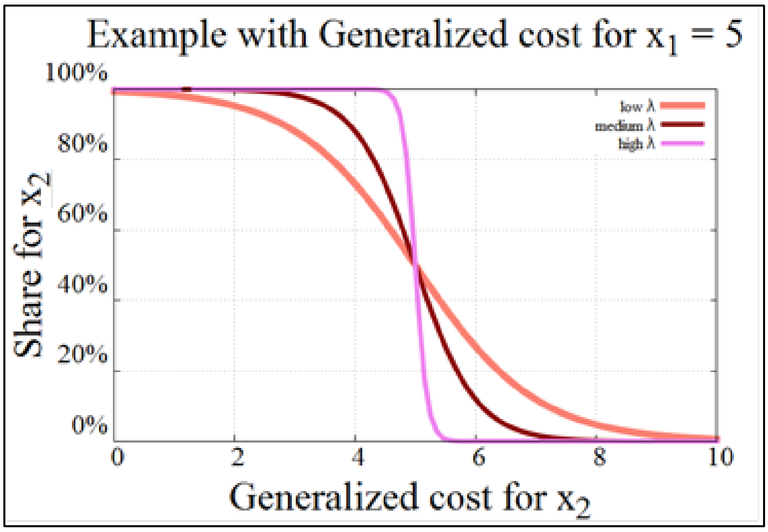


Figure 16: The effect of the scale parameter in modal shifts for a binary logit model

The S-Shaped curves of Figure 16 represent the behaviour of the shipper who will consider mode 2 less attractive as its cost increases. This change is more abrupt for high values of λ, whereas for low values the loss of market share is less sudden. Using the market shares of the two options in the baseline case, and knowing the associated generalized costs it is easy to estimate the value of the dispersion parameter; unless the costs and shares are equal for both modes in which case it is mathematically impossible to estimate the value of lamda by solving for it in equation 3.

6.5 The role of cargo value and depreciation rate

Considering the formulation of the generalized cost through equation 2, it is necessary to note the implications of the depreciation rate and the cargo value in the overall cost. This is particularly important as it is directly linked to the travel time, and can help understand the effects of policy measures and operating practices that may affect speed of service. In addition, the depreciation rate may also change for certain cargoes. For example, perishable cargoes (e.g. fresh fruits, fish) may have a very high depreciation rate as these products require fast transportation. Table 3 conducts a sensitivity analysis for various cargo values and depreciation rates, using as output the value of time for the specific cargo.

Table 3: Impact of cargo value and depreciation rate on value of time

Cargo Value (€/lm)	Value of time (€/hr·lm)

	r=1%	*r=10%*
100	0,000114155	0,001141553
1000	0,001141553	0,011415525
10000	0,011415525	0,114155251
100000	0,114155251	1,141552511
	r=3%	*r=20%*
100	0,000342466	0,002283105
1000	0,003424658	0,02283105
10000	0,034246575	0,228310502
100000	0,342465753	2,283105023

6.6 DFDS network and examples which routes fall into which structure

Based on the different structures presented in section 5.3, and considering the selected routes under examination from Task 2.1, it is possible to associate each route with its respective structure that complements it best. In reality, there may be more alternative options for shipping a product in a O-D pair using a DFDS link, but as stated in section 4.2 only reasonable alternatives will be considered. For most scenarios, only the fastest/cheapest landbased option as derived from the RoRoSECA network model is considered, along with any other maritime alternatives.

The summary of the structure per route is presented in Table 4.

Table 4: The modal split structure used for each route

Route	*Structure*
Gothenburg – Ghent	Hierarchical (Two Maritime, One Landbased)
Immingham – Esbjerg	Binary
Immingham – Rotterdam	N-way pooled to binary
Copenhagen – Oslo	Binary
Klaipeda – Kiel	Binary
Klaipeda – Karlshamn	Binary
Dover – Calais	N-way (2-Maritime, Eurotunnel) pooled to binary

6.7 Summary

This section of the report has presented the underlying theory of discrete choice modelling and its adaptation in the context of the RoRoSECA project. The formulation of the generalized cost used as the predictor for mode choice was presented. The influence of cargo value, depreciation rate, and model structure on the modal choice was also illustrated.

This model can also be useful to investigate what happens to the modal shares in case the generalized costs of some or all of the modes change. The generalized costs can change as a result of changes in fuel prices, transit times, and any of the other parameters that determine the generalized cost. They can also change as a result of measures or other policies implemented by the shipping company or the regulators so as to mitigate or reverse the negative effects of the sulphur regulation. Such measures and policies are to be examined in Year 2 and the context of WP3.

An interesting result which can be obtained after some straightforward algebraic manipulations (which we do not show here as they are mainly of theoretical interest) is the following:

- *In order to assess the merits of the possible measures and policies to be examined in WP3, it is not really necessary to know precisely, either the initial modal shares among competing modes, or (equivalently) calibration parameter λ.*

This result is important because, for the purposes of WP3, it essentially bypasses the need for obtaining accurate data for modal shares across modes, data that is many times elusive to obtain. Of course, such data is necessary to get an estimate of the final shares among the modes.

The next section presents the steps for the calibration of the modal split model assuming a hierarchical approach, and summarizes the relevant module developed in the context of Task 2.2.

7 Model Calibration

This section describes the calibration process used in the enhanced modal split models used for each Route. The process follows a two-stage model when there are nested structures, that collapse into N-way or binary structures when it is assumed that there are no correlated options. The purpose of the model calibration stage is to identify the dispersion parameters, which can then be used to estimate the modal shifts that may arise as a consequence of changes in the generalized cost of one or more options.

7.1 The steps of the calibration process in the general case

In the generic case, it is assumed that a hierarchical structure is present. As discussed in the previous sections of this report, in order to calibrate the model the following data for each mode are required:

- Market share information
- Total travel time
- Travel cost per unit cargo

Figure 17 illustrates the calibration process at each step.

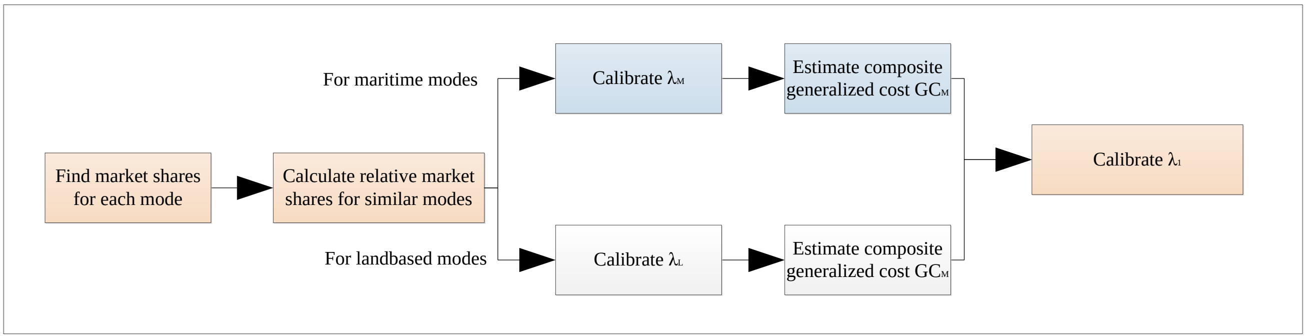


Figure 17: The steps of the calibration process

The first step is the identification of the market shares for each mode as a percentage of the overall transport demand between an O-D pair. Then depending on the structure followed, the relative market shares for similar modes need to be estimated. If for example there are three options, two maritime and one landbased with shares at 31%, 29% and 40% respectively, the relative shares for the maritime options are 51.6% and 48.4%. Based on the market shares and the calculation of the generalized cost for each option, it is possible to calibrate the secondary lamda values (λ_M , λ_L) and through these the respective composite generalized costs GC_M and GC_L using equation 8. The latter can be used to calibrate the first split lamda scale parameter. In the previous process, if there are no nests then the model collapses to a simple N-way or binary model, where the calibration of the (only) lamda λ is straightforward using equations 3 and 4 respectively.

7.2 The tool developed in the context of Task 2.2

The underlying theory of discrete choice modelling on which the enhanced modal split model is based has been presented in section 6. This section presents the tool developed for use in the project for Task 2.2 and the second year of the project. The model is developed in a spreadsheet application (Microsoft Excel) and a series of modular codes in Visual Basic have been written that facilitate the process of simulation and the performing of sensitivity analysis.

The main objective of the modular code was the creation of a user-friendly module that can be used for model calibration and simulation of changes for different levels of data availability. The main model is using the general case where a nested logit model is used. Two nests are assumed; the maritime and the land based. Within each nest a maximum of four different options are allowed at this stage of the model's development. The spreadsheet is colour coded so that the user is aware of the information required for the model calibration to occur.

A snapshot of the tool is shown in Figure 18 where the yellow cells are data requirements. The user has to provide:

- the depreciation rate r (%),
- the cargo value (€/lm) per lane-meter transported
- the monetary cost (freight rate - €/lm) for each maritime link
- the travel time (hours) for each maritime link
- the road distance (km) for each option
- the road cost (€) per lane-meter transported

The last two inputs can be retrieved from the RoRoSECA network model for the required run, and at this stage need to be manually entered in the calibration module. The model will then return in the purple cells the main outputs of the calibration stage. For the generic case where a hierarchical structure is used, then these outputs are:

- The dispersion parameter λ_1 for the primary split between the different nests
- The dispersion parameters for the secondary splits within each nest λ_M, and λ_L

.

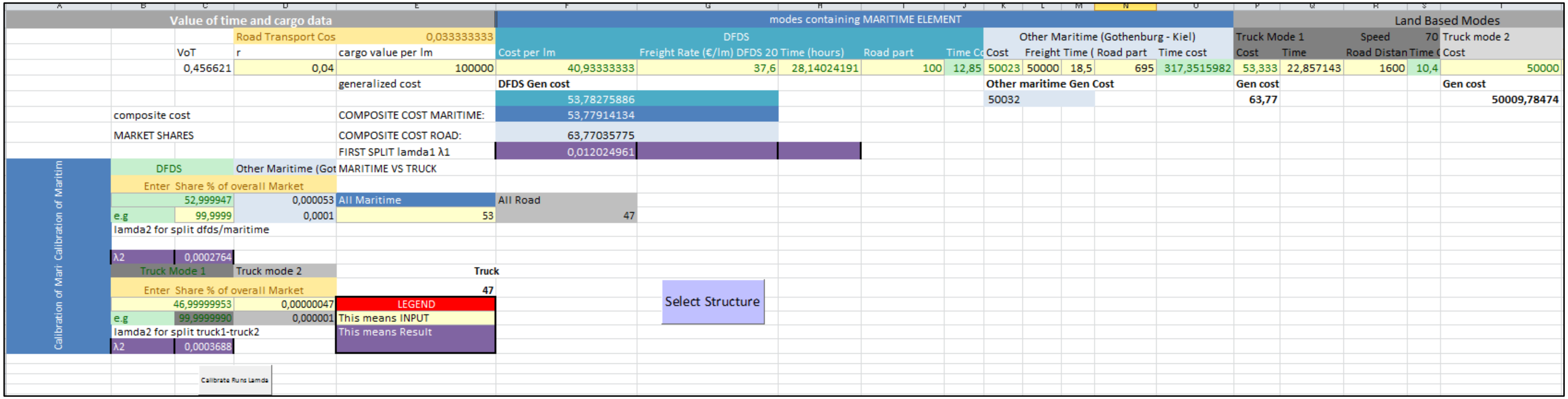


Figure 18: The calibration module for Task 2.2

The user can select to use a simpler version by clicking on the select structure button (see Figure 19). This prompts the user to select what scenario is more relevant to the case they are modelling

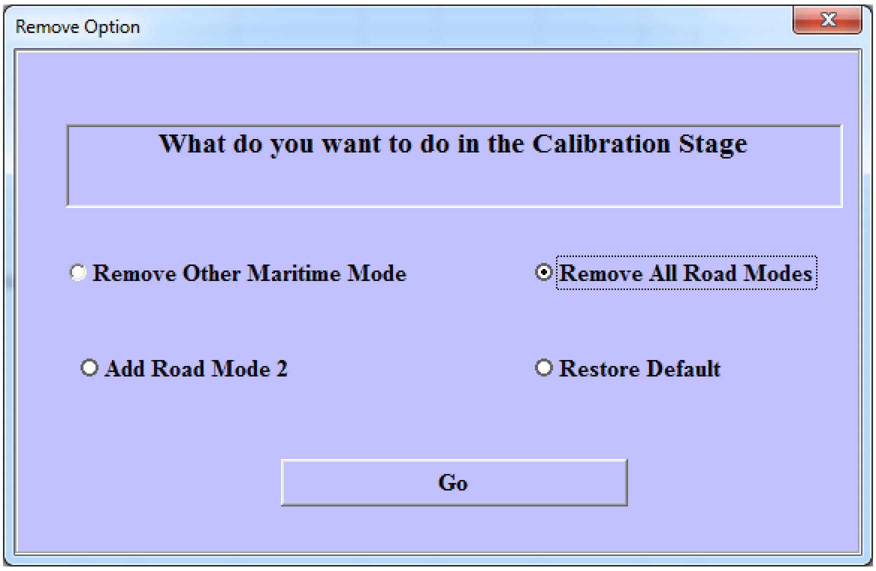


Figure 19: The selection pane for adding or removing transport modes

When a user selects to remove the other maritime mode, or all of the land based (road) modes, the module is essentially enabling the collapse of the hierarchical model to a simpler binary or N-way structure (depending how many options are left). This is achieved by assigning a very large generalized cost to the shut-down modes and reducing their respective market share to a very small number. It has to be noted that assigning a market share of zero would result in mathematical errors (divisions by zero in the calibration stage). Therefore, the model works with the assumption that the shut-down modes are undesirable, and returns very low scale parameters within the nests; signifying that the 99.99-0.01% split will not change with changes in the generalized cost of the remaining mode within the nest.

The final module within the calibration tool, is allowing the numeric simulation to calculate the dispersion parameters when certain data are not available. The same module is used to conduct the sensitivity analysis. In its current version, the module varies the values for:

- Market share (%) of each option
- Value of Cargo transported
- Depreciation Rate
- Freight Rates per lane meter

The output of the model is a detailed list of the dispersion parameter(s) for the different configurations used, as well as the key statistical information for the runs; namely the average values of the dispersion parameters and the interquartile range.

8 Simulation of modal changes and post-analysis modules

Having calibrated the model for each route and estimated the values for the dispersion parameters, it is possible to introduce changes in parameters influencing the predictor, in this case the generalized cost of each module. The new market shares after the introduction of these changes, can be predicted based on the equations 3-4-5-6 from section 6. This section presents the periods of interest for the simulation, and the different fuel price scenarios examined. The simulation assumes that the freight rates will respond to changes as a function of the fuel price differential between the different points of time where the modal choice will be modelled. The computational modules that use the predicted modal shifts as inputs are also presented. These modules will be heavily used in WP3 and are designed to allow the examination of the candidate policy and operating measures to revert the negative impacts of the regulation as per the project's objectives.

8.1 The periods of interest for the simulation

As presented in section 3.1, prior to the new limit imposed on January 1st 2015, there were concerns that the much higher fuel prices would constitute several services operating within SECA as unprofitable and could lead to severe modal shifts to road mode. In 2014, the price for 1 ton of HFO (1% sulphur) was around \$550, which in 2015 dropped to \$300, while the price for 1 ton of MGO in 2015 (Q3) was \$480. Therefore, the fuel price for MGO was actually lower than the cost of HFO used in 2014 by 12.7%, while if the regulation was still requiring a 1% sulphur limit, the fuel would cost 45.5% less. The benchmark period for all route scenarios is the situation during the year 2014, the last year before the introduction of the new limit. The fuel prices scenarios are considering the average price of fuel during 2014 as the benchmark, and the simulation is performed for various scenarios of fuel prices in 2015. The three scenarios are:

- Fuel Case 1 - for MGO 2015 prices
- Fuel Case 2 - for HFO (1% sulphur) 2015 prices
- Fuel Case 3 - for MGO 2014 prices

Essentially, Fuel Case 1 is referring to the actual fuel price difference that the ship operators faced, and thus the change in freight rates that the shippers experienced. This will allow to compare the findings of the model, with the actual change in demand due to the fuel prices in 2015 and thus conclude whether the modal split methodology used is a reasonable approach.

Fuel Case 2 is a hypothetical scenario of what would have happened if the sulphur limit had remained at 1% and thus the only difference in operating costs would be the change in fuel prices as a result of the market. It has to be noted that in this case, the investments in scrubber systems would have not taken place, and thus the fuel consumption of the vessels must be adjusted to account for this. As explained in the deliverable report on the outcome of Task 2.1, scrubber systems increase the fuel consumption of the vessel between 1.5 and 3.0% to cover their energy requirements.

Finally, Fuel Case 3 is a hypothetical scenario to illustrate what the impacts of the regulation would have been, if the prices had not unexpectedly drop to the point that it was actually cheaper to use

MGO in 2015 as compared to HFO in 2014. For this reason, the MGO fuel prices in 2014 are used to simulate the effects of the regulation as anticipated in the ex-post market and research reports.

8.2 Simulation of modal changes

The next important computational module developed revolves around the simulation of modal shifts subject to changes in the generalized costs of one or more available transport options. The module is also developed in a spreadsheet format, and is complemented by Visual Basic code that performs the sensitivity analyses on certain variables.

The main model is again using the general case for a nested logit model. Two nests are assumed; the maritime and the land based. The spreadsheet is colour coded so that the user is aware of the information required for the model calibration to occur.

The tool is shown in Figure 20. Yellow cells indicate user-input that considers the following:

- the depreciation rate r (%) which should be similar to the value used in the calibration
- the cargo value (€/lm) per lane-meter transported
- the new freight rate (€/lm) for each maritime link in the aftermath of the fuel price changes
- the new travel time (hours) for each maritime link
- the new road cost (€/lm) if it has changed as a consequence of a change in fuel prices and/or inflation.
- The dispersion parameters, which are outputs of the model calibration module.

The model will then return in the purple cells the main outputs of the simulation. These are essentially the new market shares for each mode after the introduction of the changes in the predictors (generalized cost). As seen in Figure 20, the modal shifts are given in percentage changes, and absolute changes. For example, in Figure 20 the maritime modes are now more expensive than during the calibration stage and as a result the DFDS share is expected to drop by 10.3% which is equivalent to losing 5.4% of the overall transport demand to other modes. The other maritime mode is shown in this example to lose 14.8% of its volume, a figure equivalent to losing 1.9% of the overall transport demand for the examined O-D pair. In contrast, the landbased mode is increasing its volume by 20.8% which is the result of controlling the 7.3% of the overall market which was previously transported via maritime links.

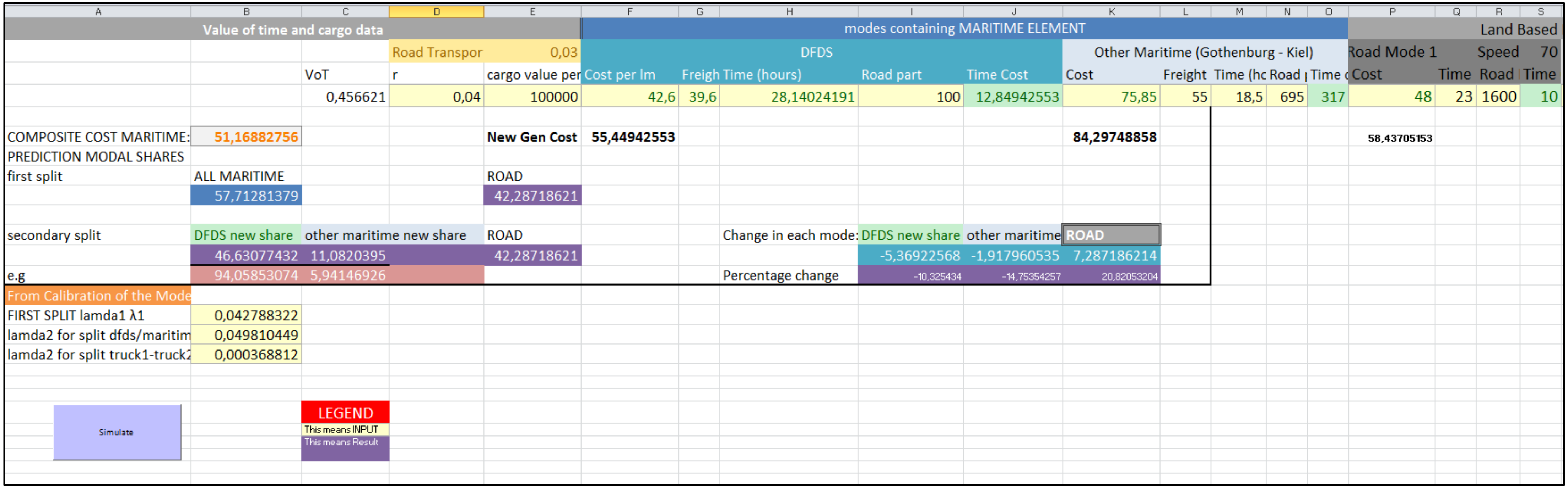


Figure 20: The simulation module for the prediction of modal shifts. A case study with hierarchical structure and three options shown

While the dispersion parameters are normally the output of the calibration module, these are shown to be in yellow cells. This is to allow users to vary the values of the dispersion parameters and view the impacts of changes in the generalized costs. This can be useful if values for dispersion parameters are taken from similar studies and contrast the results for specific changes in the predictors. The next section presents the sensitivity analysis module.

8.3 Sensitivity analysis module

Due to the difficulty in acquiring disaggregate level data for all shipments on-board DFDS vessels including information on cargo values, actual O-D path, and depreciation rate, it was deemed necessary to overcome this obstacle via simulation. This section presents the logic of the sensitivity analysis module. The module is developed in Visual Basic programming code and it varies the following parameters across a central value provided by the user:

- Initial market share during calibration for each nest/mode
- Freight rate in the aftermath of the calibration (simulation)
- New travel time for maritime links
- Depreciation rate for the estimation of value of time
- Cargo values transported for each mode
- Haulers rate per ton/km transported

The outputs are the new market shares for all different combinations of the previous variations, and a statistical summary where the important outputs are the average change and certain measures of dispersion (interquartile range, median, variance). For most runs, the total number of simulations is in the range of a few thousands and the calculation time is a few minutes in an office personal computer. The number of simulations can easily increase to address a higher accuracy for the sensitivity analysis if required. A planned extension to this module is to allow users to perform a random generation of inputs (in a Monte-Carlo simulation fashion), instead of a total enumeration.

8.4 Post-simulation modules

The objectives of the RoRoSECA project are not limited to the development of the modal split model that allows the prediction of potential modal shifts. It is necessary to consider the economic repercussions to the shipping companies, as it may prove that a significant loss of market share can constitute an existing service unprofitable. The modelling framework is therefore enhanced through a module that compares the costs and revenues that DFDS is facing in each route, taking into account the revenue generated by cargo and passengers, and the fuel costs for each scenario. It has to be noted that at this stage (WP2) no changes in the sailing frequency and sailing speed are considered, as these are measures that are part of WP3 and will be examined in Task 3.2. Table 5 summarizes the information provided by DFDS for the examined routes:

Table 5: The KPI provided by DFDS for the examined routes

Route	Year	Number of Trips	Utilization freight	Average rate	NO. Pax	On board Revenue per Pax
Gothenburg-Ghent	2013	540	xx	xx		
	2014	553	xx	xx		
	2015	569	xx	xx		
Esbjerg- Immingham	2013	499	xx	xx		
	2014	512	xx	xx		
	2015	580	xx	xx		
Rotterdam-Felixstowe	2013	1503	xx	xx		
	2014	1514	xx	xx		
	2015	1637	xx	xx		
Copenhagen-Oslo	2013	680	xx	xx	xx	xx
	2014	704	xx	xx	xx	xx
	2015	680	xx	xx	xx	xx
Klaipeda-Kiel	2013	668	xx	xx	xx	xx
	2014	625	xx	xx	xx	xx
	2015	652	xx	xx	xx	xx
Klaipeda-Karlshamn	2013	710	xx	xx	xx	xx
	2014	717	xx	xx	xx	xx
	2015	710	xx	xx	xx	xx
Dover-Calais	2013	6725	xx	xx	xx	xx
	2014	6200	xx	xx	xx	xx
	2015	4794	xx	xx	xx	xx
Esbjerg-Harwich	2013	281	xx	xx	xx	xx
	2014	230	xx	xx	xx	xx
	2015					
Marseilles-Tunis	2013	292	xx	xx		
	2014	284	xx	xx		
	2015	298	xx	xx		

Due to confidentiality concerns, the actual numbers for the average freight rates, revenue generated on-board by passengers and passenger fares are not shown in this version of the report and are shown by xx in the table. While the data of Table 5 are aggregate, it is possible to draw conclusions on the effects of the regulation. DFDS has also provided the vessel deployment for each of the examined routes, including all vessel changes for a period between January 2014 up to May 2016. Using information on the vessel's carrying capabilities and information on their individual fuel consumption (see section 8.6) it is possible to draw a good picture of how the route profitability has been affected.

8.5 Cost Benefit Formulation

As seen in Figure 12 the CBA analysis from the operator's perspective is based on the revenue generated during each voyage and the costs of said voyage. The revenue comprises of the freight rates paid by the shippers for the cargo transported, the passenger fares (for Ro-Pax and cruise vessels), and any on-board spending.

Fuel costs are proportional to the fuel consumption and depend heavily on the fuel price. There are other operating costs for each journey, which in principle are not affected by the fuel price. It is however important to understand what proportion of the overall voyage costs, are attributed to fuel consumption. This proportion varies across different ship types (bulk, containerships, Ro-Ro). Typically, for faster sailing ships the contribution of fuel costs is expected to be greater. For example, Stopford (2009) notes that for bulk carriers the bunker costs may be 40% for older vessels, dropping down to 33% for more modern ships. Ronen (2011) considers that for certain containerships sailing at design speeds, fuel costs may constitute more than 75% of its operating costs. For Ro-Ro ships there have not been as many studies to provide similar figures. The operating costs are comprised of fuel costs and staff salaries, vessel maintenance costs, port fees, and stevedoring. In the DFDS case studies, due to data confidentiality the cost information provided for the purposes of this project was aggregate and only expressed the fuel costs as a percentage of the overall operating costs, excluding hotel and stevedoring costs. Table 6 summarizes the confidential information provided by DFDS.

Table 6: Fuel cost as share of total operating costs (due to confidentiality the actual percentages are not shown)

Fuel cost as share of total vessel operating cost (excluding hotel and stevedoring)		
Route	**2014**	**2015**
Got-Ghe	*xx%*	*xx%*
CPH-OSL	*xx%*	*xx%*
Esb-IMM	*xx%*	*xx%*
Rot-Flx	*xx%*	*xx%*
Kiel-Klaip	*xx%*	*xx%*
Dov-Cal	*xx%*	*xx%*

The share of fuel costs has dropped significantly for most routes, which is a repercussion of the very low fuel prices in 2015. This is strengthened by the fact that certain ships were already equipped with scrubbers since before 2014, and as a result the fuel costs for these vessels have been lowered further as HFO is still used. However, the figures in Table 6 do not take into account the scrubber investment costs.

As this project focuses mainly on the implications of the new legislation on ship operators, the focus is on their profitability at a specific route. The profitability KPI of the ship operator at each voyage on a route, is a simple cost-benefit calculation shown in eq.5.

$$KPI_{prof} = \sum_{i \in C} R_i \cdot Q_i - C_j \qquad (9)$$

Eq. 9 considers the revenue of moving Q_i (lm) quantities of commodity i at a unit revenue R_i (€/lm), minus the operating costs of C_j(€) running the ship j in this route. Summing over all journeys of all vessels on a specific route in a given time period, the overall profitability of the route can be estimated, and used as a benchmark when changes in key variables (e.g. fuel prices, units transported) are observed. If a route proves to be unprofitable to the point where it should be shut down, the cargo will shift to the remaining modes according to the outputs of the model.

8.6 Fuel consumption module for each ship in each route

DFDS has also provided confidential information on the actual fuel consumption for vessels deployed between 2014 and 2016 in the examined routes. A sample of the relevant information provided is shown in Figure 21.

Ships	Jan-14	Feb-14	Mar-14
ANGLIA SEAWAYS			
Distance [Nm]			
ME HFO			
ME MGO			
AUX E HFO			
AUX E MGO			
Boilers HFO			
Boilers MGO			
No of trips			
No of days			

Figure 21: The data provided by DFSD for fuel consumption

Figure 21 shows the format of data received. For the particular ship (Anglia Seaways), during the period shown there was no fuel consumption as the vessel was in layup. The information provided for each vessel was the actual fuel consumption broken-down by engine type, and fuel type. This information is not sufficient for the cost estimations, and as such Visual Basic code was written to process these data into an appropriate format for the profitability modules developed in section 8.5. The output of this code is shown in Figure 22[5] where in purple cells are the processed data.

Analysis complete	Jan-14	Feb-14
Distance [Nm]	8558.7	9731.1
ME HFO	xx	xx
ME MGO		
AUX E HFO	xx	xx
AUX E MGO	xx	xx
TOTAL AUX	xx	xx
total aux PER TRIP	xx	xx
Boilers HFO		
Boilers MGO	xx	xx
total boilers per trip	xx	xx
Boilers MGO/Aux MGO	xx	xx
Aux (propulsion over berth)		
No of trips	21	24
No of days	31	28
Fuel Consumption per NM ME	xx	xx
Fuel Consumption per NM AUX	xx	xx
Fuel Consumption per NM ME at port per T	xx	xx
Total HFO	xx	xx
Total MGO	xx	xx

Figure 22: Post-processing output of fuel consumption (confidential data marked as 'xx')

This module is run for the information provided for all DFDS vessels deployed in the routes examined. Coupled with information on price levels for the different fuel types (as seen in Table 7), it is possible to estimate accurately the fuel costs per journey and under certain assumptions calculate fuel costs per activity of the vessel (at berth versus sailing).

[5] The numbers shown in this screenshot are on purpose in very small fonts, as this information is deemed confidential from DFDS

Table 7: Sample of Rotterdam fuel prices for various fuel types[6]

USD	IFO 380			ULSFO		MGO
Date	Low S	High S	Diff	from	to	
25 apr 16		186,50		355,00	362,00	373,50
22 apr 16		188,50		330,00	360,00	377,50
21 apr 16		183,50		360,00	366,00	377,50
20 apr 16		179,50		325,00	345,00	360,50
19 apr 16		174,50		315,00	340,00	355,50
18 apr 16		166,50		315,00	325,00	343,50
15 apr 16		172,50		316,00	334,00	343,50
14 apr 16		178,50		327,00	336,00	355,50
13 apr 16		175,50		325,00	335,00	352,50
12 apr 16		174,50		322,00	326,00	342,50
11 apr 16		170,50		307,00	320,00	335,50
08 apr 16		162,50		297,00	311,00	327,50
07 apr 16		149,50		293,00	309,00	306,50
06 apr 16		149,50		280,00	290,00	301,50
05 apr 16		141,50		277,00	285,00	297,50
04 apr 16		144,50		292,00	292,00	314,50
01 apr 16		153,50		300,00	320,00	318,50

The information shown in Table 7 is in terms of USD ($) per ton of fuel. These data were processed using the exchange rates between USD and Euro(€) for the same period, and subsequently aggregated to monthly averages, as the latter is the price used to define the BAF.

This is possible due to the breakdown of fuel consumption to each engine type, and the information on the actual sailing times and berth durations for each vessel (also provided by DFDS, and cross-checked with published schedules). It is known (Zis et al., 2014) that boilers are operating when the main engines are switched off, and thus the boiler fuel consumption is attributed to at-berth time. In addition, vessels that are not equipped with scrubbers had to still burn MGO while at berth prior to the new limits. Thus, it is possible to derive the fuel consumption at berth from the auxiliary engines. This information is vital for the second year of the project, as part of the measures to be examined in WP3 will revolve around changes in sailing speed and frequency, which in turn will change the number of hours spent at berth. Thus, through these modules it will be possible to accurately predict the new fuel consumptions in the context of the examined what-if scenarios. The outputs of the fuel consumption module are also used in the environmental analysis module which is presented in the next section.

8.7 Environmental analysis module

The environmental analysis module is converting the fuel consumption as estimated from the previous module into emissions, via multiplication with appropriate emission factors. These factors are taken from the IMO recommendations, and are also compatible with the outputs of the SHIP DESMO model of Task 2.3. The environmental analysis module developed in the context of Task 2.2,

[6] Note that the ULSFO is a hybrid HFO fuel that is abiding by the regulation, and is used in some DFDS vessels

essentially complements the enhanced modal split methodology framework by allowing the estimation of emissions for the main pollutant species per either of:

- Voyage
- Ship
- Route (monthly or quarterly)
- Lane meter of cargo transported

While the previous are not part of the objectives of Task 2.2, these will be useful in formulating KPI for comparison purposes in year 2 of the project. A snapshot of the module is shown in Figure 23, where predicted emissions on a hypothetical scenario are shown for various emission factors.

What if Scenario: What Would be without SECA new limit

Assumption: Scrubbers are increasing fuel consumption by 3%, reduce SOX PM by 97 and 85%,
Same number of trips
Vessels would not have been equipped with scrubbers even in 2014

	Jan-14	Jan-14	Jan-14	Feb-14	Feb-14	Feb-14	Mar-14	Mar-14	Mar-14	Apr-14	Apr-14	Apr-14
ME HFO	985,98437	1095,429223	1245,06	1144,92	1036,53	1256,8	1238,53	1147,76	1063,85	1087,48	1157,62	0
ME MGO	0	0	0	0	0	0	0	0	0	0	0	0
AUX E HFO	47,640851	76,77475728	89,5903	85,271	74,4937	84,1748	105,353	87,0971	77,5835	99,9029	100,787	0
AUX E MGO	42,9	24,91015257	18,2226	26,6379	26,9988	17,2816	25,5315	29,7302	24,9968	21,8447	18,305	0
Boilers HFO	0	0	0	0	0	0	0	0	0	0	0	0
Boilers MGO	3,6796341	11,46952843	7,11689	10,0614	12,1279	7,47573	14,3766	14,6389	10,2613	9,41748	2,59087	0
Total Fuel	11271,25634											
Total Emissions												
CO_2	3368,043243	3766,876453	4237,349	3948,482	3585,154	4255,155	4312,798	3987,583	3667,465	3797,723	3985,68	0
SO_2	20,76566367	23,51683897	26,74374	24,67728	22,29864	26,86893	26,95748	24,78582	22,89921	23,8101	25,20998	0
NO_x	50,37670684	56,32404262	63,34079	59,03784	53,61204	63,60617	64,4849	59,6309	54,83742	56,77904	59,5754	0
PM	4,262932032	4,766202091	5,359967	4,995846	4,53671	5,382424	5,456783	5,046032	4,640402	4,804704	5,041335	0
HC	2,623786814	2,933543886	3,298999	3,074887	2,792294	3,312821	3,358588	3,105776	2,856116	2,957242	3,102885	0
CO	2,623786814	2,933543886	3,298999	3,074887	2,792294	3,312821	3,358588	3,105776	2,856116	2,957242	3,102885	0
Total Emissions per Quarter												
CO_2	35128,90663											
SO_2	219,5136148											
NO_x	525,2508126											
PM	44,44729825											
HC	27,35681316											
CO	27,35681316											

Figure 23: Snapshot of the environmental analysis module

8.8 Considering a shut-down threshold

While the details of the costs and benefits associated with a specific route were not provided by DFDS, it is possible to draw some conclusions on the profitability of a route by comparing the revenues generated in the before and after cases. The fuel consumption modules developed in section 7.3 are also enabling a reliable estimation of operating costs. As a result, it is possible to construct some simplified KPI per each route and thus identify the routes that may be threatened in the future. Considering that the operating costs (save the fuel costs) are not changing, if the revenue minus the operating costs become negative the shutting down of a route may be an option. In that case, the simulation needs to be re-run forcing an infinite generalized cost for the shut-down route, effectively not allowing any shippers to choose this particular mode. What this threshold is (e.g. at what loss the shipping company would actually shut down the service and allocate the vessel(s) in a different route) depends on the strategy of the shipping company. In addition, in the context of WP3 prior to shutting down the route, the potential of certain measures to avert this from happening need to be considered. The constructed methodological framework allows for this examination through an iterative approach.

8.9 Summary

This section has presented the heart of the modelling framework for Task 2.2. The developed modules were presented with the capabilities they offer along with their limitations, particularly for case studies with lack of sufficient data. The next section will present the RoRoSECA network model which was developed to model the travel time and costs for the landbased options. The outputs of the network model are used in both the calibration and simulation stages of the enhanced modal split methodology presented in the previous sections.

9 The RoRoSECA Network model

This section describes the network model used for the RoRoSECA project. The overall purpose of the RORO SECA Network Model has been to develop a tool for calculation and assessment of transport costs and competitive relations within freight transport. The tool can model the supply (or performance) of an intermodal transport system and visualise competitive relations between different modes.

9.1 Background

The RORO SECA Network Model is a tool that can model the cost of freight transport within an intermodal transport system. In contrast to traditional transport models, it does not include any modelling of the demand for transport or assignment of transport flows. Instead, it feeds information to other parts of the RORO SECA project.

The backbone of the model is a digital transport network for selected countries in the Northern part of the European Union from where it is possible to model a generalised cost of transport for the entire network. The network model can handle both link-based costs and node- (point)-based costs this makes it possible also to model e.g. different kinds of modal shifts. The transport system modelling tool are fully integrated within the geographical information system (GIS) ArcInfo Workstation. Part of the geographical coverage of the RORO SECA Network Model can be seen in Figure 24.

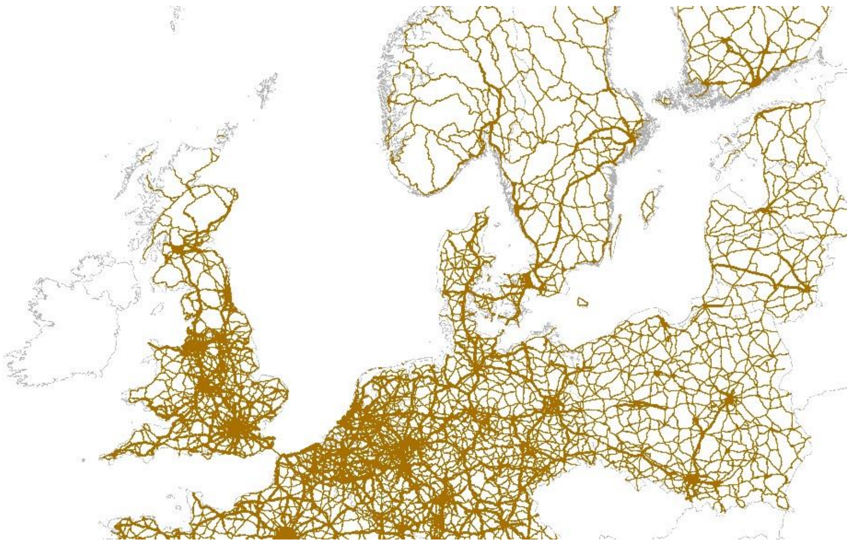


Figure 24: Part of the geographical coverage of the road network in the RoRoSECA model.

9.2 Modelling the performance of the transport system

The modelling of the cost of traversing the intermodal transport system are divided into two steps. First a modelling of the physical performance of the transport system and secondly a calculation of the cost associated with the use of the transport system. The modelling of the physical performance of the transport system gives as result the distance and transport time for traversing space using the intermodal network. The calculation of the cost associated with the use of the intermodal transport system is based on the physical performance of the transport system as the costs are divided into:

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

The modelling of the physical measurements and calculations of costs are described in the following subsections.

9.2.1 The digital network and modelling of distances and transport time

The modelling of distances and transport time are automatically handled by the geographical information system. This is exactly similar to e.g. car navigations systems and route finding tools on the internet. One specific functionality of the RORO SECA Network Model has however to be mentioned. In order to handle e.g. drive-rest regulations the tool includes an event-manager that can place specific transfer points in the network at a given location based on an arbitrarily condition.

9.2.2 The transport costs

As the main purpose is to model the cost of freight transport, an important step in the modelling is the transformation of the physical measurements (transport distances and time) into monetary values. The monetary values are calculated as a generalised cost for traversing each link in the digital network and a cost of passing through specific nodes.

The generalised cost for each link are calculated by summarising three cost contributions:

- Distance dependent costs
- Time dependent costs
- Fare and toll costs

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:

$DD_{cost} = (DD_{CC1} + \ldots + DD_{CCn}) \text{ x } TransportDist$

Where DDcost is the total Distance Dependent cost for the link

DDCC1 … DDCCn is the Distance Dependent 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 financial costs). The time dependent cost for each road link are defined as:

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

Where TDcost is the total Time Dependent cost

TDCC1 … TDCCn is the Time Dependent Cost Components

TransportTime is the time used to traverse the link

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 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.

9.3 Initial values used in the modelling

One of the main purposes of the RORO SECA 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 technical solution in the RORO SECA Network Model has been to develop a cost model based on a simple functional classification of links and nodes within the digital network and then to use a SQL approach to calculate the costs of traversing the transport system. 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 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 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 are chosen. 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.

The value of time (VOT) is in the initial calculation 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 can be seen in Table 8.

Table 8: The cost components for the value of time.

Component	Value-2016 (EUR/h of operation for 2 TEU)
Depreciation	13.07
Wages	28.93
Reparation	1.33
Capacity cost	7.33
Duties	0.93
Total time dep. cost (VOT)	51.59

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 originating from the Danish Manual for Economic Evaluation of Transport Investments. The used cost components and the associated value are shown in Table 9.

Table 9: The cost components for the vehicle operating cost.

Component	Value-2016 (EUR/km for 2 TEU)
Diesel	0.23
Oil	0.02
Tires	0.06
Reparation	0.09
Duties	0.14
Total distance dep. Cost	0.54

The same VOC are used for all countries with the exception of Germany. For Germany the MAUT (0.13 EUR/km) has been added to the VOC bringing the total VOC within Germany up to 0.67 EUR/km.

The initial calculations does not include modelling of drive-rest restrictions.

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 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 10.

Table 10: 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 view as a frailty conservative estimate.

The sea transport system in the initial calculation is somehow much simpler than the road transport system – each sea link are basically assigned a cost based on the fare.

9.4 Generating thematic maps

The output of the RORO SECA Network Model are two types of thematic maps:

- Isocost maps
- Differential maps

Each type are described in the following sections.

9.4.1 Isocost maps

Isocost maps are showing different cost levels for the accumulated cost of transport from a given origin using the shortest possible (in this case the least expensive) route. Transport costs are illustrated as uniform bands of isocosts. An often used variant of the isocost map is the isocrone map that only shows the transport time without valuating it into monetary units.

The RORO SECA Network Model has been implemented in such a way that when a specific event occurs like e.g. passing a toll bridge, the model adds a penalty either as a cost or an additional travel time to the calculation. This gives a more realistic modelling of the transport cost.

The calculated isocost map for a land (truck) based transport chain from Gothenburg in Sweden to destinations around the SECA area can be seen in Figure 25.

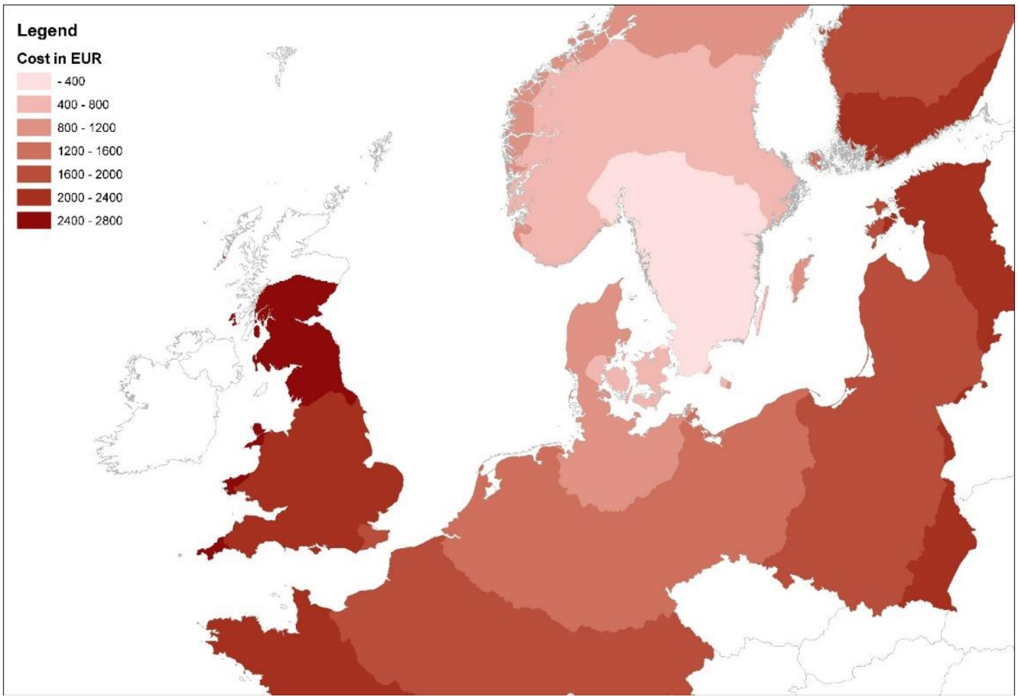


Figure 25: The isocost map of a land based (truck) transport from Gothenburg in Sweden to destinations in the SECA area.

The network was then redefined to include the Gothenburg – Ghent sea link and the isocost calculation was repeated. The isocost map for the least cost transport chain after the introduction of the Gothenburg – Ghent sea link is shown on Figure 26.

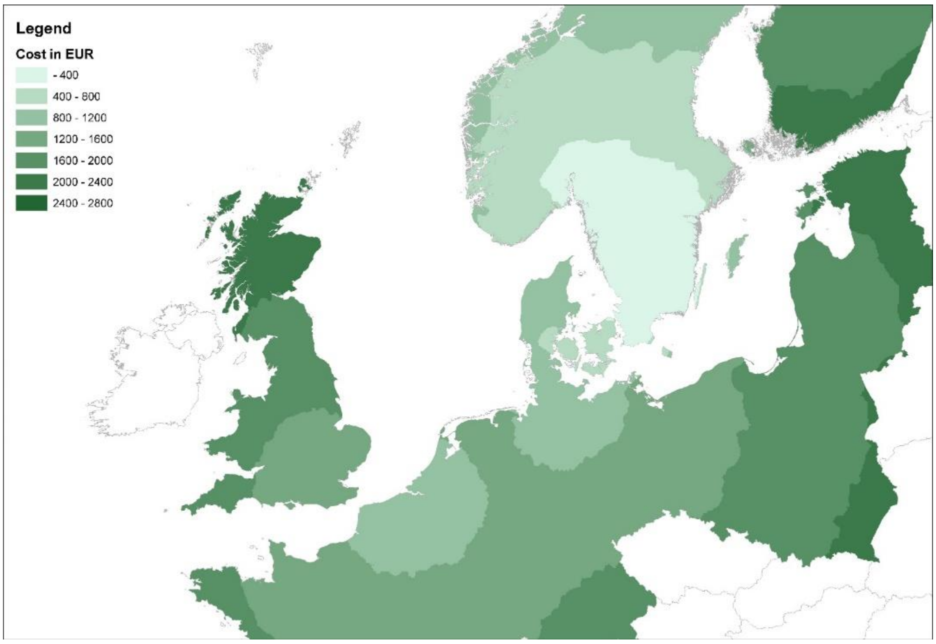


Figure 26: The isocost map of a land based (truck) transport from Gothenburg in Sweden to destinations in the SECA area after the introduction of the Gothenburg – Ghent Sea link.

The influence of the inclusion of the Gothenburg - Ghent sea link is clearly seen on Figure 26 where a "sea link beachhead" in the form of an 800-1200 EUR isocost band originates from Ghent.

When the isocost map on Figure 26 are compared to the one on Figure 25 it can be seen that the isocost bands in Sweden, Norway, Denmark, the northern and the eastern part of Germany and the Baltic states are identical. This indicates that the land based transport chain is the most competitive in these areas. Outside that area the Gothenburg - Ghent sea link has influenced the accumulated transport costs.

These shapes give the first indication on where the competitive borders between the two transport chains are situated. The location of the competitive transport borders becomes much clearer when looking at a differential map.

9.4.2 Differential maps

A differential map is basically two isocost maps that are subtracted. The differential map on Figure 27 is the result of a "subtraction" between Figure 26 and Figure 25.

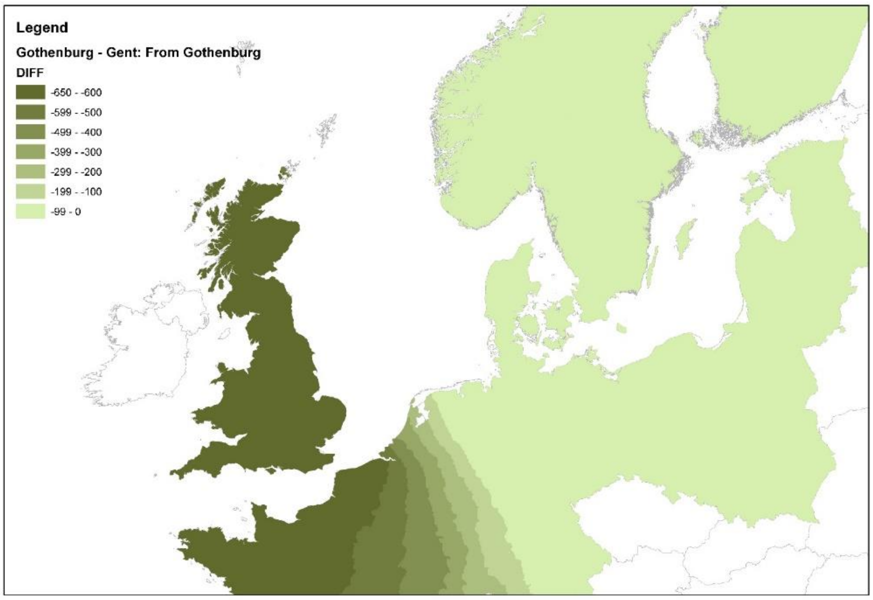


Figure 27: Differential map showing the effect (reduction) on transport cost by the introduction of the Gothenburg – Ghent sea link.

Figure 27 illustrates not only the areas where the intermodal transport chain using the Gothenburg – Ghent sea link is competitive but also gives an indication on how competitive the sea link is. The different intervals correspond to the decrease in transport cost due to the introduction of the Gothenburg - Ghent sea link. Basically Figure 27 shows that at intermodal transport chain using the Gothenburg - Ghent sea link has a competitive advance over road transport from Gothenburg to the south-western part of Germany, the western part of the Netherlands and all of Belgium, Luxemburg, France and the UK. The competitive border between the land based transport and transport using the sea link is situated just around the 0-99 EUR intervals following a line dividing the Netherlands and cutting of the south-western part of Germany.

It has to be noted, that all other sea links than the Gothenburg – Ghent sea link has been omitted from the calculations in order to illustrate the functionality of the RORO SECA model. These will naturally be included in the final calculations.

For further validation and evaluation, differential maps for the Klaipeda – Kiel sea link are shown and commented below.

Figure 28: Differential map showing the effect of the Klaipeda – Kiel sea link for a transport originating in Kiel.

As can be seen on Figure 28 the competitive boarder for transport originating in Kiel and using the Klaipeda – Kiel sea link to reach the Baltic States is located just south of Kaliningrad. The map on Figure 28 also shows that there can be cost savings up to 300 EUR in the hinterland of the port of Klaipeda.

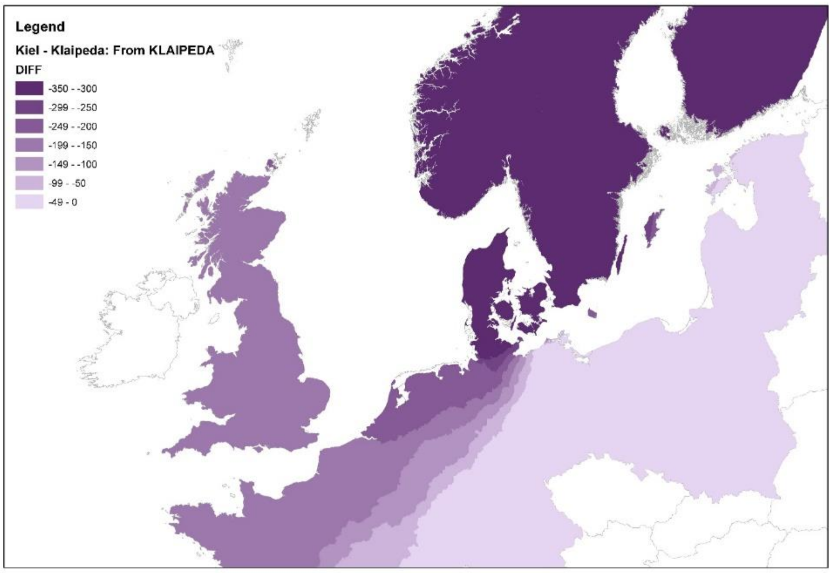


Figure 29: Differential map showing the effect of the Klaipeda – Kiel sea link for a transport originating in Klaipeda.

Figure 29 shows the potential cost savings for at transport originating in Klaipeda using the Klaipeda – Kiel sea link to reach the central European continent. The maps shows cost savings up to 300 EUR for transports reaching Scandinavia and up to 200 EUR for transport reaching the UK and northern parts of France. The competitive boarder between the sea link and a unimodal truck transport is located on a southwestern line across Germany and France. As goes for the cost savings towards Scandinavia it has to be noticed that a number of competing sea links has been omitted from the calculations in order to illustrate the functionality of the RORO SECA Network Model.

9.5 Calculations

The maps generated using the RORO SECA Network Model to some extent reflects different needs and questions developed during the project. This means that following description of sea links and calculation cities are dynamic and can (and properly will) change according to project progress.

9.5.1 Sea links

Based upon the initial calculation a number of additional Sea-links (that are not DFDS) are identified and included in the intermodal network.

Company	Port A	Port B	Distance	Sailing time	Sailings
Stena	Harwich	Hoek van Holland	106 NM (196km)	7-8	14 per week
Stena	Harwich	Rotterdam	123 NM (228km)	8-9	4-5 per week
Stena	Esbjerg	Immingham	326 NM (604km)	18	6 per week
Stena	Oslo	Frederikshavn	156 NM (289km)	12	6 per week
Stena	Karlskrona	Gdynia	168 NM (311km)	10.5	16 per week
DFDS	Cuxhaven	Immingham	324 NM (600km)	24	5 per week
DFDS	Klaipeda	Kiel	397 NM (735km)	22	6 per week
DFDS	Gothenburg	Ghent	577 NM (1069km)	33	3 per week
DFDS	Dover	Calais	26 NM (48km)	1.5-2	19-20 per day
DFDS	Dover	Dunkirk	38 NM (70km)	2	74-76 per week
DFDS	Dieppe	Newhaven	64 NM (119km)	4.5	21 per week
P&O	Dover	Calais	26 NM (48km)	1.5-2	23 per day
EUROTunnel	Folkestone	Calais	-	Transit time 1.5 (actual 0.58)	36 per day (not clear)

9.5.2 Calculation cities

The RORO SECA model calculates and generates maps for a specific origin. Choosing these origins are not only a matter of e.g. what and how much that are exported from a location. Other factors are of equally importance for instance if a location is a vital modal point or a bottleneck in the intermodal transport system. Based upon these assumptions a list of initial origins are identified. As mentioned above the list of calculation cities are dynamic and will change as the project progress.

Origin Cities		**Especially relevant for the RORO sea link**
OlofStrom	OLFS	Gothenburg Ghent
Umea	UMEA	
Stockholm	STOH	
Gothenburg	GOTH	
Ghent	GHNT	
Brussels	BRUS	
Antwerp	ANTW	
London	LOND	Dover Calais
Southampton	SOHA	
Birmingham	BIRM	
Nottingham	NOTH	
Sheffield	SHEF	
Dunkirk	DUNK	
Brussels	BRUS	
Paris	PARI	
Amsterdam	AMST	
Rotterdam	ROTD	
Hook of Holland	HOOK	
Klaipeda	KLAI	Klaipeda Kiel
Kaunas	KAUN	
Kiel	KIEL	
Vilnius	VILN	
Riga	RIGA	
Minsk	MINS	
Gdansk	GDAN	
Rostock	ROST	
Hamburg	HAMB	
Berlin	BERL	
Aarhus	AHUS	

10 Effects of new legislation for each route

This section presents the first results of running the models developed in the context of the RoRoSECA project. The analysis is conducted for each of the seven routes for three main fuel price scenarios. For each DFDS route the report presents what actually happened in terms of transported cargoes in the years 2014 and 2015, commenting on the patterns observed. This includes the deployed capacity (e.g. the maximum number of lane-meters available to carry cargo – multiplication of vessel capacity with number of trips), and the utilized capacity (actual lane-meters transported). Subsequently, the main input variables in the model are presented for each route, including the ranges of the sensitivity analyses.

The main competitive modes for each route are also discussed, and information on their market share is provided. For routes where market shares information was not reliable, a simulation approach was used. Finally, the three Fuel Case scenarios presented in section 8.1 are considered and the results are of the runs are presented for illustrative O-D cases in terms of distance trade-offs between the various modes. A short discussion on the risks associated with each DFDS route is closing the presentation of each route.

10.1 Gothenburg - Ghent

The Gothenburg – Ghent route of DFDS is one of the most interesting scenarios, as the vessels deployed are running on scrubbers, and these investments preceded the regulation. As a result, the vessels were already running on increased costs throughout 2014 (assuming that the investments were converted into equivalent annualized costs).

10.1.1 Fleet deployed

In the period 2014 to 2015 a total of 5 different vessels had been deployed, and at any given month three vessels were deployed (except July 2014 when 2 vessels were only used). The year 2015 show an increased deployment of the two larger vessels (Begonia, Freesia) which may be a consequence of the increased transport demand in the route. However, the vessel deployment criteria of DFDS are not provided and only speculation can be made. The technical specifications of the 5 vessels used in the examined period are summarized in Table 11.

Table 11: Deployed vessels in Gothenburg - Ghent

Vessel	SO_x abatement	Months deployed in Route	Built or Retrofit Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity	
						Lane-meters	Passengers
Petunia Seaways 	Scrubbers	10	2004	22.5	20070	3831	12
Magnolia Seaways 	Scrubbers	24	2003	22.5	20070	3831	12
Primula Seaways 	Scrubbers	23	2004	22.5	20070	3831	12
Begonia Seaways 	Scrubbers	(12/ 2015)	2004	22.5	20070	4650	12
Freesia Seaways 	Scrubbers	13	2005	22.5	20070	4650	12

10.1.2 Statistics on deployment and utilization

Based on Table 11 it is interesting to note that towards the end of 2015 and in the first months of 2016, the two larger ships in terms of lane-meter capacity (Begonia and Freesia) were moved to this route. Figure 30 shows the comparison of the deployed capacity in the two years of interest:

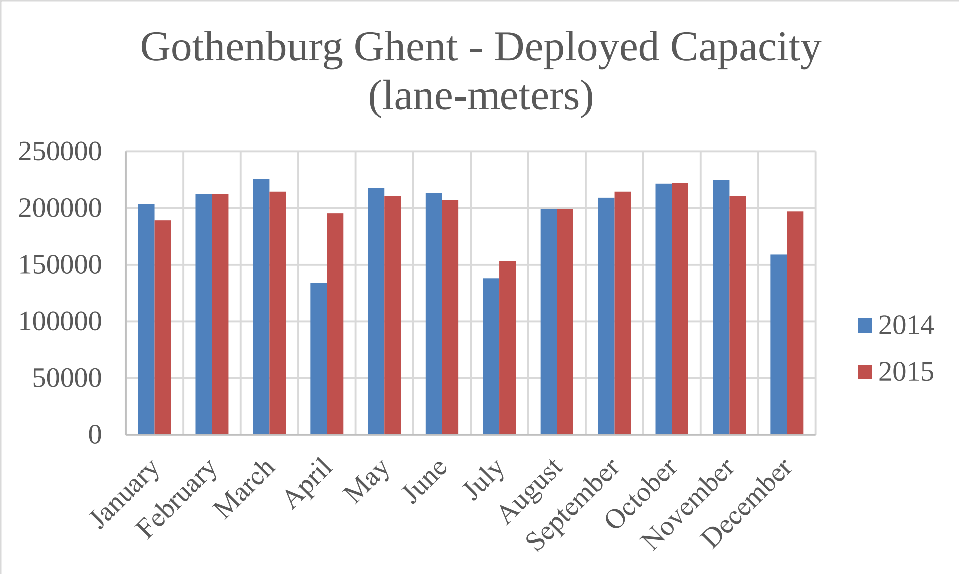


Figure 30: The deployed capacity per month for Gothenburg – Ghent

The seasonality of the service can be easily observed, where in July for both years the deployed capacity has dropped. For most months there are not great differences in the two years. Figure 31 shows the annual change in deployed capacity, and utilization capacity for the two years.

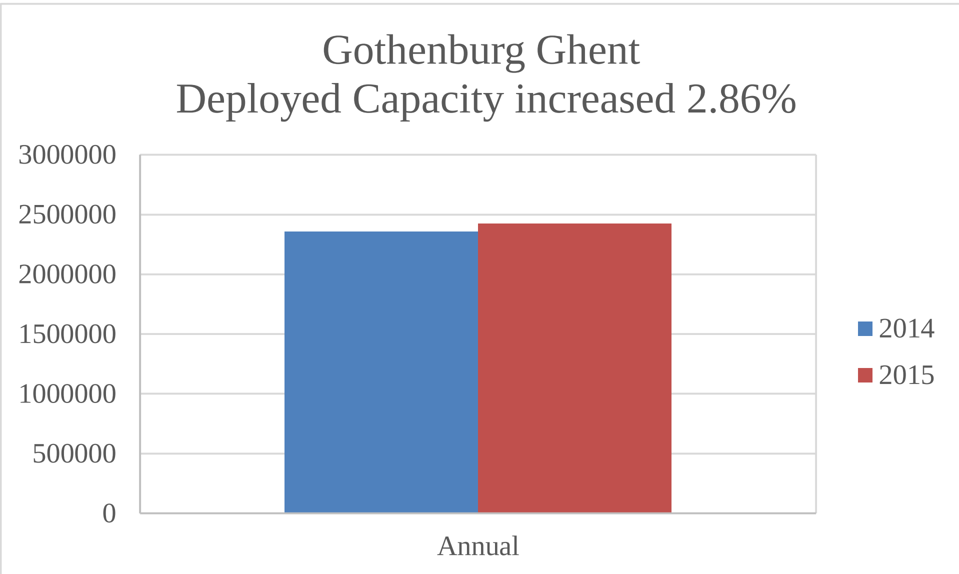


Figure 31: Deployed Capacity for Gothenburg – Ghent

A notable increase of 2.86% is observed in the total lane-meter capacity offered between the two years. This is an almost direct repercussion of the fact that the number of trips in the two years increased by 2.89% (from 553 to 569). However, the change in transported volume of freight is more impressive for this Route. This is shown in Figure 32.

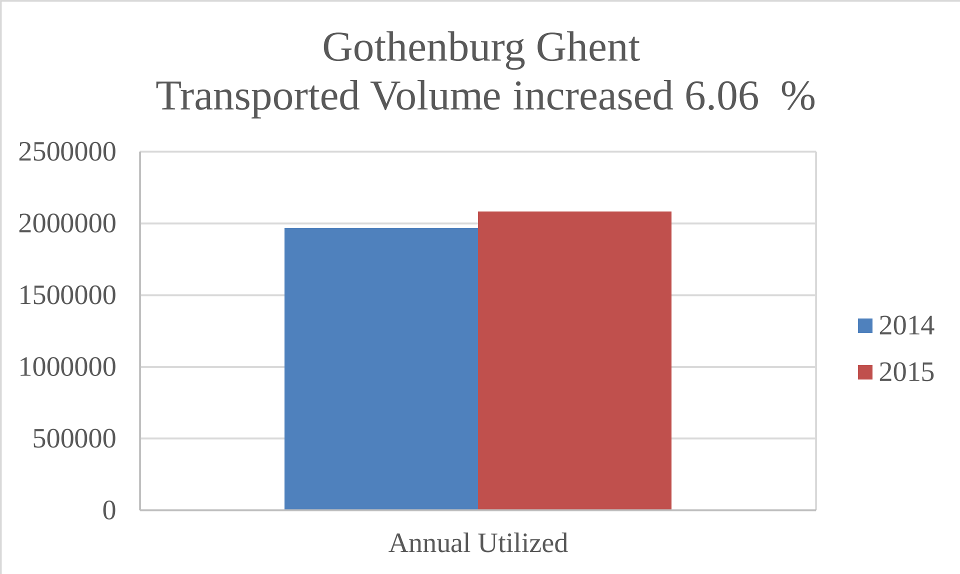


Figure 32: Transported Volume for Gothenburg – Ghent

Table 12 summarizes the number of trips and the change in utilization rates in for the two years on the Gothenburg – Ghent service.

Table 12: Overview of Gothenburg – Ghent changes

Year	HFO price ($/ton)	Trips Total	Utilization Rate (%)	Transported Volume change	Freight Rate change	Revenue change
2014	533	553	xx	NA	-1.51%	NA
2015	263	569	xx	+6.058%	-5.62%	+0.09%

It can be seen that the generated revenue of the route has essentially remained the same, despite the lower freight rates as a consequence of the increased volume transported. However, considering that the fuel costs are much lower, it can be derived that the economic performance of the route has improved considerably. This is also evident from the fact that the bunker costs were 30% of the overall operating costs in 2015, in comparison to 45% in 2014.

10.1.3 Environmental performance of Route

The environmental performance of the route has changed in-between the 2 years. As shown in the previous section, the overall capacity utilization of the service has improved. In terms of fuel consumption, this is presented per quarter for the two years in Figure 33.

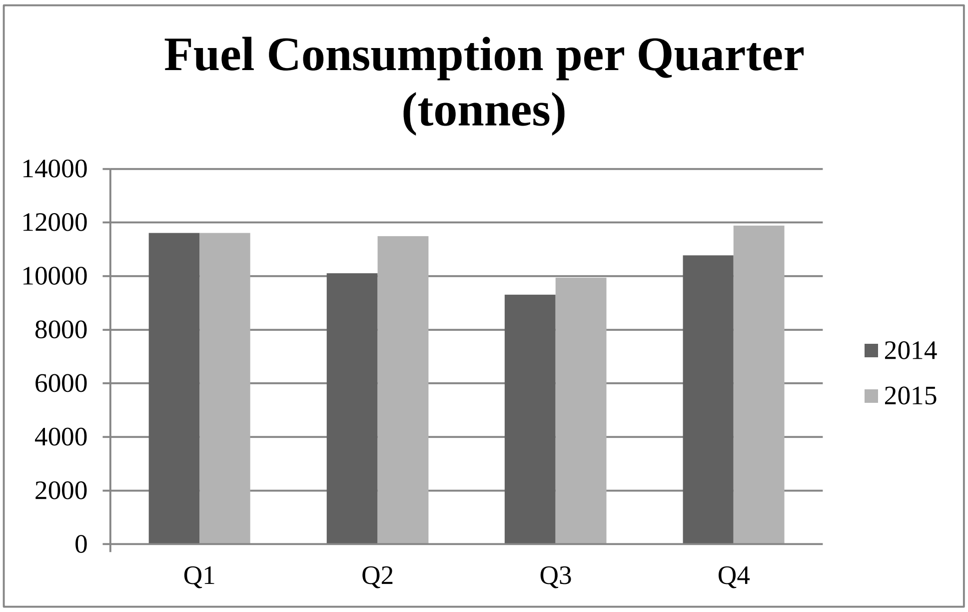


Figure 33: Fuel consumption per quarter in Gothenburg – Ghent

The increase in fuel consumption may appear misleading. There are more trips and thus more activity taking place. At the same time, this fuel consumption is given by DFDS and is based on measurements at each arrival at each port for all vessels. In 2015, larger vessels were deployed on the route which is also contributing to increasing overall fuel consumption. While speed information was not explicitly given by DFDS, most vessels show an increase fuel consumption per NM, which may be a result of an increase sailing speed due to the lower fuel costs. The next graphs compare emissions per lane-meters for CO_2 and SO_2 emissions, based on the fuel consumption provided by DFDS and the actual transported lane-meters of cargo, multiplied with appropriate emission factors.

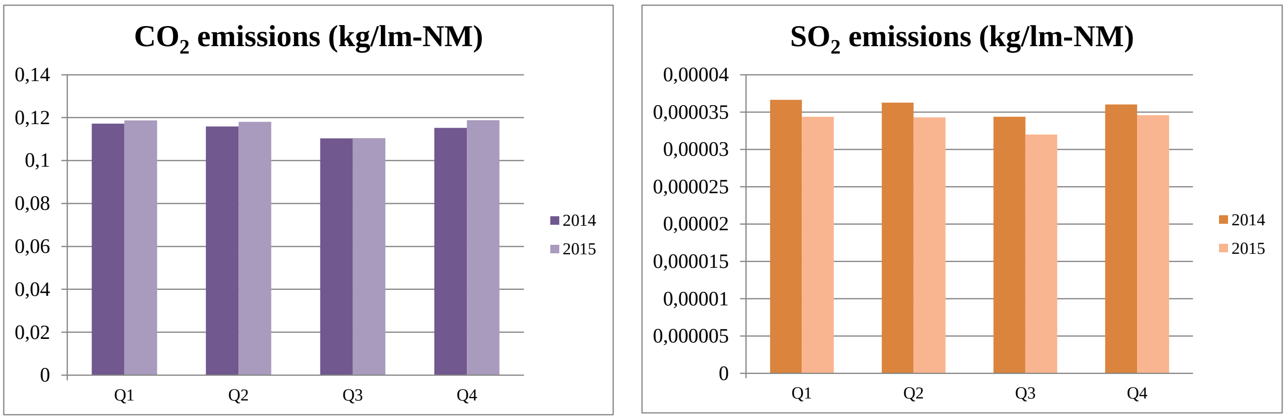


Figure 34: Emissions (kg/lm-NM) for CO_2 and SO_2

The results show that the CO_2 emissions per lane-meter have marginally increased which is essentially the trade-off between the increased utilization capacity of the vessels, and the increased fuel consumption per trip (due to either higher sailing speeds, or less efficient vessels deployed). For SO_2 emissions, the picture is different with lower emissions observed. Considering that all deployed vessels were already equipped with scrubbers, the emissions are low for both years. The lower values in 2015, may be attributed to the fact that HFO was not used in the auxiliary engines according to the data provided by DFDS. This means that despite the use of scrubbers, the exhaust gases from the auxiliary engines were not filtered in the scrubber system. As a result, MGO was used for the auxiliary engines and thus due to the regulation a small benefit for SO2 emissions was observed (in addition to the main benefit due to the investment in the scrubber system).

10.1.4 Competitive modes considered

The port of Ghent is only connected to Gothenburg via the DFDS link. There are certain services from Gothenburg to other European ports that can considered as viable alternatives. This section considers the Gothenburg – Kiel service offered by Stena line, due to the similar number of departures per day offered. The land distances and times from Kiel to the potential destinations are retrieved from the RoRoSECA network model. An almost fully landbased option is also going to be considered, where it is possible to drive from Gothenburg to Denmark, and use a small ferry service from Puttgarden to Rødby in order to cross over to mainland Europe.

10.1.5 Baseline scenario and model calibration

The baseline scenario considered is summarized in Table 13. The market shares are provided as ranges, for typical shipments between Sweden and Belgium and are based on Eurostat estimates. The calibration results for the dispersion parameters are also shown, after conducting sensitivity analysis on the initial market shares, and cargo values.

Table 13: The baseline case and the calibration results

	Gothenburg - Ghent								
	Via DFDS			Via Stena			Road only		
Baseline (2014)	Share (%)	Road Distance (km)	Total time (hr)	Share (%)	Road Distance (km)	Total time (hr)	Share (%)	Road Distance (km)	Total time (hr)
	24-30	100-300	38±2	21-29	600-800	22±2	39-49	1600±300	23±2
Dispersion parameters	Average			Standard Deviation			Interquartile Range		
λ_1 (Maritime-Land)	0,02724			0,23936			0,00173:0,00883		
λ_M (DFDS – Stena)	0,02523			0,10318			0,01659:0,03376		

The dispersion parameter values are positive, indicating a negative correlation between generalized cost and probability of choosing a particular mode. The values presented in Table 13 are the average as taken from the sensitivity analyses conducted. The values between Maritime-Land options are comparable in terms of order of magnitude with previous studies in the field, but a little lower in this example due to the larger variability on cargo values used in the simulation.

10.1.6 New freight rates due to fuel prices

This route is essentially a cargo route, as the vessels only have provision for 12 passengers (drivers). In section 8.5 it was discussed that the share of fuel costs over the operating costs for this route dropped from 45% to only 30%. Considering that DFDS has deployed scrubber-equipped vessels on these routes, this significant drop is reasonable. However, the freight rates are still calculated based on the fuel price differential with MGO to account for the additional costs due to the regulation. This freight rate per lane-meter has actually dropped by 5.624% between 2014 and 2015. This actually constitutes the ferry crossing with DFDS cheaper for shippers than the year before the regulation, without considering the effects of inflation on the market.

10.1.7 Results of simulation

The simulation was performed for a range of inputs including variations on: dispersion parameters (as produced by the calibration), road distances for each maritime option, new freight rate for landbased options, cargo values, and depreciation rate. The results are summarized in Table 14.

Table 14: Modal shifts for Gothenburg - Ghent

	Gothenburg - Ghent					
	New Shares					
	Via DFDS		Via Stena		Road only	
	Average	IQ range	Average	IQ range	Average	IQ range
	Fuel Case 1					
% change	+1.23	1.09:1.56	-1.02	-0.95:-1.21	-0.22	-0.06:-0.37
% average difference	+3.98		-4.71		-0.47	
	Fuel Case 2					
% change	+1.68	1.38:2.15	-1.05	-0.76:-1.67	-0.63	-0.08:-0.44
% difference	+5.56		-4.73		-1.38	
	Fuel Case 3					
% change	-1.02	-0.49:-1.05	+0.44	0.37:0.80	+0.58	0.05:0.25
% difference	-3.34		+2.04		+1.35	

The results show that with the actual fuel prices, DFDS was expected to see an increase of 3.98% in its cargo volumes transported. Or in other words, it was expected to capture an additional 1.23% of the overall transport demand modelled. This finding agrees with the actual case. For Fuel Case 2, where the freight rates would be further decreased as a consequence of the calculation of BAF with HFO prices in 2015 levels, it is seen that the shares could increase up to 5.56% on average, which is equal to capturing 1.68% of the overall transport demand. However, increasing freight rates as per the MGO prices in 2014 (Fuel Case 3) shows that DFDS would lose 3.34% of the cargo volumes transported, or 1.02% of the overall transport demand modelled. While this loss may not be impressive, for a Ro-Ro company operating near the breakeven point it could be important. In addition, considering that the results are shown assuming no change in the Stena line pricing, the actual increase in the fully land-based mode would be even greater.

10.1.8 Discussion on risk

This route shows to have improved in terms of utilization capacity and volumes of cargo transported. This is concurrent with the expectations as the fuel costs for this route have dropped more in comparison to other DFDS routes due to the fact that all vessels are using scrubbers. In addition, the freight rate charged per lane-meter has decreased in comparison to the 2014 levels, which explains the increase in the probability of choosing the DFDS route for the shippers. However, as Fuel Case scenario 3 illustrated, an increase in fuel prices will similarly affect this route, constituting it less attractive in comparison to the other options that are more landbased. Considering that the vessel deployment will not change greatly in such a scenario, the fact that the vessels are using scrubbers may help the company internalize part of the increase in freight rates that may be triggered due to an increase in fuel prices. However, there may be cargo flows lost to other competitors. The route is not at major risk due to the nature of cargoes transported, and the partnership with Volvo on transporting machinery and cars to Europe.

10.2 Rotterdam – Felixstowe

The Rotterdam – Felixstowe route is a Ro-Ro service connecting the United Kingdom with the Netherlands. The route is interesting due to the high sailing frequency and short sailing distance.

10.2.1 Fleet deployed

In the examined period, during any given month three Ro-Ro vessels were deployed. There have been five different vessels sailing this route between 2014 and 2015. The voyage normally takes 8 hours with a sailing distance of 121 NM. Of the deployed vessels, three have been retrofitted to use scrubbers (one in 2013, two in 2014), one was sold by DFDS (Flandria) and the last one (Anglia) is still using low-sulphur fuel to comply with the regulation. The specifications of the five vessels are shown in Table 15.

Table 15: Deployed vessels in Rotterdam – Felixstowe

Vessel	SO_x abatement	Months deployed in Route	Built or Retrofit Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity	
						Lane-meters	Passengers
Britannia Seaways 	Scrubbers	2	2000	21.1	21600	2772	12
Suecia Seaways 	Scrubbers	23	1999	21.5	21600	2772	12
Selandia Seaways 	Scrubbers	23	1999	21.1	21600	2772	12
Anglia Seaways 	Low sulphur Fuel	9	2000	18.6	10950	1692	12
Flandria Seaways 	Low sulphur Fuel	15	2000	18.6	10950	1562	12

10.2.2 Statistics on deployment and utilization

The summary of the deployed capacity in the Rotterdam – Felixstowe service is shown in Figure 45.

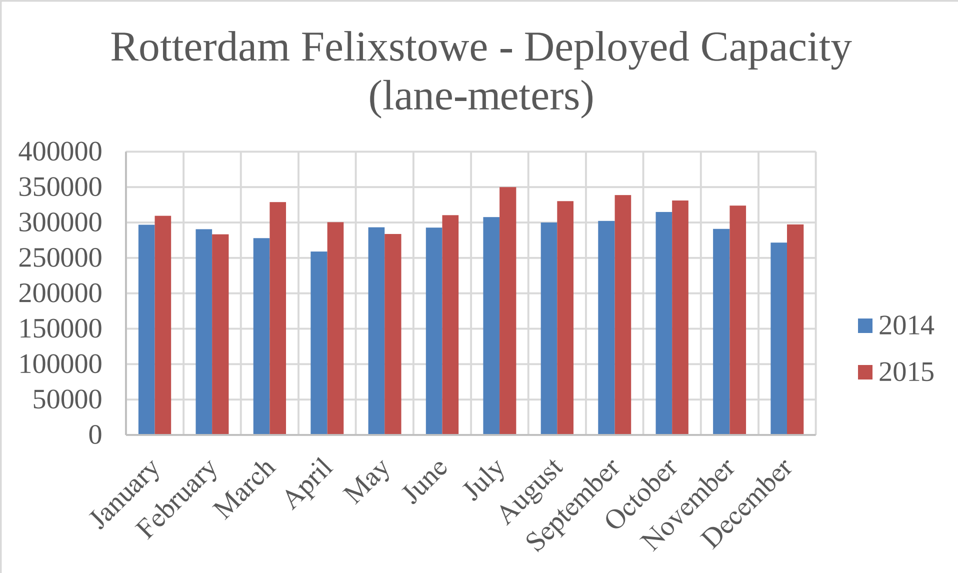


Figure 35: The deployed capacity per month for Rotterdam - Felixstowe

An increase is observed for most months in the deployed capacity of the vessels. The aggregated deployment in annual is shown in Figure 36.

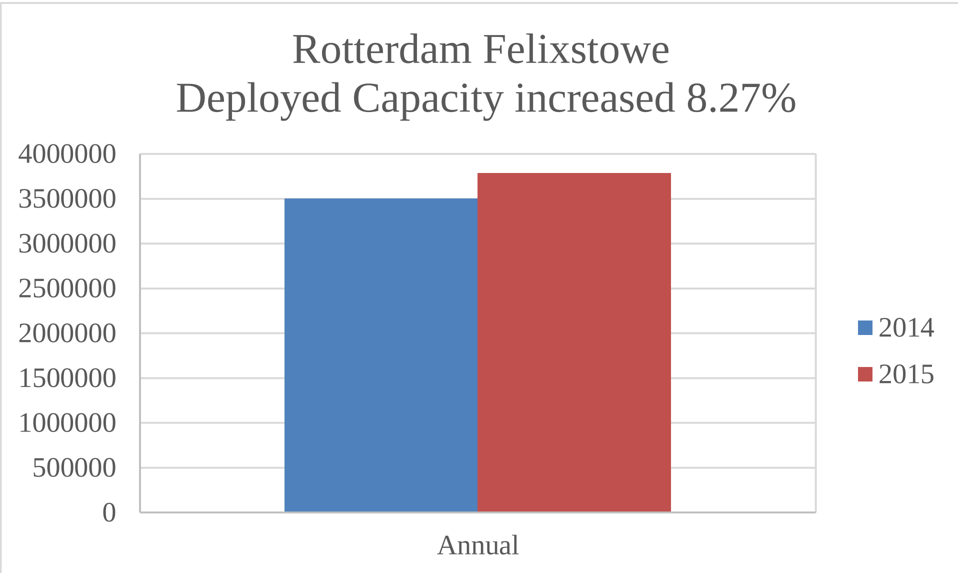


Figure 36: Deployed Capacity for Rotterdam – Felixstowe

An important increase of 8.27% is observed in the overall deployed capacity in lane-meters for the route. The number of trips increased by an almost identical figure (8.12% from 1514 to 1637 trips), which is reasonable as the deployed vessels have very similar capacities. The change in actual transported volume is shown in Figure 37.

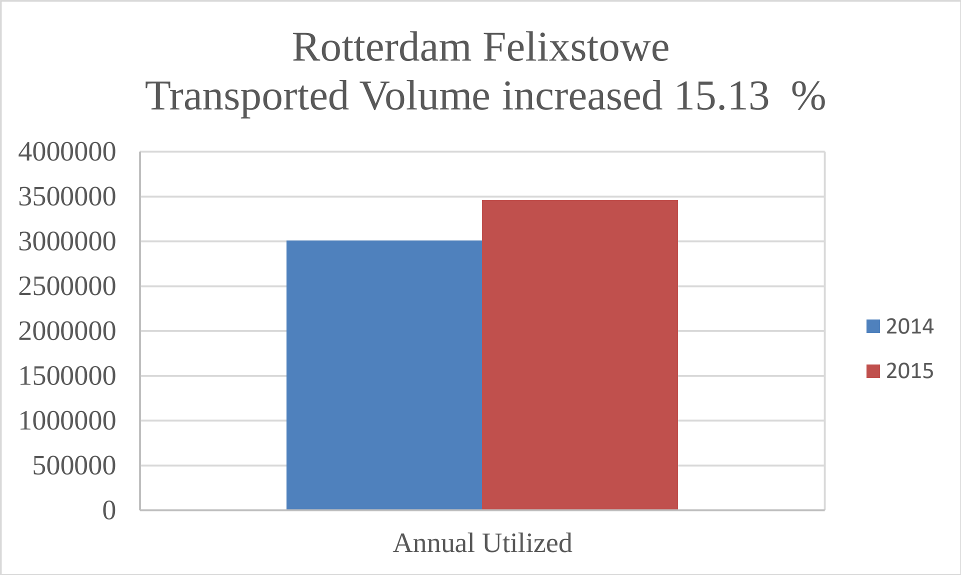


Figure 37: Transported Volume for Rotterdam – Felixstowe

A very important increase in actual transported volumes of 15.13% is observed, which shows improved capacity utilization due to the greater increase than the one shown in Figure 36. A statistical summary of the route is provided in Table 20.

Table 16: Rotterdam – Felixstowe comparison between 2014-2015

Year	Fuel price ($/ton)		Trips Total	Utilization Rate (%)	Transported Volume change	Cargo Rate change (%)	Revenue (%)
	HFO	MGO					
2014	533	816	1514	xx	NA	1.00	NA
2015	263	478	1637	xx	15.13	0.5	15.71

It can be observed that the revenue generating performance of this route has improved considerably, in agreement with the actual transport increase. The lower fuel prices did not result in a reduction in freight rates, which have marginally increased. Taking into account however inflation, the actual freight rates may be lower. The utilization ratio has improved further reaching 91.4% which indicates that vessels on this route are operating near capacity. If transport demand would increase, the company would have to consider offering more departures per week. The bunker costs in this route in 2014 were 40% and were reduced to 30% in 2015 of the overall operating costs. This decrease shows that the profitability of the route has improved as the generated revenue has increased, while the costs have decreased. This situation could change if fuel prices increase in the future, as the fuel costs are significant in this route's economic balance.

10.2.3 Environmental performance of Route

The fuel consumption per quarter for the Rotterdam – Felixstowe route is shown in Figure 38.

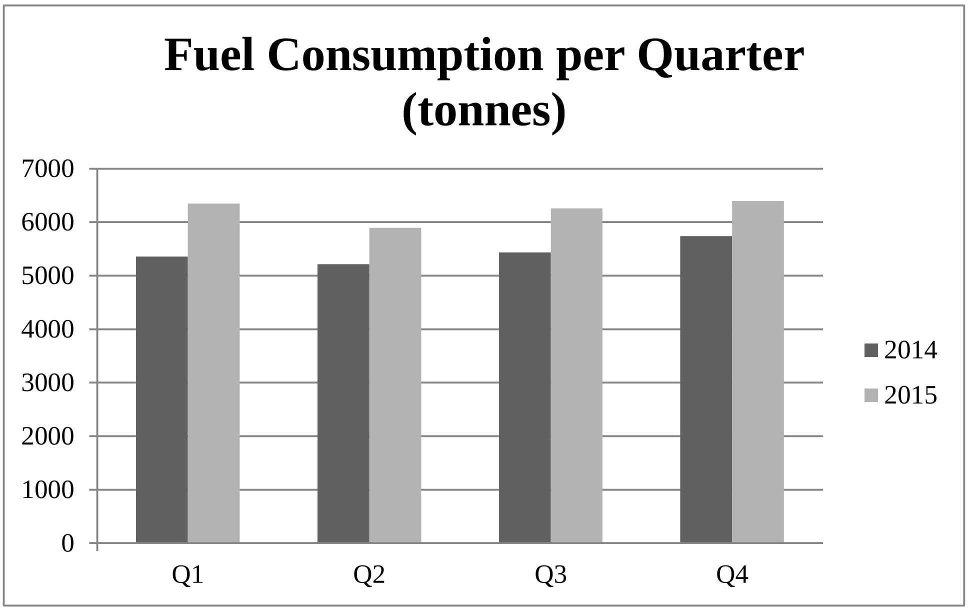


Figure 38: Fuel consumption per quarter in Rotterdam – Felixstowe

An increase is observed throughout 2015. This can be attributed to the different vessel deployment, and potentially changes in sailing speed. The barcharts in Figure 39 present the carbon and sulphur emissions for the route, in terms of kilogram per transported lm-NM.

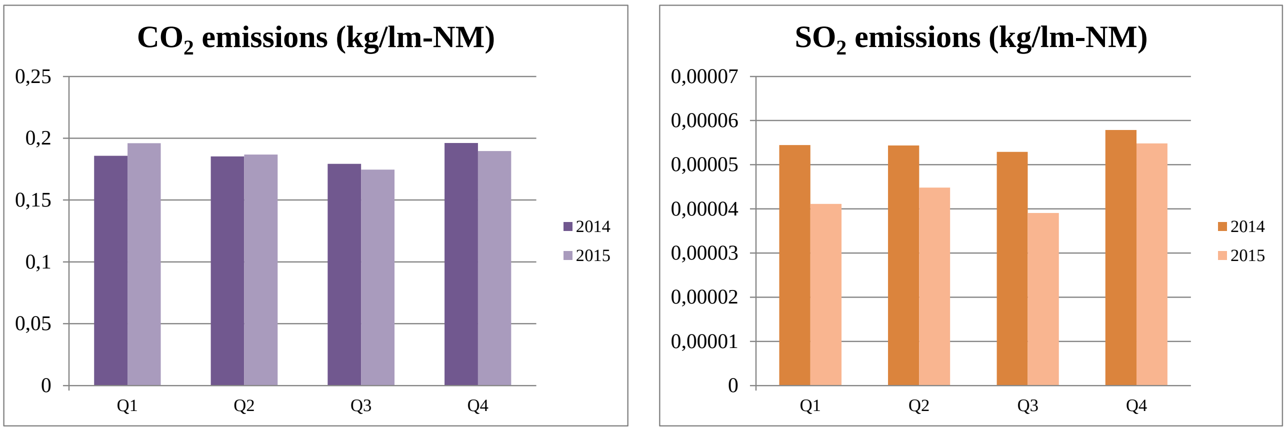


Figure 39: Emissions (kg/lm-NM) for CO_2 and SO_2

The results show that the CO_2 emissions per lane-meter has not changed significantly despite the higher fuel consumption. This is a consequence of the considerably improved utilization ratio of the vessels. For sulphur emissions, it is clear that the regulation has helped decrease them. The reduction is lower than in other routes due to the fact that most vessels were equipped with scrubbers during 2014 (it is assumed that they systems were active).

10.2.4 Competitive modes considered

The Esbjerg – Immingham route is competing with a landbased option (if Eurotunnel is used to cross the Channel), with a driving distance of approximately 575km between the two ports. There are certain ferry services from Stena (Rotterdam to Harwich, Hoek van Holland to Harwich) which could also be used, but are not considered competitive in the ensuing case study. There are also several feeder services for container transportation between the two ports.

10.2.5 Baseline scenario and model calibration

Table 21 presents the baseline scenario used in the calibration stage. The market shares are provided as illustrative ranges. The calibration is conducted and the resulting value of the dispersion parameter λ is shown, considering a sensitivity analysis on initial market shares, cargo values, and depreciation rate of cargo.

Table 17: The baseline case and the calibration results

	Rotterdam - Felixstowe					
	Via DFDS/Stena			Landbased (Eurotunnel)		
Baseline (2014)	Share (%)	Road Distance (km)	Total time (hr)	Share (%)	Road Distance (km)	Total time (hr)
	30-40	100±50	8±2	60-70	500 ±100	7±2
Dispersion parameter	Average			Interquartile Range		
λ (Maritime-Land)	0.14			0.127:0.175		

10.2.6 New freight rates due to fuel prices

The share of fuel costs over the operating costs for this route dropped from 40% to only 30%. This is a reasonable reduction as most vessels were already equipped with scrubbers, and the price of HFO dropped considerably within that year.

The freight rates are calculated based on the fuel price differential with MGO to account for the additional costs due to the regulation, and there was a very minor increase in what the shippers are paying (0.5% between 2014 and 2015).

10.2.7 Results of simulation

The simulation was performed for a range of inputs including variations on: dispersion parameter λ, additional road distance for both options, new freight rate for landbased options, cargo values, and depreciation rate. The results are summarized in Table 1Table 18.

Table 18: Modal shifts for Rotterdam - Felixstowe

	Rotterdam - Felixstowe			
	New Shares			
	Via DFDS		Road only	
	Average	IQ range	Average	IQ range
	Fuel Case 1			
% change	0.93	0.08:1.93	-0.925	-1.93: -0.08
% average difference	2.89		-1.36	
	Fuel Case 2			
% change	1.84	1.84:2.13	-1.84	-2.13:-1.84
% difference	5.85		-2.67	
	Fuel Case 3			
% change	-0.59	-0.72:-0.51	0.59	0.51:0.72
% difference	-1.85		0.89	

The results show that with the actual fuel prices, the maritime options were expected to see an increase of 2.89% in its cargo volumes transported. Or in other words, it was expected to capture an additional 0.93% of the overall transport demand modelled. This finding is of smaller magnitude to what actually happened (approximately 10% increase, which was the maximum result retrieved from the simulation). This is either due to an increase in haulers rates for road transportation, an average high cargo value of transported cargoes, or simply an increase in the overall transport demand between the two countries. Aggregate level data are required to conclude.

For Fuel Case 2, where the freight rates would be further decreased as a consequence of the calculation of BAF with HFO prices in 2015 levels, the shares would increase up to 5.85% on average, which is equal to capturing 1.84% of the overall transport demand. However, increasing freight rates as per the MGO prices in 2014 (Fuel Case 3) shows that the maritime modes would lose 1.85% of the cargo volumes transported, or 0.6% of the overall transport demand modelled. This route is considered robust, but the results show that it has also been negatively affected by the regulation's presence indirectly.

10.2.8 Discussion on risk

The route has increased its revenue due to the much higher transport demand in 2015. The fuel costs have also decreased as part of the operating costs, further enhancing the profitability prospects of this service. The route has not seen the negative effects of the regulation as most vessels in the service were already equipped with scrubbers even before 2014. Considering the high share of bunker costs in the overall operating costs, the route may lose some cargo volumes if HFO prices increase significantly and force much higher freight rates. Note also that we have not considered the case that shippers using the Ro-Ro service would contemplate switching to a container carrier as a result of the sulphur regulation, even though this is conceivable.

10.3 Esbjerg - Immingham

The Esbjerg – Immingham route is a Ro-Ro service connecting the United Kingdom with Jutland in Denmark. The route is interesting due to the high sailing frequency and changes in deployment during the last two years, showing a significant rise in transported volumes.

10.3.1 Fleet deployed

In the examined period, during any given month two Ro-Ro vessels were deployed. There have been five different vessels sailing this route between 2014 and 2015. The voyage normally takes 18 hours with a sailing distance of 324 NM. Of the deployed vessels, three have been retrofitted to use scrubbers (one in 2014, two in 2015), one is no longer chartered by DFDS (Ark Forwarder) and the last one is still using low-sulphur fuel to comply with the regulation. The specifications of the four vessels are show in Table 19.[7]

Table 19: Deployed vessels in Esbjerg – Immingham

Vessel	SO_x abatement	Months deployed in Route	Built or Retrofit Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity	
						Lane-meters	Passengers
Jutlandia Seaways 	Low-sulphur fuel	7 (all in 2014)	2010	20	18900	3332	12
Ark Forwarder 	Low-sulphur fuel	3 (all in 2014)	1998	22	23040	2715	12
Ark Dania 	Scrubbers (2015)	12	2014	20.5	19540	3000	12
Ark Germania 	Scrubbers (2015)	17	2014	20.5	19540	3000	12

10.3.2 Statistics on deployment and utilization

The summary of the deployed capacity in the Esbjerg – Immingham route is shown in Figure 45.

[7] Britannia Seaways is shown in Table 15

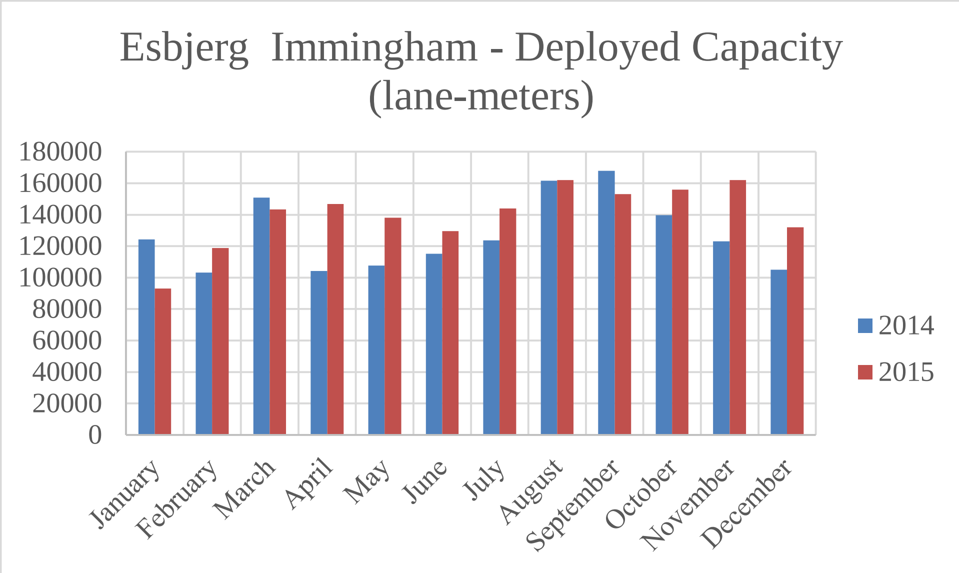


Figure 40: The deployed capacity per month for Esbjerg - Immingham

A significant increase is observed for most months in the deployed capacity of the vessels. Aggregating the deployment in annual terms shows the overall increase in Figure 41.

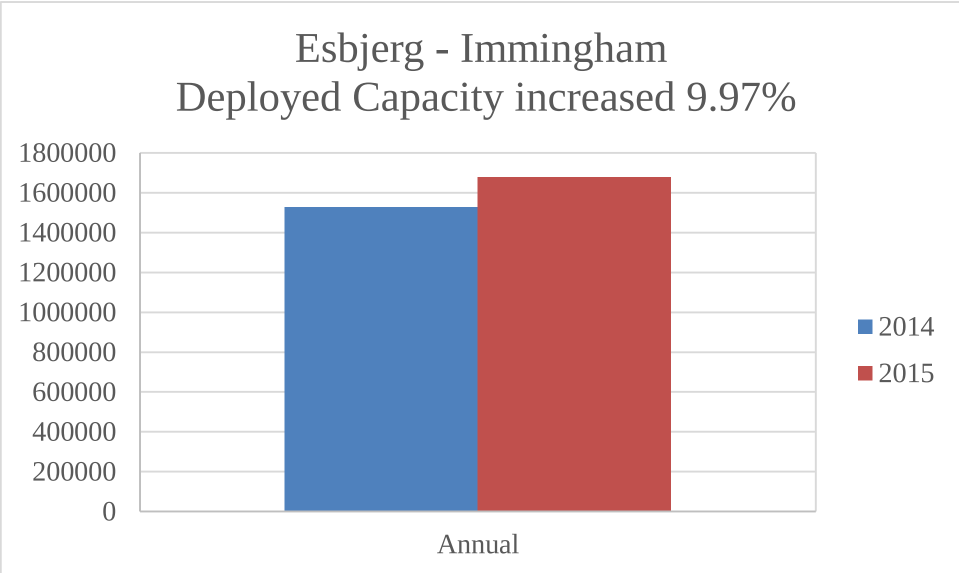


Figure 41: Deployed Capacity for Esbjerg – Immingham

An important increase of 9.97% is observed in the overall deployed capacity in lane-meters for the route. The number of trips increased by a slightly larger figure (13.28%; from 512 to 580 trips), which hints that smaller vessels were deployed in 2015. The change in actual transported volume is shown in Figure 47.

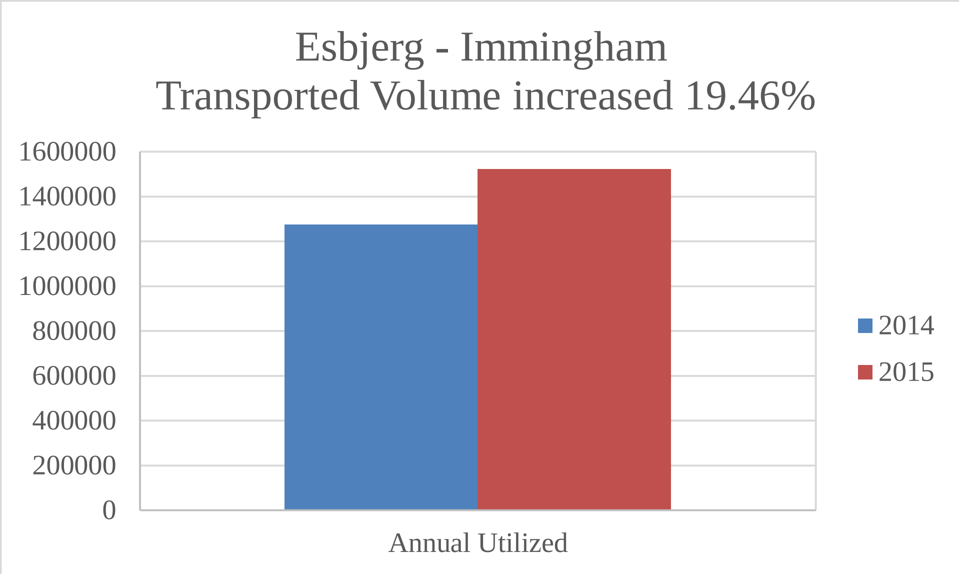


Figure 42: Transported Volume for Esbjerg – Immingham

An impressive increase in actual transported volumes of 19.46% is observed, which shows improved capacity utilization given that the deployed capacity in lane-meters did not increase as much. A statistical summary of the route is provided in Table 20.

Table 20: Esbjerg – Immingham comparison between 2014-2015

Year	Fuel price ($/ton)		Trips Total	Utilization Rate (%)	Transported Volume change	Cargo Rate change (%)	Revenue (%)
	HFO	MGO					
2014	533	816	512	xx	NA	-2.35	NA
2015	263	478	580	xx	19.46	-0.5	18.85

It can be observed that the revenue generating performance of this route has improved considerably, due to the great increase in transport demand. The lower fuel prices allowed a small reduction in freight rates; however the increase in transport demand is far greater than anticipated. The improved utilization ratio has also helped reduced the operating costs per lane meter transported. The bunker costs in this route are estimated by DFDS to have dropped from 49% to 39% in 2015. This fact definitely helps further increase the profitability of the route. However, it has to be noted that for this route fuel costs are a very significant part of the operating costs, and as such the route will be more vulnerable to future increases in fuel prices.

10.3.3 Environmental performance of Route

The actual fuel consumption for the two years in the Esbjerg – Immingham route is shown per quarter in Figure 43.

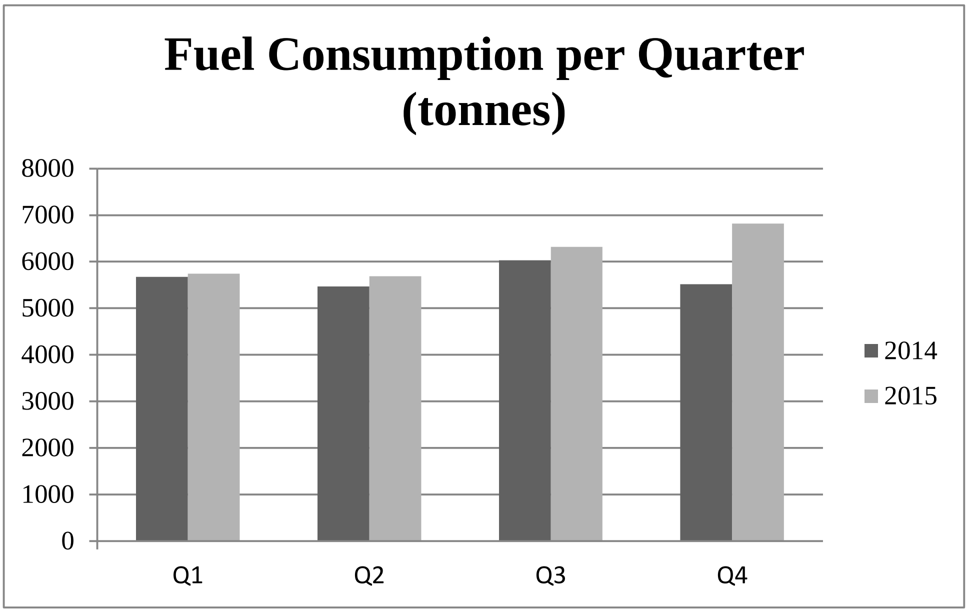


Figure 43: Fuel consumption per quarter in Esbjerg – Immingham

An increase is observed, particularly in the quarter, which can be attributed to the different vessel deployment, and potentially a change in sailing speed. The graphs in Figure 44 compare the carbon and sulphur emissions based on the fuel consumption in the Esbjerg – Immingham route, in terms of emissions per lane-meter.

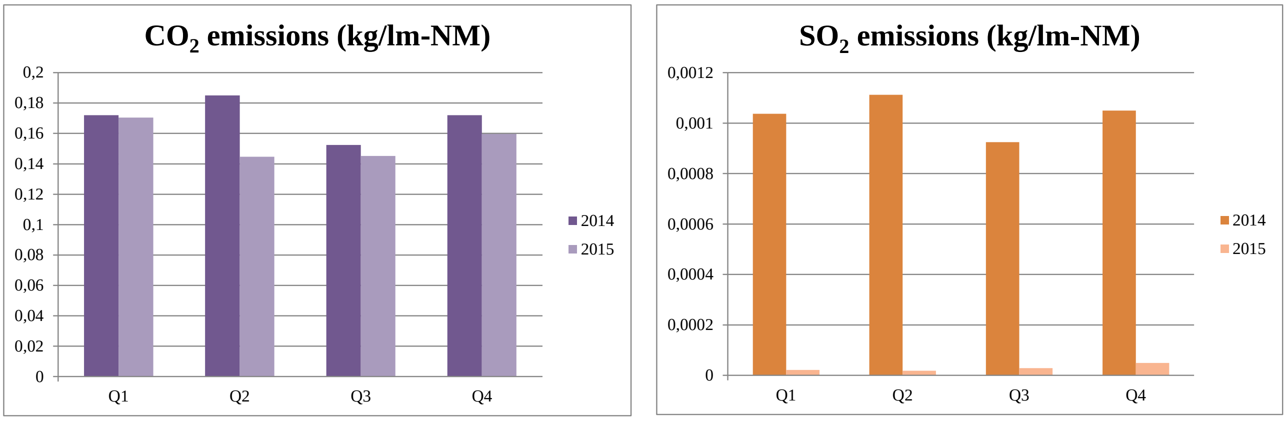


Figure 44: Emissions (kg/lm-NM) for CO_2 and SO_2

The results show that the CO_2 emissions per lane meter has decreased despite the higher fuel consumption. This is a consequence of the considerably improved utilization ratio of the vessels. For sulphur emissions, it is clear that the regulation has helped decrease these significantly.

10.3.4 Competitive modes considered

The Esbjerg – Immingham route is competing with a fully land based option (if Eurotunnel is used to cross the Channel), with a driving distance of approximately 1450km between the two ports. The route also competes with a service from Stena lines that is offering very similar departure times and length of voyage. The case study compares the pooled maritime flows with a land based alternative, to facilitate comparisons.

10.3.5 Baseline scenario and model calibration

Table 21 presents the baseline scenario used in the calibration stage. The market shares are provided as illustrative ranges. The calibration is conducted and the resulting value of the dispersion parameter λ is shown, considering a sensitivity analysis on initial market shares, cargo values, and depreciation rate of cargo.

Table 21: The baseline case and the calibration results

	Esbjerg - Immingham					
	Via DFDS/Stena			Landbased (Eurotunnel)		
Baseline (2014)	Share (%)	Road Distance (km)	Total time (hr)	Share (%)	Road Distance (km)	Total time (hr)
	60-70	100±50	18±2	30-40	1500±200	19±2
Dispersion parameter	Average			Interquartile Range		
λ (Maritime-Land)	0.08			0.071:0.094		

The value of λ is less than in other cases indicating that with the underlying assumptions a change in the generalized cost of one option would not trigger a massive modal change.

10.3.6 New freight rates due to fuel prices

This route is essentially a cargo route, as the vessels only have provision for 12 passengers (drivers). In section 8.5 it was discussed that the share of fuel costs over the operating costs for this route dropped from 49% to only 39%. Considering that DFDS has deployed for most of 2015 the retrofitted scrubber-equipped vessels on these routes, this significant drop is reasonable as the vessels use HFO which is significantly cheaper.

The freight rates are still calculated based on the fuel price differential with MGO to account for the additional costs due to the regulation, and the decrease in what the shippers are paying is minimal (freight rate per lane-meter has dropped by 0.5% between 2014 and 2015).

10.3.7 Results of simulation

The simulation was performed for various combinations of dispersion parameter (as produced by the calibration), road distance, freight rate for landbased options, cargo values, and depreciation rate. The results are summarized in Table 34.

Table 22: Modal shifts for Esbjerg - Immingham

	Esbjerg - Immingham			
	New Shares			
	Via DFDS/Stena		Road only	
	Average	IQ range	Average	IQ range
	Fuel Case 1			
% change	0.94	0.92:1.09	-0.94	-1.09:0.92
% average difference	1.53		-2.4	
	Fuel Case 2			
% change	1.55	1.44:1.82	-1.55	-1.82:-1.44
% difference	2.49		-4.18	
	Fuel Case 3			
% change	-0.72	-0.81:-0.62	0.72	0.62:0.81
% difference	-1.13		1.99	

The results show that with the actual fuel prices, the maritime options were predicted to increase by 1.53%., which is equivalent to capturing an additional 0.94% of the overall transport demand modelled. This finding is much smaller than what actually occurred. This can be either to an overall increase in the transport demand (all modes increased, but the probability of choosing maritime also increased by the predicted figure), or due to other external events which were not accounted for. For instance, the refugee camps near the Eurotunnel may have decreased some flows through the option.

For Fuel Case 2, with even lower freight rates due to the assumption that HFO would still be used, the shares would increase up to 2.49% on average, which is equal to capturing 1.55% of the overall transport demand. However, with increases in MGO prices to the levels of previous years, a drop of 1.13%, or 0.72%, of the overall transport demand modelled is predicted.

10.3.8 Discussion on risk

The route has increased its revenue due to the much higher transport demand in 2015. The fuel costs have also decreased as part of the operating costs, and as such the profitability of the route has improved considerably. The route has not seen the negative effects of the regulation due to the use of scrubber systems and the increased throughput observed. However, as the route is competing with Stena and a landbased option, given the high share of bunker costs in the overall operating costs, the route may face problems in the future if the fuel prices return to previous higher levels.

10.4 Copenhagen –Oslo

The Copenhagen – Oslo is the only cruise route examined in the context of the RoRoSECA project. The different purpose of the service has implications on its revenue and cost structure. The route is not considered threatened by competition; however interesting conclusions may be drawn on the effects of the regulation on the service.

10.4.1 Fleet deployed

In the examined period, the two traditionally deployed vessels on the route maintained operation. In principle, the two vessels are departing daily from each port in a crossing that takes approximately 17.5 hours. Of the two vessels, Crown Seaways was recently retrofitted with scrubber systems, the first of the passenger DFDS ferries to use this technology. The Pearl Seaways switched to low sulphur fuel following the lower limits imposed on January 1st 2015. The technical specifications of the vessels are shown in Table 23 Table 31 provides the information for the Kaunas Seaways vessel.

Table 23: Deployed vessels in Copenhagen – Oslo

Vessel	SO_x abatement	Months deployed in Route	Built or Retrofit Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity	
						Lane-meters	Passengers
Crown Seaways 	Scrubbers (2015)	24	1994	16	19880	1370	1790
Pearl Seaways 	Low-sulphur fuel	24	1989	16	23370	1482	1989

10.4.2 Statistics on deployment and utilization

Based on an analysis of data provided by DFDS on fleet deployment and frequency of trips, a summary of the deployed capacity in the Copenhagen – Oslo route is shown in Figure 45.

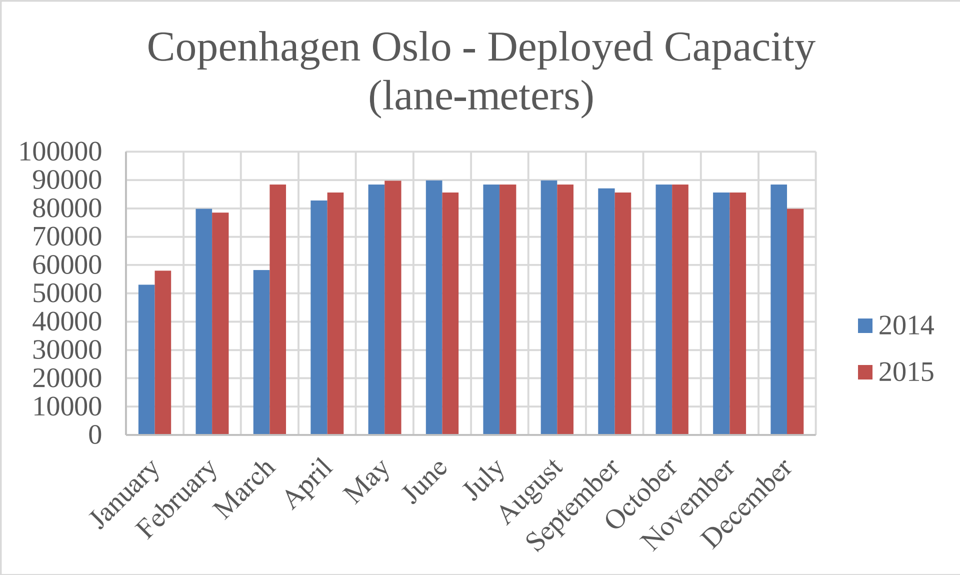


Figure 45: The deployed capacity per month for Copenhagen - Oslo

A small increase is observed for most months in the deployed capacity of the vessels. In March 2013 the deployed capacity was smaller than usual, which is probably relevant to maintenance of one of the vessels, and potentially retrofitting operations to install scrubbers on Crown Seaways. The aggregated annual levels are summarized in Figure 46.

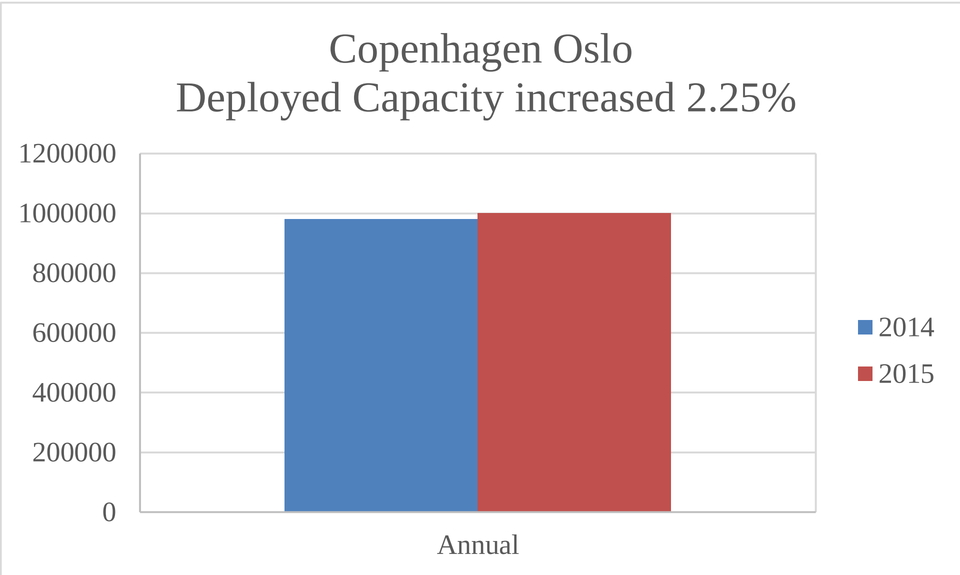


Figure 46: Deployed Capacity for Copenhagen – Oslo

A small increase of 2.25% is observed in the overall deployed capacity in lane-meters for the route, taking into account the situation in March 2014. Thus, the actual change of deployment due to an increase in transport demand was smaller. The number of trips increased by a similar figure (2.18%; from 687 to 702 trips. The change in actual transported volume is shown in Figure 47.

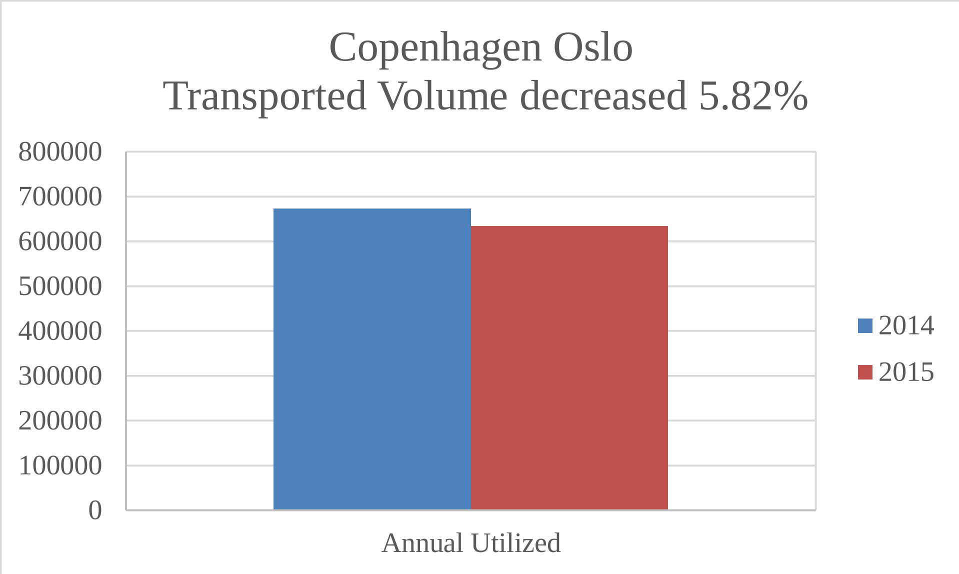


Figure 47: Transported Volume for Copenhagen – Oslo

A considerable decrease in actual transported volumes of 5.82% is observed. In this particular route, this is not a consequence of a less efficient deployment, as the service is essentially fixed to attract passengers. Therefore, a decrease in the transport demand for cargo is the main conclusion. However, passenger volumes are shown to have increased. This is evident in the main statistics of the route summarized in Table 24.

Table 24: Copenhagen – Oslo comparison between 2014-2015

Year	Fuel price ($/ton)		Trips Total	Utilization Rate (%)	Transported Volume change	Rate change (%)		Pax change (%)	Revenue (%)
	HFO	MGO				Cargo	Pax		
2014	533	816	687	xx	NA	3.86	-1.68	-2.38	NA
2015	263	478	702	xx	-5.82	1.58	-1.96	5.67	4.28

It can be observed that the revenue generating performance of this route has improved considerably, despite the loss of transported cargo. It is noteworthy that the numbers of passengers also increased, while passenger fares have decreased. The bunker costs in this route are estimated by DFDS to have dropped from 33% to 21% in 2015, and as a result this route's profitability has increased considerably despite the lower sulphur limits.

10.4.3 Environmental performance of Route

The total fuel consumption per quarter for the two years in the Copenhagen – Oslo route is presented in Figure 48.

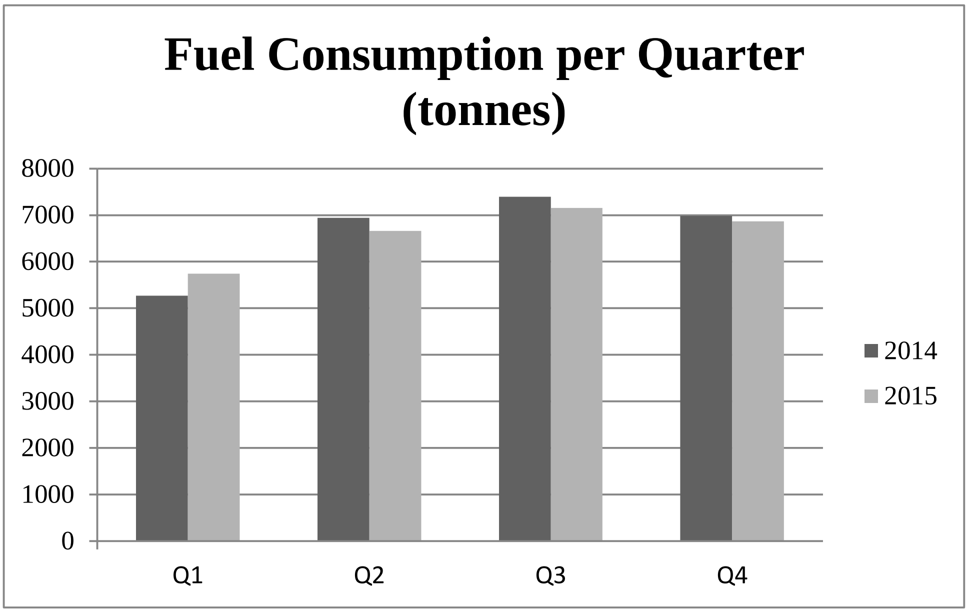


Figure 48: Fuel consumption per quarter in Copenhagen – Oslo

An increase is observed in only the first quarter, which can be attributed to the March 2014 lower deployment. The fuel consumption appears to have decreased in the other three quarters. Figure 49 compares the carbon and sulphur emissions based on the fuel consumption in the Copenhagen – Oslo route, in terms of emissions per lane-meter.

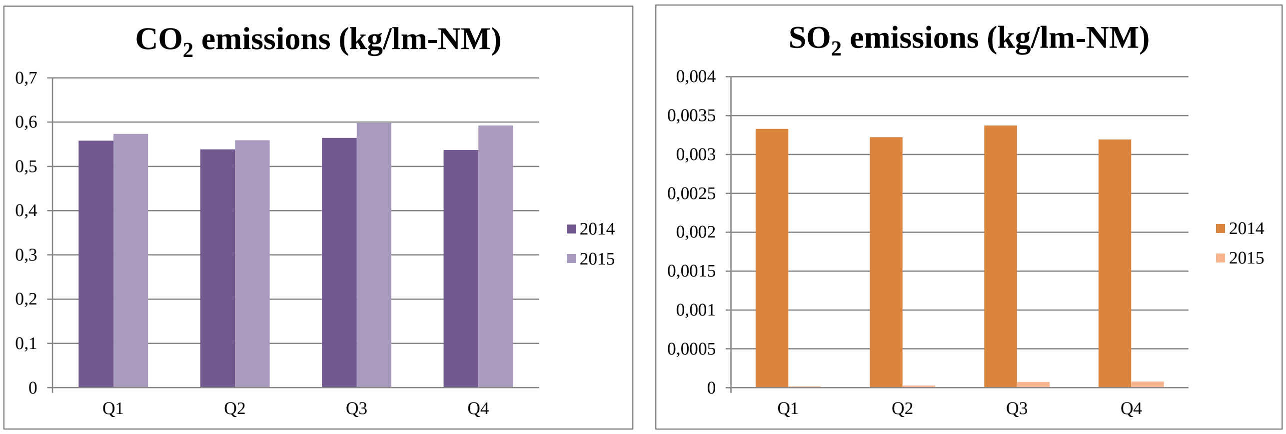


Figure 49: Emissions (kg/lm-NM) for CO_2 and SO_2

The results show that the CO_2 emissions per lane-meter have increased despite the lower fuel consumption. This is a consequence of the lower transported cargo volume. However, the allocation of emissions for cruise ships is more complicated and the graphs of Figure 49 are produced under the assumption that all emissions are attributed to cargo. In practice, the emissions per passenger carried have decreased. In terms of sulphur emissions, it is clear that the regulation has helped decrease these significantly. It has to be noted, that the sulphur emissions for 2014 were estimated on the assumption that Crown Seaways started using the scrubber systems in 2015.

10.4.4 Competitive modes considered

The Copenhagen – Oslo route is mainly targeted for passengers. Many of these passengers choose to travel by ship instead of flying or driving mainly because of the specific attributes of the service that cannot be found in air or road travel, such as on board entertainment, casino, or simply the satisfaction of spending a night on a ship. Hence for these passengers air travel or even driving between the two cities is not a real alternative except of course if the price of the sea voyage becomes very high. For cargoes, there are certain options using a smaller ferry crossing (Oslo – Frederikshavn from Stena Lines, and a road distance of 670 km to Copenhagen), or driving along the coast of Sweden after crossing the Øresund bridge (total distance of 603 km). The latter is the alternative examined in this case study.

10.4.5 Baseline scenario and model calibration

Table 25 summarizes the baseline scenario used in the calibration stage. The market shares are provided as illustrative ranges, considering that the road transport option is much faster than the cruise ship. The calibration is conducted and the value of the dispersion parameter λ is provided, showing the effects of the sensitivity analysis on initial market shares, cargo values, and depreciation rate of cargo.

Table 25: The baseline case and the calibration results

	Copenhagen - Oslo					
	Via DFDS			Landbased (Øresund bridge)		
Baseline (2014)	Share (%)	Road Distance (km)	Total time (hr)	Share (%)	Road Distance (km)	Total time (hr)
	20-25	100±50	19±1	75-80	600±100	8.5±2
Dispersion parameter	Average			Interquartile Range		
λ (Maritime-Land)	0.108			0.101:0.131		

The value of λ is higher than in other cases indicating that with the underlying assumptions a change in the generalized cost of one option could trigger a more significant modal change.

10.4.6 New freight and passenger rates due to fuel prices

The revenue structure of this route is based on three key characteristics:

- Transported freight (11.86% of 2015 revenue)
- Number of passengers (28.39%)
- On-board revenue from passenger activity (59.75%)

The above numbers suggest that essentially the performance of this route mainly depends on the revenue generated on-board, as expected for a cruise route. The passenger fares are also important, and the overall improvement in the route shows the importance of increasing the number of passengers from 2014 to 2015.

10.4.7 Results of simulation

The simulation was performed for a range of inputs including variations on: dispersion parameters (as produced by the calibration), road distances for each maritime option, new freight rate for landbased options, cargo values, and depreciation rate. The results are summarized in Table 26.

Table 26: Modal shifts for –Copenhagen-Oslo

	Copenhagen - Oslo			
	New Shares			
	Via DFDS		Road only	
	Average	IQ range	Average	IQ range
	Fuel Case 1			
% change	-1.76	-2.1:-1.62	1.76	1.62:2.1
% average difference	-8.24		2.25	
	Fuel Case 2			
% change	-0.89	-1.57:1.04	0.89	1.04:1.57
% difference	-5.19		0.93	
	Fuel Case 3			
% change	-2.64	-3.54:-1.54	2.64	1.54:3.54
% difference	-11.07		3.64	

The results show that with the actual fuel prices, the maritime options were predicted to decrease by 8.24%., which is equivalent to losing the 1.76% of the overall transport demand modelled. This finding is slightly bigger than what actually occurred (5.82%). This can be either to an overall increase in the transport demand (all modes increased, but the probability of choosing maritime decreased), or due to the nature of the transported cargo.

For Fuel Case 2, with lower freight rates due to the assumption that HFO would still be used, the shares would decrease less (5.19% on average), which is equal to losing just 0.89% of the overall transport demand. However, with increases in MGO prices to the levels of previous years, a drop of 11.07%, or 2.64%, of the overall transport demand modelled is predicted. It has to be stressed however that the performance of this route is not dependent on cargo volumes.

10.4.8 Discussion on risk

Despite the reduction of the cargo transported, the route has increased its revenue due to the higher number of passengers using the service. The fuel costs have also decreased as part of the operating costs, and as such the profitability of the route has improved considerably. The route is under no threat from the regulation, though an increase in fuel prices could lower the volume of transported freight, and reduce the profitability ratio of the service.

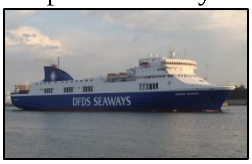
10.5 Klaipeda – Kiel

The Klaipeda – Kiel route is very interesting as it is directly competing with fully landbased alternatives due to the geography of the two ports. In addition, three of the four vessels deployed in this Ro-Pax route are equipped with scrubbers (one since 2014, the other two during 2015), which has implications on the cost of running the route.

10.5.1 Fleet deployed

In the examined period, 4 different vessels had been deployed, and at any given month two vessels were deployed. Three of the four vessels are sister ships with very similar capacities in freight and passengers. The smaller vessel of the four (Optima Seaways) saw increased deployment in this route in the year 2015. This may be attributed to the overall smaller transport demand noticed in this route, as well as a potential increased transport demand in other DFDS services using the same vessels. The technical specifications of the 4 vessels used in the examined period are summarized in Table 27.

Table 27: Deployed vessels in Gothenburg - Ghent

Vessel	SO_x abatement	Months deployed in Route	Built or Retrofit Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity	
						Lane-meters	Passengers
Victoria Seaways 	Scrubbers	15	2009	23.5	24000	2490	600
Optima Seaways 	Scrubbers	10	1999	21	18900	2115	328
Athena Seaways 	Low sulphur	9	2007	23.5	24000	2490	600
Regina Seaways 	Scrubbers	14	2010	24	24000	2496	600

10.5.2 Statistics on deployment and utilization

Given the utilization capacity provided by DFDS in the examined period, and the vessel deployment (number of voyages per month), it is possible to compare the deployed capacity of the two years, and draw some conclusions on the actual transported volumes of cargo, as well as the passenger traffic. The deployed capacity of DFDS in the Klaipeda – Kiel route per month is summarized in Figure 50.

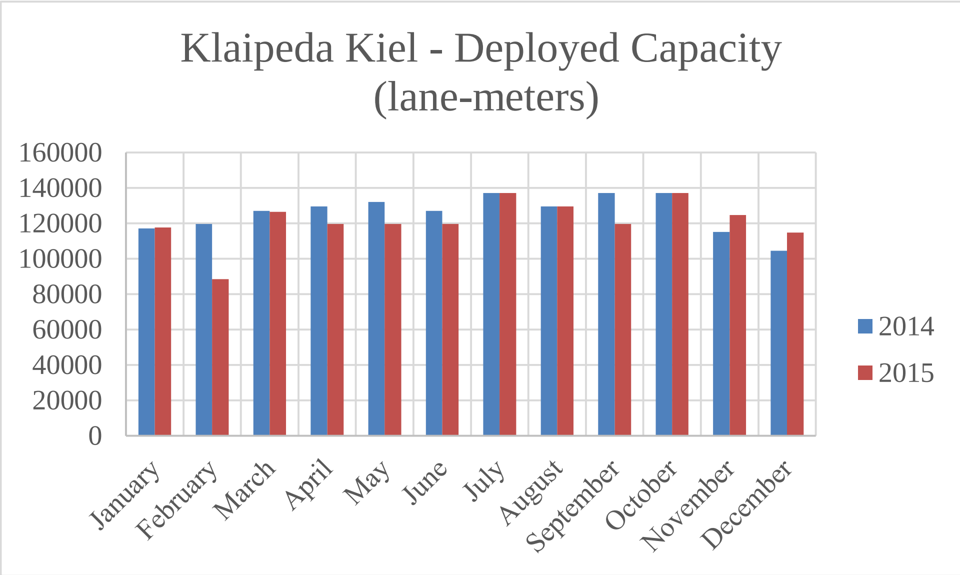


Figure 50: The deployed capacity per month for Klaipeda – Kiel

It can be seen that for most months the deployed capacity was reduced in comparison to 2014. This is particularly evident in February 2015, and months where the smaller vessel was used. The reduced trend (with the exception of January and December) is evident in the aggregated annual deployed capacity shown in Figure 51.

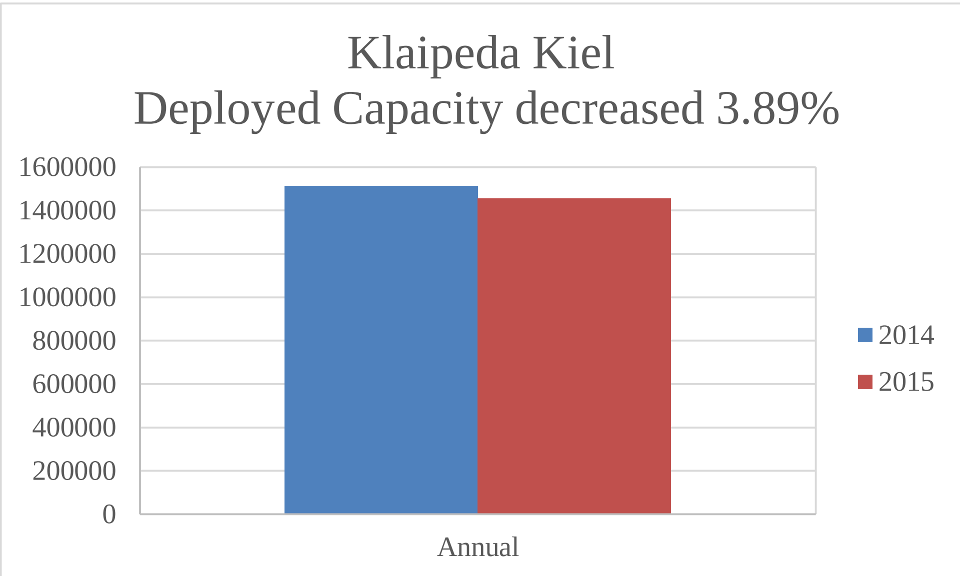


Figure 51: Deployed Capacity for Klaipeda – Kiel

A significant decrease of 3.89% is observed in the overall deployed capacity in lane-meters for the route. The number of trips practically remained the same (minor increase of 0.65%; 611 to 615). The change in actual transported volume is shown in Figure 52.

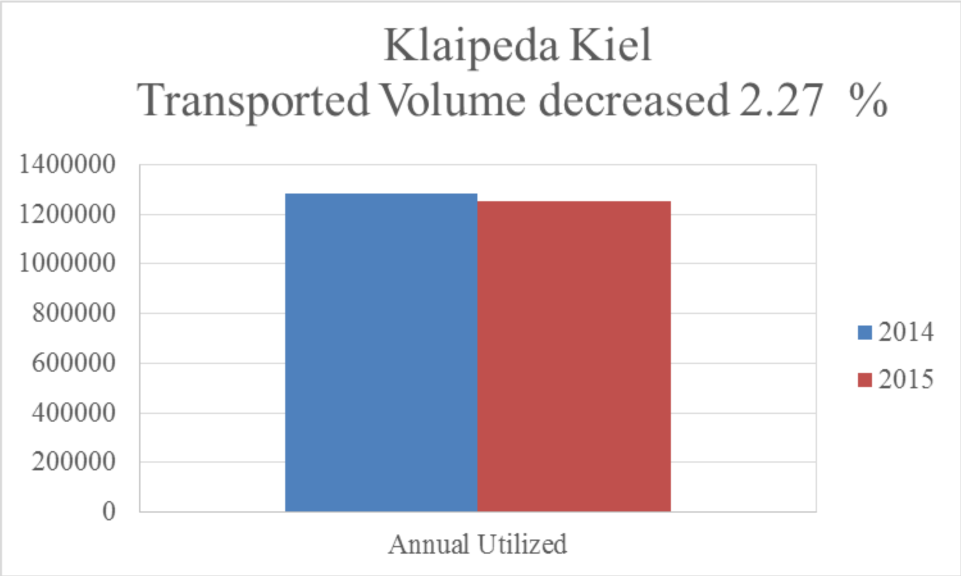


Figure 52: Transported Volume for Klaipeda – Kiel

As with other routes, it can be seen that the utilized capacity has increased as the transported volume has decreased at a smaller rate than the deployed capacity. This is an indication of improved vessel deployment despite the fact of a lesser transport demand for freight between the two ports.

The number of trips and the change in utilization rates for the examined period on the Klaipeda – Kiel route are summarized in Table 28.

Table 28: Klaipeda – Kiel comparison between 2014-2015

Year	HFO price ($/ton)	Trips Total	Utilization Rate (%)	Transported Volume change	Rate change (%)		Pax change (%)	Revenue (%)
					Carg o	Pax		
2014	533	611	xx	NA	-1.93	-1.87	-0.83	NA
2015	263	615	xx	-2.27	-7.71	+4.64	-10.30	-8.89

It can be observed that the revenue generating performance of this route has deteriorated significantly. This is a combination of the reduced transported volume of cargo and passengers, and the reduced fares (for cargo). It is noteworthy that the reduction in passenger numbers is greater than the respective cargo; this can be explained by the higher passenger fare rates charged, whereas cargo fares were reduced. However, the operating costs of the route have also decreased given that the bunker costs were 21% in 2015 down from 28% in 2014.

10.5.3 Environmental performance of Route

The total fuel consumption per quarter for the two years in the Klaipeda – Kiel route is presented in Figure 53.

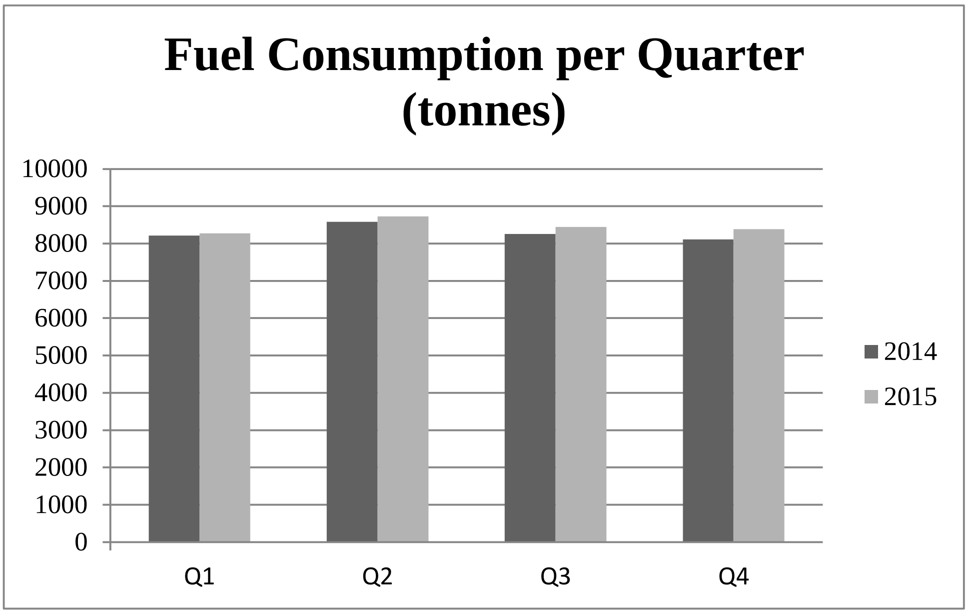
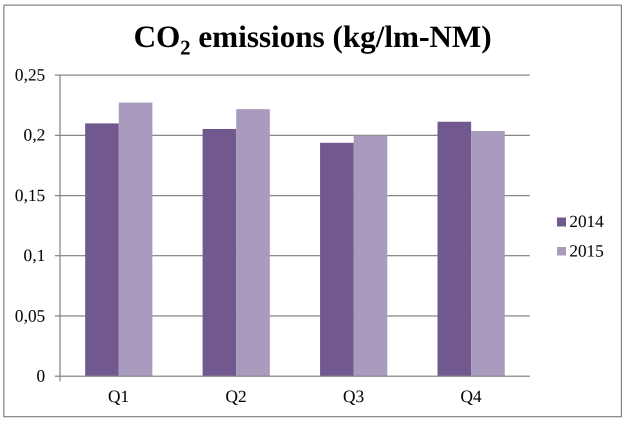


Figure 53: Fuel consumption per quarter in Klaipeda - Kiel

The increase in fuel consumption is very minor and can be attributed to the change in deployment, as well as to a potential speed increase due to lower fuel prices. The next barcharts compare the carbon and sulphur emissions based on the fuel consumption as reported by DFDS on the Klaipeda – Kiel, in terms of emissions per lane-meter.



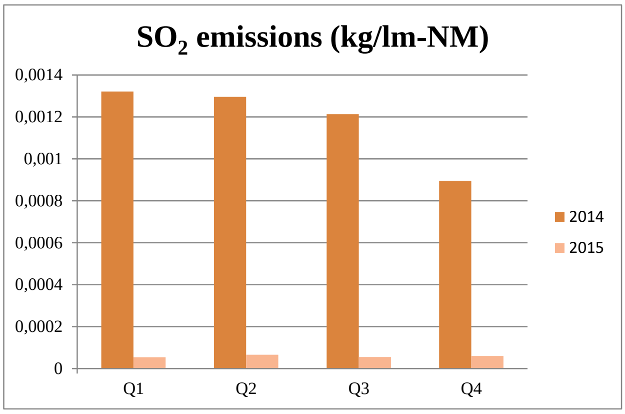


Figure 54: Emissions (kg/lm-NM) for CO_2 and SO_2

The results show that the CO_2 emissions per lane-meter have increased in comparison with the first three quarters, whereas in the fourth quarter the emissions are reduced. Considering that the vessels are sailing at improved utilization rates, this result is reasonable considering that two of the vessels were very recently equipped with scrubbers and as a result their fuel consumption has increased. In addition, one vessel is running on MGO in the year 2015 which has a higher emission factor than HFO. Considering a potential increase in sailing speed due to the lower fuel costs, the results are not surprising. In terms of sulphur emissions, these are reduced for all scenarios and are considerably low as a repercussion of the lower sulphur limit and the late installation of the scrubbers. This shows that for this particular route the legislation had a significant improvement in sulphur emissions, but a trade-off is observed for the carbon dioxide emissions.

10.5.4 Competitive modes considered

The port of Klaipeda is only connected to Kiel via the DFDS link. While there are certain ferries that sail along the north of Poland and Germany, the main competitor for this route is the fully landbased options. Therefore, a binary logit model is used for this Route, where the road transport costs and times are taken from the RoRoSECA network model.

10.5.5 Baseline scenario and model calibration

Table 29 summarizes the baseline scenario used in the calibration stage. The market shares are provided as ranges based on Eurostat estimates. The calibration is conducted and the value of the dispersion parameter λ is provided, showing the effects of the sensitivity analysis on initial market shares, cargo values, and depreciation rate of cargo.

Table 29: The baseline case and the calibration results

<table>
<tr><td rowspan="2"></td><td colspan="6">Klaipeda – Kiel</td></tr>
<tr><td colspan="3">Via DFDS</td><td colspan="3">Road only</td></tr>
<tr><td rowspan="2">Baseline (2014)</td><td>Share (%)</td><td>Road Distance (km)</td><td>Total time (hr)</td><td>Share (%)</td><td>Road Distance (km)</td><td>Total time (hr)</td></tr>
<tr><td>51-61</td><td>100-300</td><td>28 ±2</td><td>39-49</td><td>1600±200</td><td>21±2</td></tr>
<tr><td>Dispersion parameter</td><td colspan="3">Average</td><td colspan="3">Interquartile Range</td></tr>
<tr><td>λ
(Maritime-Land)</td><td colspan="3">0.0189</td><td colspan="3">0.0038:0.0164</td></tr>
</table>

The value of λ is smaller than in other cases indicating that with the underlying assumptions a change in the generalized cost of one option will not trigger an overwhelming modal shift. This shows that the route is expected to be less affected by the regulation and the potential increase in freight rates. This expectation agrees with the fact that the bunker fuel costs as part of the operating costs are smaller in comparison to other routes. As a result, the route is more robust not only from a potential threat on modal shifts, but also because of the lesser increase in total operating costs a potential increase in fuel prices will trigger.

10.5.6 New freight and passenger rates due to fuel prices

The revenue structure of this route is based on three key characteristics:

- Transported freight (79.03% of 2015 revenue)
- Number of passengers (17.28%)
- On-board revenue from passenger activity (3.69%)

The previous numbers suggest that essentially the performance of this route mainly depends on the cargo transported.

10.5.7 Results of simulation

The simulation was performed for a range of inputs including variations on: dispersion parameters (as produced by the calibration), road distances for each maritime option, new freight rate for landbased options, cargo values, and depreciation rate. The results are summarized in Table 30.

Table 30: Modal shifts for Klaipeda - Kiel

	Klaipeda Kiel			
	New Shares			
	Via DFDS		Road only	
	Average	IQ range	Average	IQ range
	Fuel Case 1			
% change	-0.29	-0.08:-0.29	0.29	0.08:0.29
% average difference	-0.62		+0.55	
	Fuel Case 2			
% change	0.93	0.18:0.96	-0.93	-0.18:-0.96
% difference	+2.12		-1.65	
	Fuel Case 3			
% change	-0.73	-0.16:-0.64	0.73	0.16:0.64
% difference	-1.56		+1.31	

The results show that with the actual fuel prices, DFDS was expected to see a drop of 0.62% in its cargo volumes transported, or lose 0.3% of the total transport demand in the simulated scenarios. This finding is less than the actual transport volumes lost, but it should be noted that there is no information on the overall transport demand across the two years. However, it is clear that the modal split model predicts a drop in the probability of choosing the maritime link for most scenarios as seen from the interquartile range. Fuel Case 2 (HFO prices 2015) shows that if the regulation had not been in place, DFDS would be expected to increase its transported cargo. Thus, while this route is more robust it has also been negatively affected by the regulation’s presence. For Fuel Case 3, the predicted loss is more significant but still not an extreme number as in other routes. Therefore, the route is considered relatively robust compared to other routes examined for even a high price scenario..

10.5.8 Discussion on risk

Despite the reduction of the transported volume, the reduction of operating costs is significant due to the lower fuel prices so the performance of the route is not threatened currently. It has been shown earlier that this route is more robust, and therefore a potential increase in the fuel prices may trigger a bigger loss of cargo, however due to the non-existent competition from other maritime services the route is not at risk. This is additionally influenced from the closure of certain other routes in the Baltic (e.g. Klaipeda – Travemünde) which shows that there is an overall decline in the area.

10.6 Klaipeda – Karlshamn

The Klaipeda – Karlshamn route is interesting as it is the route facing the least competition from road transport. Due to its geography, it is expected that this route will be more robust in comparison to other DFDS routes to the impacts of the new SECA sulphur limits. The Klaipeda port is not served by any other ferry companies, and the alternative options include short ferry services that also require long road distance legs.

10.6.1 Fleet deployed

In the examined period, mainly 4 different vessels had been deployed, the same as in the Klaipeda Kiel, with an additional vessel deployed (Kaunas Seaways) for a period of two months, and Sirena Seaways for 1 month. At any given month two vessels were deployed. The smaller vessel of the four (Optima Seaways) was planned to be deployed throughout 2016. This may be attributed to the overall smaller transport demand noticed in this route, as well as a potential increased transport demand in the Klaipeda – Kiel route in 2016. The technical specifications of the main 4 vessels used in the examined period were shown in section 10.5.1, while the details of Sirena Seaways are shown in section 10.8.2 (the route Esbjerg – Harwich which was the main route on which Sirena was deployed). Table 31 provides the information for the Kaunas Seaways vessel.

Table 31: Other vessel in Klaipeda - Karlshamn

Vessel	SO_x abatement	Months deployed in Route	Built or Retrofit Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity	
						Lane-meters	Passengers
Kaunas Seaways 	MGO	2	1994	16.5	10600	1539	262

10.6.2 Statistics on deployment and utilization

Given the utilization capacity provided by DFDS in the examined period, and the vessel deployment (number of voyages per month), it is possible to compare the deployed capacity of the two years, and draw some conclusions on the actual transported volumes of cargo, as well as the passenger traffic. The deployed capacity of DFDS in the Klaipeda – Karlshamn route per month is summarized in Figure 55.

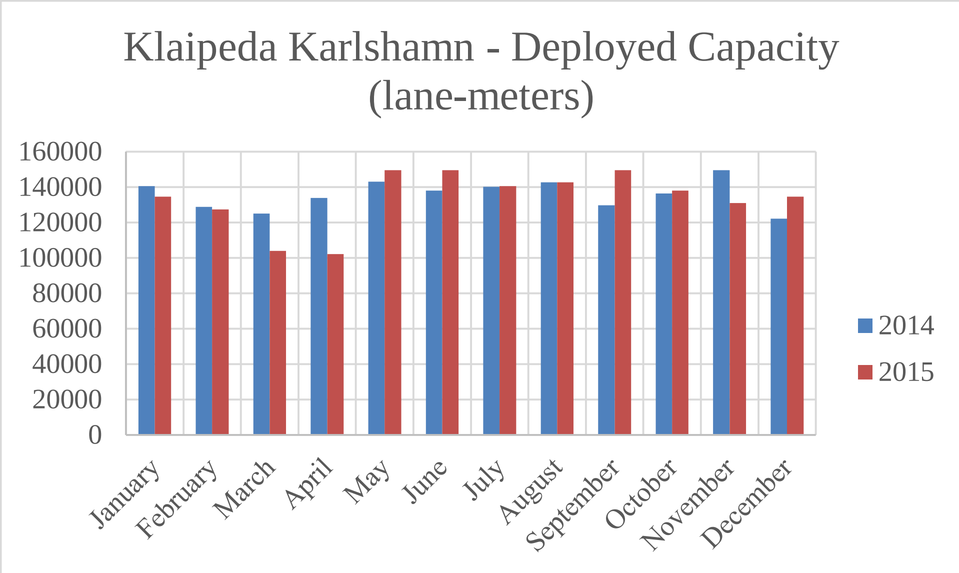


Figure 55: The deployed capacity per month for Klaipeda – Karlshamn

A mixed situation is observed with some months seeing increased deployment in 2015 and others reduced. However, the picture is clearer on aggregated annual levels seen in Figure 56.

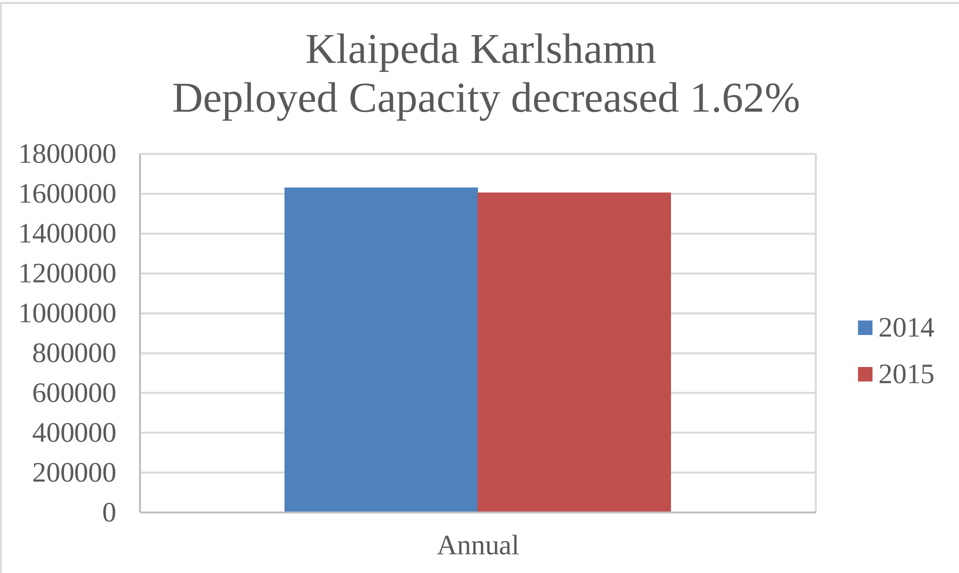


Figure 56: Deployed Capacity for Klaipeda – Karlshamn

A small decrease of 1.62% is observed in the overall deployed capacity in lane-meters for the route. The number of trips practically remained the same (minor decrease of 0.98%; 717 to 710). The change in actual transported volume is shown in Figure 57.

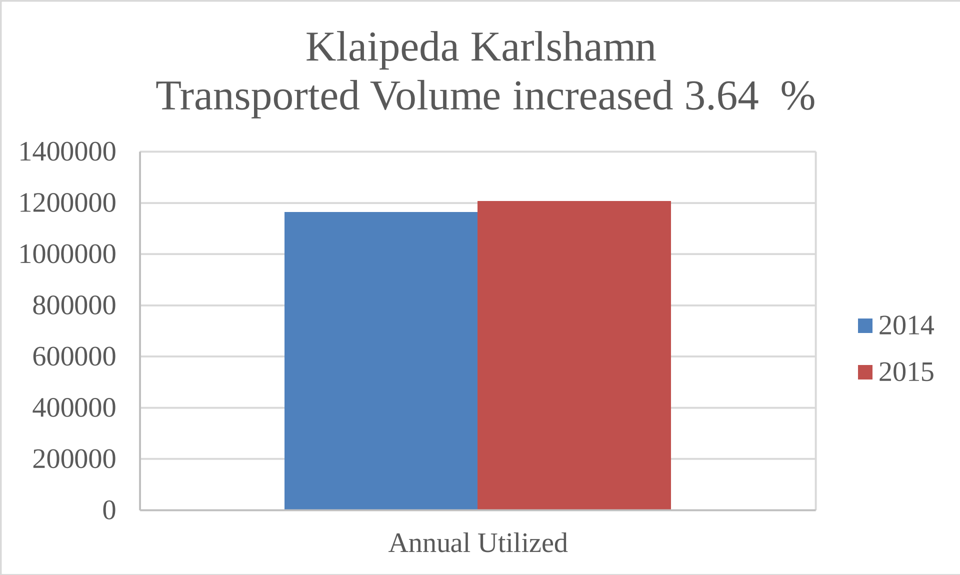


Figure 57: Transported Volume for Klaipeda – Kiel

A notable increase in actual transported volumes of 3.64% is observed. Therefore, despite the fact that smaller vessels were essentially assigned, due to the significant increase in utilization factors the route has increased the amounts of cargo transported. This may also explain the changes in transported volumes of the Klaipeda – Kiel route, as essentially the two routes were using the same pool of vessels.

The number of trips and the change in utilization rates for the examined period on the Klaipeda – Karlshamn route are summarized in Table 32.

Table 32: Klaipeda – Karlshamn comparison between 2014-2015

Year	HFO price ($/ton)	Trips Total	Utilization Rate (%)	Transported Volume change	Rate change (%)		Pax change (%)	Revenue (%)
					Cargo	Pax		
2014	533	717	xx	NA	13.75	0.23	11.48	NA
2015	263	710	xx	3.64	-2.32	6.45	6.15	3.73

It can be observed that the revenue generating performance of this route has increased in similar levels as the transported volume, despite the small decrease in cargo freight rates. It is noteworthy that the numbers of passengers also increased, despite the increase in passenger fare rates. DFDS did not provide information on what proportion of the operating costs were due to fuel costs, but as the same pool of vessels as the Klaipeda – Kiel route were used, it can be presumed that a similar operating cost structure is present.

10.6.3 Environmental performance of Route

The total fuel consumption per quarter for the two years in the Klaipeda – Karlshamn route is presented in Figure 58.

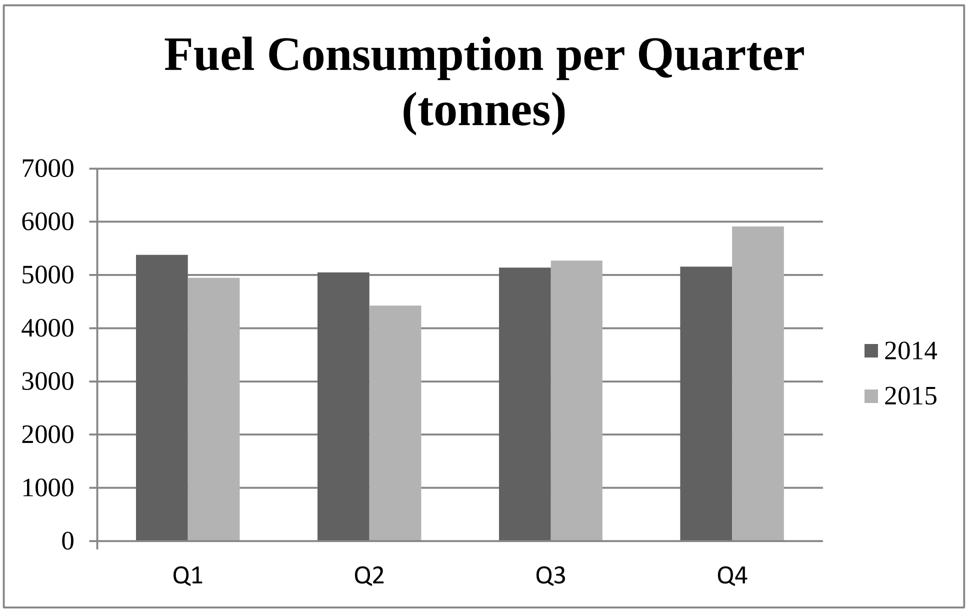


Figure 58: Fuel consumption per quarter in Klaipeda – Karlshamn

The first two quarters a decrease in fuel consumption is observed, and the picture is reversed in the last two quarters of each year in the comparison period. The next barcharts compare the carbon and sulphur emissions based on the fuel consumption as reported by DFDS on the Klaipeda – Karlshamn, in terms of emissions per lane meter.

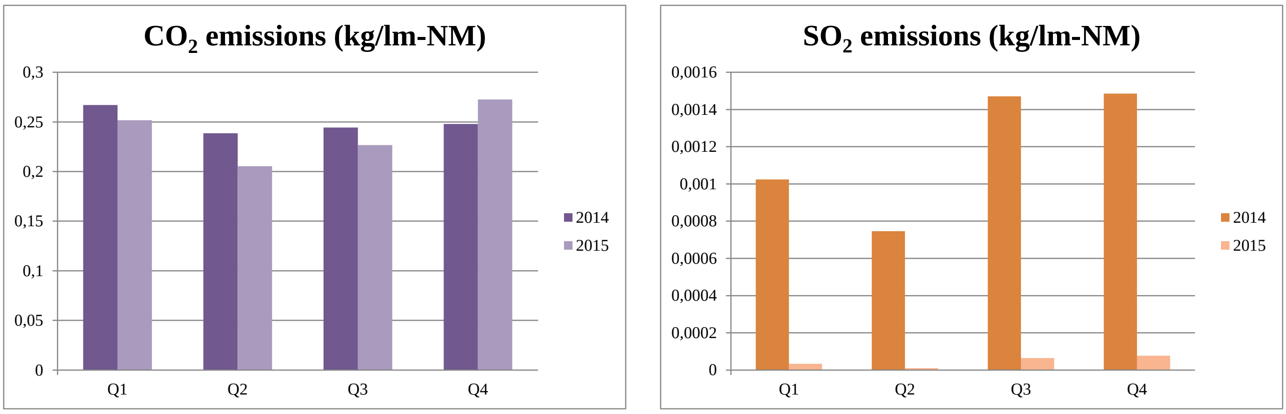


Figure 59: Emissions (kg) per lane meter for CO_2 and SO_2

The results show that the CO_2 emissions per lane meter are lower than the Klaipeda – Kiel, which is expected due to the lower fuel consumption observed. Comparing within the route for both years, it seems that for the first three quarters the environmental efficiency had improved, but not in the last one. The vessels were sailing at improved utilization rates in 2015, which counters the expected increase in fuel consumption due to the recent retrofit of two of the vessels with scrubbers, and the higher emission factor for the vessels that switched to MGO. In terms of sulphur emissions, these are reduced for all scenarios and are considerably lower as a repercussion of the lower sulphur limit and the late installation of scrubbers for most of the vessels in the route.

10.6.4 Competitive modes considered

The port of Klaipeda is only connected to Karlshamn via the DFDS link. A fully land

based option is not considered a reasonable alternative, as the total distance from port to port is would be 1076 km and a ferry crossing of 166NM (Nynäshamn to Ventspils) or an even greater driving distance of 1756 km and a ferry from Rostock to Gelder. For illustrative purposes as competitor the Stena service from Gdynia to Karlskrona will be considered (168 NM maritime leg, crossing time of approximately 11 hours. Therefore, a binary logit model is used for this Route, where the road transport costs and times are taken from the RoRoSECA network model.

10.6.5 Baseline scenario and model calibration

Table 33 summarizes the baseline scenario used in the calibration stage. The market shares are provided as ranges based on Eurostat estimates. The calibration is conducted and the value of the dispersion parameter λ is provided, showing the effects of the sensitivity analysis on initial market shares, cargo values, and depreciation rate of cargo.

Table 33: The baseline case and the calibration results

	Klaipeda – Karlshamn					
	Via DFDS			Stena		
Baseline (2014)	Share (%)	Road Distance (km)	Total time (hr)	Share (%)	Road Distance (km)	Total time (hr)
	67-77	100±50	13±3	23-33	200±100	11±6
Dispersion parameter	Average			Interquartile Range		
λ (Maritime-Land)	0.08			0.075:0.09		

The value of λ is larger than in other cases indicating that with the underlying assumptions a change in the generalized cost of one option could trigger a more significant modal change. As a result, the route is robust mainly due to the lack of competition from other modes, but if a new service was introduced that had similar travel times then a change in freight rates could lead to important shifts.

10.6.6 New freight and passenger rates due to fuel prices

The revenue structure of this route is based on three key characteristics:

- Transported freight (79.0% of 2015 revenue)
- Number of passengers (17.3%)
- On-board revenue from passenger activity (3.7%)

The previous numbers suggest that essentially the performance of this route mainly depends on the cargo transported, but passenger revenue was also important especially following the increase in fares in 2015.

10.6.7 Results of simulation

The simulation was performed for a range of inputs including variations on: dispersion parameters (as produced by the calibration), road distances for each maritime option, new freight rate for landbased options, cargo values, and depreciation rate. The results are summarized in Table 34.

Table 34: Modal shifts for Klaipeda - Karlshamn

	Klaipeda - Karlshamn			
	New Shares			
	Via DFDS		Road only	
	Average	IQ range	Average	IQ range
	Fuel Case 1			
% change	1.12	1.14:1.26	-1.12	-1.14:-1.26
% average difference	1.64		-3.57	
	Fuel Case 2			
% change	2.76	2.75:3.12	-2.76	-2.75:-3.12
% difference	5.85		-14.14	
	Fuel Case 3			
% change	-4.12	-3.94:-4.54	4.12	3.94:4.54
% difference	-3.98		9.09	

The results show that with the actual fuel prices, DFDS was expected to see an increase of 1.64% in its cargo volumes transported, or in other words capture an additional1.12% of the overall transport demand in the scenario. This finding is in agreement with the actual change in transported volumes as reported by DFDS (3.64% vs 1.64%) if the fact that the simulation is performed on average cargo values, and no information was provided on the cargo mixture transported. For Fuel Case 2 (HFO prices 2015) shows that if the regulation had not been in place, DFDS would be expected to increase its transported cargo. The predicted increase is reaching a modal shift of 2.76% of the overall transport. This is the average assuming a smaller reduction in the fares of the competitive link. In addition, the competitive option is assumed to use a lengthier road segment which is less affected by the change in bunker prices. Thus, while this route is more robust it has also been negatively affected by the regulation's presence. For Fuel Case 3, a loss of 4.12% of the overall transport demand is predicted. This is assuming a smaller change in the freight rates of the competitive service, which may not be realistic for similar sea links. However, the results presented in this case study were based on a worst case assumption to illustrate the potential negative effects of the new limit.

10.6.8 Discussion on risk

Despite the reduction of the deployed capacity, the route has increased its transported volume, while at the same time operating costs are lower despite the use of MGO, due to the low fuel prices. As with the Klaipeda Kiel route, this service is very robust due to the low competition from fully landbased modes, and the scarcity of alternative maritime routes. Therefore a potential increase in the fuel prices is not expected to threaten the viability of the service.

10.7 Dover – Calais

The Dover – Calais is of particular interest as it is the route with the highest frequency of service and the smallest sailing distance. The route is directly competing with Eurotunnel which is essentially a landbased mode, and very similar transport costs and times are observed between the two. Until 2014 there had been more ferry services in this route, however certain operators went bankrupt and in addition there have been major disruptions occurring in early 2015. Overall, this route has been severely affected by external events, and not only by the lower sulphur limits.

10.7.1 Fleet deployed

In the examined period, there have been several changes in the fleet deployment in terms of both number of vessels and the specific vessels deployed at any given time. From January 2014 until November two Ro-Pax vessels were deployed. From December 2014 until March 2015 (inclusive) only one vessel was serving the route from DFDS. The two-vessel service was restored after this period, and there were plans of increasing the vessels to three in 2016 following the shutting down of the myferrylink ferries service. Throughout the examined period vessels relying on low-sulphur fuel were deployed, though it is noteworthy that in 2016 DFDS is operating two scrubber-equipped vessels. The technical specifications of the 3 vessels used in the examined period are summarized in Table 35:

Table 35: Deployed vessels in Gothenburg - Ghent

Vessel	SO_x abatement	Months deployed in Route	Built or Retrofit Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity	
						Lane-meters	Passengers
Malo Seaways 	Low sulphur	9	2000	25	39600	1950	405
Calais Seaways 	Low sulphur	24	1990	21	21120	1784	2000
Dieppe Seaways 	Low sulphur	11	2007	23.5	24000	2490	600

10.7.2 Statistics on deployment and utilization

Given the utilization capacity provided by DFDS in the examined period, and the vessel deployment (number of voyages per month), it is possible to compare the deployed capacity of the two years, and draw some conclusions on the actual transported volumes of cargo, as well as the passenger traffic. The deployed capacity of DFDS in the Klaipeda – Kiel route per month is summarized in Figure 60.

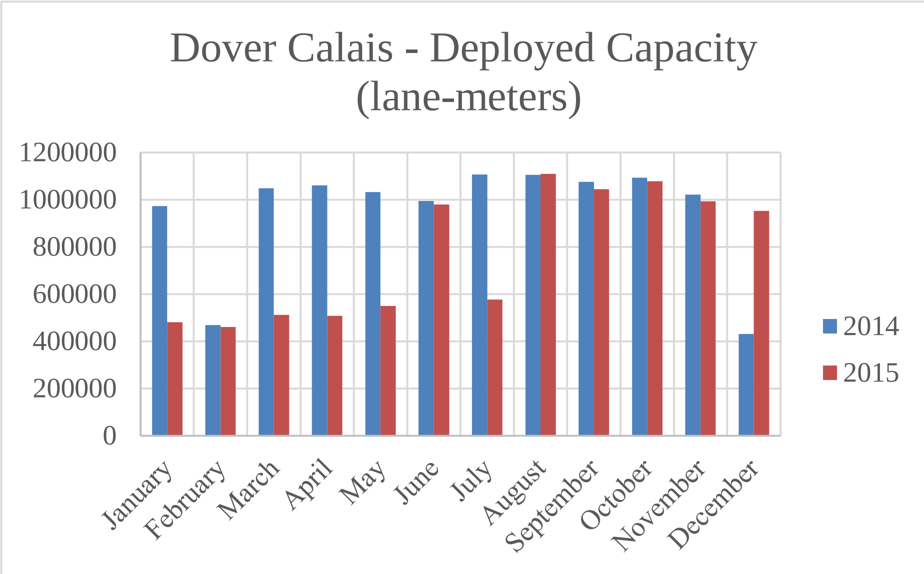


Figure 60: The deployed capacity per month for Dover – Calais

It can be seen that for most months the deployed capacity was reduced in comparison to 2014. This is particularly evident in the period between January and May, when the situation with the refugee crisis and a number of strikes (early 2015) affected the number of sailings per day. The reduced trend (with the exception of December) is evident in the aggregated annual deployed capacity shown in Figure 61.

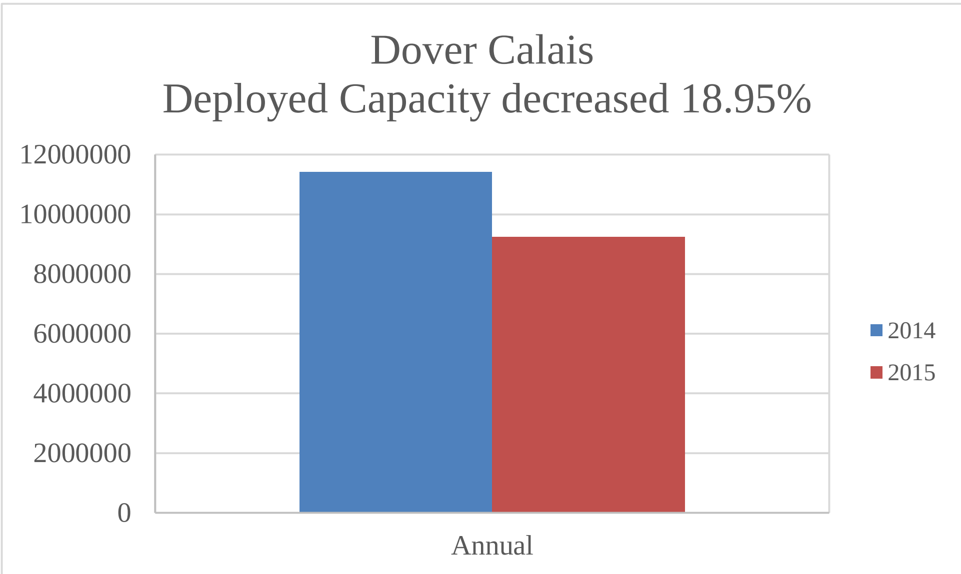


Figure 61: Deployed Capacity for Dover – Calais

A very significant decrease of 18.95% is observed in the overall deployed capacity in lane-meters for the route. The number of trips also drastically dropped (decrease of 19.58%; 6210 to 4994). The change in actual transported volume is shown in Figure 62.

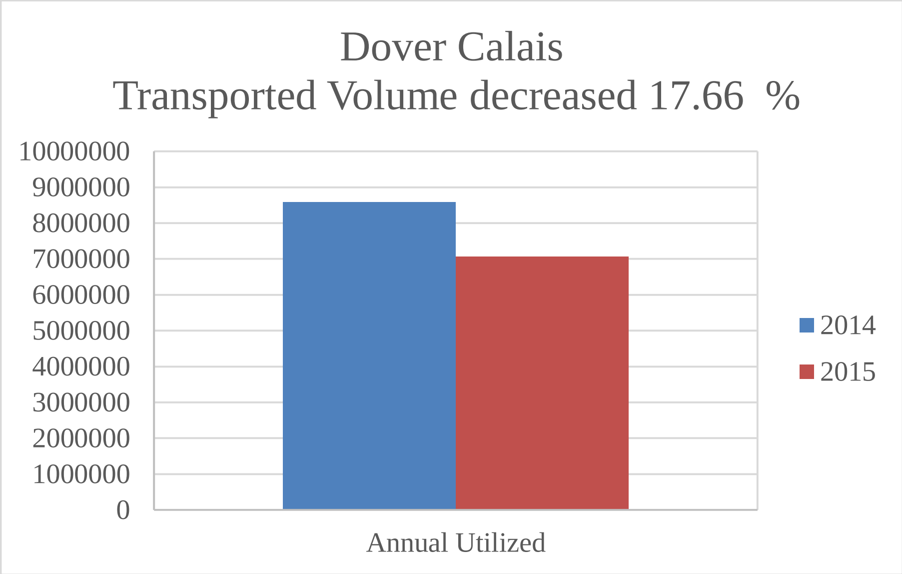


Figure 62: Transported Volume for Dover – Calais

It can be seen that the utilized capacity has increased as the transported volume has decreased at a smaller rate than the deployed capacity. This shows again an improved vessel deployment despite the fact of a lesser transport demand for freight between the two ports.

The number of trips and the change in utilization rates for the examined period on the Dover – Calais route are summarized in Table 36.

Table 36: Dover – Calais comparison between 2014-2015

Year	Fuel price ($/ton)		Trips Total	Utilization Rate (%)	Transported Volume change	Rate change (%)		Pax change (%)	Revenue (%)
	HFO	MGO				Cargo	Pax		
2014	533	816	6210	xx	NA	1.79	11.76	1.57	NA
2015	263	478	4994	x	-4.644	9.36	22.1	-28.65	-18.04

It can be observed that the revenue generating performance of this route has deteriorated significantly. This is a combination of the reduced transported volume of cargo and passengers, despite the fact that fare rates have increased for both passengers and cargo. It is noteworthy that the reduction in passenger numbers is greater than the respective cargo; this can be explained by the higher increase in passenger fare rates compared to cargo fares, as well as due to the external events affecting the route. The operating costs of the route have decreased significantly given that the bunker costs were 23% in 2015 down from 33% in 2014.

10.7.3 Environmental performance of Route

The total fuel consumption per quarter for the two years in the Dover – Calais route is presented in Figure 63.

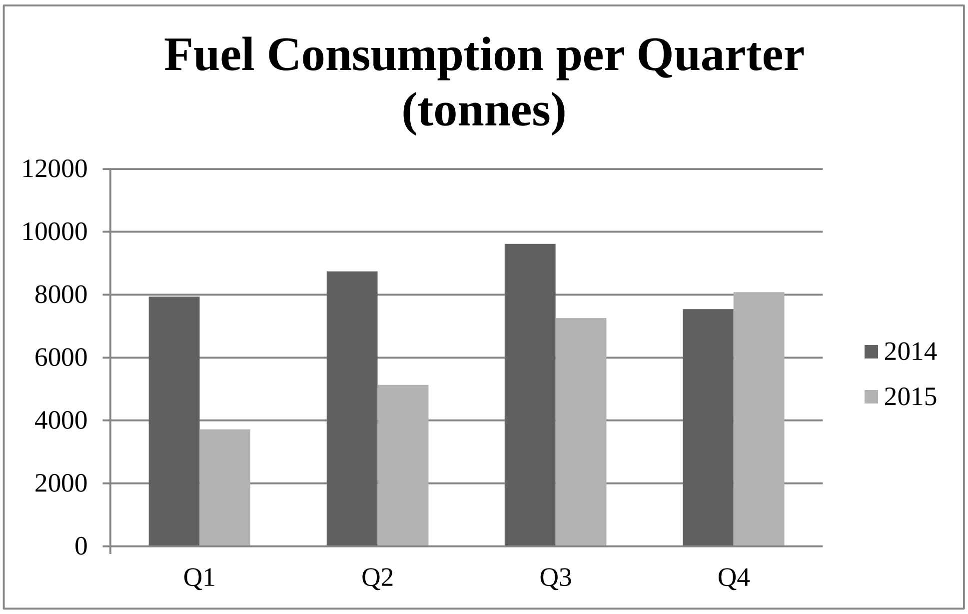
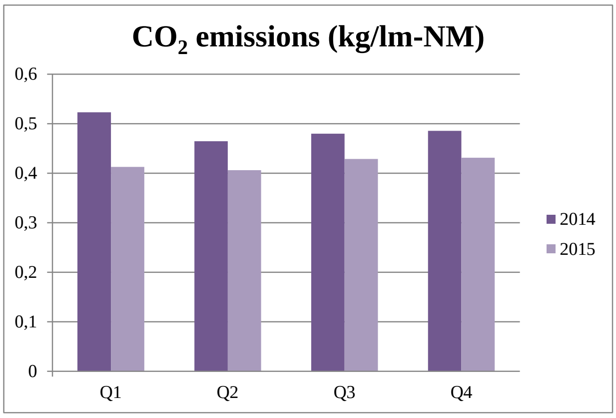


Figure 63: Fuel consumption per quarter in Dover – Calais

The change in fuel consumption follows the change in deployment which was far lesser in the first two quarters of 2015. The next barcharts compare the carbon and sulphur emissions based on the fuel consumption as reported by DFDS on the Dover – Calais service, in terms of emissions per lane meter.



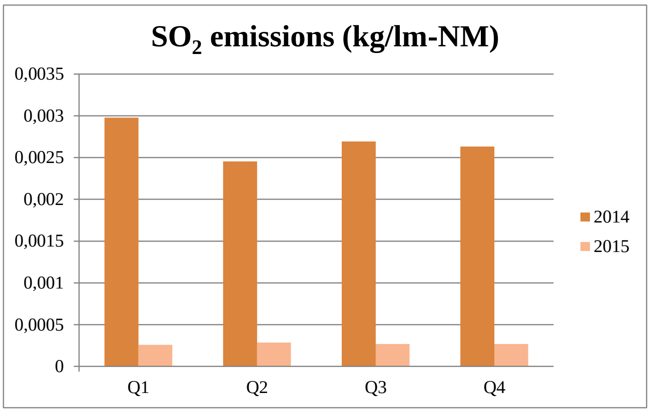


Figure 64: Emissions (kg/lm-NM) for CO_2 and SO_2

The results show that the CO_2 emissions per lane meter have decreased in comparison with 2014. This can be partly attributed to the improved utilization rate per vessel, as well as to a potential change in sailing speed due to the external effects on the route, and the deployment of a low-powered vessel in the months where only one vessel was deployed (Calais Seaways). In terms of sulphur emissions, these are reduced for all scenarios and are considerably lower as a repercussion of the lower sulphur limit and the use of MGO for all machinery. This shows that for this particular route the legislation had a significant improvement in sulphur emissions. It will be interesting to continue this analysis in year 2 of the project as scrubber-equipped vessels are currently deployed in the service (since January 2016).

10.7.4 Competitive modes considered

As stated earlier the competition DFDS is facing in the Dover-Calais route is mainly from Eurotunnel. In recent years, there were also services from P&O ferries and Myferrylink. The latter was operating under lease from Eurotunnel which was not renewed. Figure 65 summarizes the transported volume (in trailers) as reported in the Shippax CFI journal for 2014 and 2015.[8]

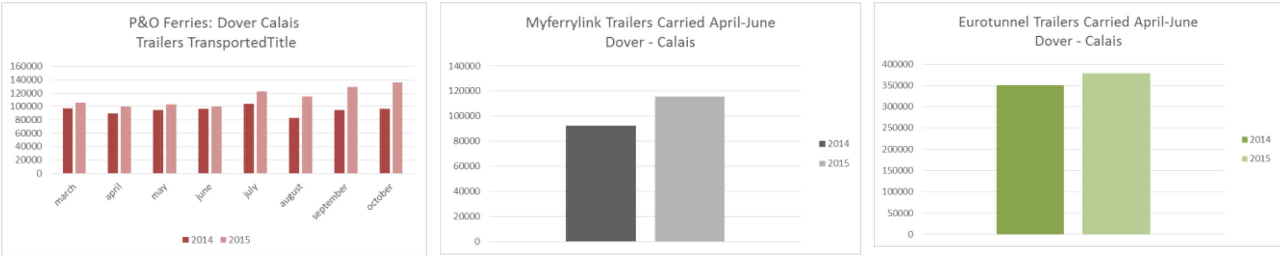


Figure 65: Trailer throughput for alternative Cross-Channel crossings

For all competitive services it is clear that there has been an increase in the number of transported trailers. This indicates an overall increase in transport demand between the UK and Europe. However, the DFDS statistics are showing a decline in overall transported volumes which further complicates the analysis of this route. For this reason, the ensuing analysis is based on what was expected to happen on DFDS based on the new freight rates charged in 2015, and what would have happened for different fuel price scenarios. The comparison is made between DFDS and Eurotunnel in a binary structure to simplify the analysis for this route.

10.7.5 Baseline scenario and model calibration

Table 37 summarizes the baseline scenario used in the calibration stage. The market shares are provided as ranges based on the throughput of trailers provided by Shippax CFI and using interpolation for missing data, and aggregating over maritime transport demand for the other ferries. This is a rather crude assumption, but due to the external events affecting the route this case study is predominantly conceptual to illustrate the effects of the regulation. Further work will be conducted in Year 2 of the project when data on 2016 will become available (as the situation is smoothed). The calibration is conducted and the value of the dispersion parameter λ is provided, showing the effects of the sensitivity analysis on initial market shares, cargo values, and depreciation rate of cargo. The road distance for both modes is deliberately considered very small, as it is assumed that both modes are heavily competing to each other, and as a result the driving distance from origin to port of departure, and from port of arrival to final destination is the same for both.

[8] The available data as presented in the journal. For Eurotunnel and Myferrylink only information for the second quarter was available (April-June)

Table 37: The baseline case and the calibration results

<table>
<tr><td rowspan="2"></td><td colspan="6">Dover – Calais</td></tr>
<tr><td colspan="3">Via DFDS</td><td colspan="3">Eurotunnel</td></tr>
<tr><td rowspan="2">Baseline (2014)</td><td>Share (%)</td><td>Road Distance (km)</td><td>Total time (hr)</td><td>Share (%)</td><td>Road Distance (km)</td><td>Total time (hr)</td></tr>
<tr><td>39-49</td><td>10</td><td>3±0.5</td><td>51-61</td><td>10</td><td>2±1</td></tr>
<tr><td>Dispersion parameter</td><td colspan="3">Average</td><td colspan="3">Interquartile Range</td></tr>
<tr><td>λ (Maritime-Land)</td><td colspan="3">0.015</td><td colspan="3">0.01-0.02</td></tr>
</table>

The value of λ is indicating that with the underlying assumptions a change in the generalized cost of one option will trigger a significant modal shift. This conclusion agrees with the findings of the RoRoSECA network model, and it is also validated from the very competitive freight rates between the different available options to the shippers. This shows that the route is expected to be affected by the regulation when compared to Eurotunnel, and a significant increase in fuel prices could result in the company increasing freight rates and losing cargoes, or increased operating costs in an effort to internalize the bunker surcharges.

The bunker fuel costs as part of the operating costs are considerable in comparison to other routes. As a result, the route is robust mainly due to the nature of trade and the overall high demand of transport in the cross-channel routes; however the lower sulphur limits could result in modal shifts towards rail.

10.7.6 New freight and passenger rates due to fuel prices

The revenue structure of this route is based on three key characteristics:

- Transported freight (74.8% of 2015 revenue)
- Number of passengers (17.2%)
- On-board revenue from passenger activity (8%)

The previous numbers suggest that the performance of this route mainly depends on the cargo transported.

10.7.7 Results of simulation

The simulation was performed for a range of inputs including variations on: dispersion parameters (as produced by the calibration), road distances for each maritime option, new freight rate for Eurotunnel, cargo values, and depreciation rate. The results are summarized in Table 38.

Table 38: Modal shifts for Dover - Calais

	Dover Calais			
	New Shares			
	Via DFDS		Eurotunnel	
	Average	IQ range	Average	IQ range
	Fuel Case 1			
% change	-4.8	-3.3:-8.3	4.8	3.3:8.3
% average difference	-8.95		10.78	
	Fuel Case 2			
% change	-3.6	-1.7:-6.9	3.6	1.7:6.9
% difference	-6.91		7.81	
	Fuel Case 3			
% change	-5.3	-3.6:-9.1	5.3	3.6:9.1
% difference	-9.74		11.71	

The results show that with the actual fuel prices, DFDS was expected to see a drop of 6.91% in its cargo volumes transported, or lose 3.6% of the total transport demand in the simulated scenarios. This finding is less than the actual transport volumes lost, but as stated earlier this route was under the influence of various external factors that greatly reduce the frequency of service offered by DFDS. It is clear that the modal split model predicts a drop in the probability of choosing the maritime link for most scenarios as seen from the interquartile ranges. For Fuel Case 2, the predicted loss is less significant as it is expected, due to the lower fuel costs that would have been enjoyed from the MGO prices. This loss of market is expected to be more significant if fuel prices return to the 2014 levels for MGO. However, considering the pricing policy of DFDS the freight rates would have increased in comparison to Eurotunnel. This is a conceptual result, as more information is required on the pricing strategies of the two alternatives.

10.7.8 Discussion on risk

The great reduction of the transported volume is a consequence of the turbulent start of the year 2015 and is not related to the new sulphur limit, as the volumes have increased ever since. The reduction of operating costs is significant due to the lower fuel prices (even though MGO is used) so the performance of the route is not threatened. Coupled with the fact that one of the main maritime competitors has been shut-down, this route is not at risk. The modus operandi of the Dover-Calais ferry routes has been in the context of receiving the trailers that Eurotunnel cannot serve with the rail service. The service is considered robust; however it is interesting for additional analysis in case fuel prices increase significantly, as it allows the consideration of many operating measures to counter the potential increased operating costs.

10.8 Miscellaneous Routes

As stated in the report on the outcome of Task 2.1, the RoRoSECA project would also examine two additional routes of DFDS. These are the Marseille – Tunis route which is the only route not affected by the regulation, and the Esbjerg – Harwich route that was shut down in the end of 2014, just before the regulation.

10.8.1 Marseille – Tunis

Two Ro-Ro ferries sail on this service, with three sailings per week in each direction. The duration of the voyage is between 34 and 36 hours, with a total distance of 472 NM. The vessel specifications are shown in Table 39.

Table 39: The specifications of vessels deployed in Marseille-Tunis

Vessel	SO_x abatement	Months deployed in Route	Built or Retrofit Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity	
						Lane-meters	Passengers
Ark Futura 	MGO at berth in Marseille	24	1996	18.5	11120	2308	12
Beachy Head 	MGO at berth in Marseille	24	2003	21	12600	2606	12

In previous years, there was a Ro-Pax service from SCNM (Société Nationale Maritime Corse Méditerranée) operating the route, but the company went bankrupt in 2014 and was rebranded to Maritime Ferries in 2016. Shippax provides data on the transported passengers and cars from SCNM, but does not provide information on the DFDS volumes. DFDS has provided aggregate yearly statistics for the route which are summarized in Table 40.

Table 40: The effects of the low fuel price on the Marseille – Tunis route

Year	HFO price ($/ton)	Trips Total	Utilization Rate (%)	Transported Volume change	Freight Rate change	Revenue change
2014	533	284	xx	NA	+2.38%	NA
2015	263	298	xx	+5.44%	-3.61%	+1.64%

It can easily be seen that this route is very positively affected by the low fuel prices. In 2015 the freight rates were reduced by 3.6% (whereas in 2014 they increased by 2.38% from 2014 fares), which triggered an increase of 5.44% in the transported lane-meters. DFDS increased the deployment by 4.92% (more trips), which is slightly lower than the increase in transported volume. Essentially, the fleet deployment also marginally improved as seen from the Utilization rate achieved. The revenue generated in the route increased by 1.64% as a consequence of the increase in volumes transported (despite the lower freight rate). The fuel costs however decreased substantially due to the much lower price. Information on what percentage of the overall operating costs are attributed to fuel costs were not provided by DFDS for this route.

The Marseille – Tunis route is practically unrivalled from land based modes, and it does not compete with the Ro-Pax services that still operate. Therefore, there is no reason to perform a modal split calibration for this route. However, certain conclusions can be drawn from this route as it is the only service not affected by the regulation. The very positive effects noted from the ship operators perspective (better than in the SECA affected routes), clearly show that the very low fuel prices have benefited the ship operator greatly. This illustrates that the Ro-Ro sector that has been affected by the SECA lower limits, cannot capitalize completely on the lower bunker prices. This particular route, will not be affected even in the case of an increase in fuel prices as it will still rely on HFO unless the Mediterranean Sea is designated as a new SECA zone. The picture may change post-2020 when the global cap will be reduced to 0.5%, but due to the low competition with landbased modes this route should not be at risk. It will still serve as a good benchmarking instance with the seven selected routes, in year 2 of the project and the examination of potential mitigation measures.

10.8.2 Esbjerg - Harwich

The Esbjerg-Harwich route was the only remaining Ro-Pax service linking the United Kingdom with Scandinavia. A historic route for DFDS which had been in operation for 140 years, was shut down in September 2014 in anticipation of the increased operating costs in the post January 2015 SECA limits. However, the route was struggling financially for a long period. Sirena Seaways was the last vessel deployed in this service (based on DFDS deployment information, from at least January 2013) and at the time was running on HFO switching to MGO while at berth. The technical specifications of Sirena Seaways are shown in Table 41.

Table 41: The specifications of the last vessel deployed in Esbjerg - Harwich

Vessel	SO_x abatement	Built or Retrofit Year	Cruising Speed (knots)	Engine Output (kW)	Vessel Capacity	
					Lane-meters	Passengers
Sirena Seaways 	MGO at berth in Esbjerg, Harwich. Scrubber retrofit in 2015 (post closure)	2002	23	18900	2056	610

The service was not in direct competition with other Ro-Pax services. There was a recent debate on the referendum of the United Kingdom on staying in the European Union, and pro-Brexit campaigners used the shutting down of the last remaining service connecting the UK with Scandinavia as an argument against EU membership. The service however was in competition for passengers with other modes (air transport, road) and was not performing well in the last years. DFDS noted in its press release[9] announcing the closure that this is due to the sulphur limits, and the loss of cargo to road transport. DFDS additionally noted the increasing competition with airlines, and the loss of tax-free sales rights on-board the route as contributing factors to the decision. At the time of the closure decision, DFDS estimated an additional burden of £2m a year. DFDS suggested the use of Esbjerg - Immingham route for the freight cargo previously using the Esbjerg – Harwich service, and the Newcastle – Amsterdam and cross-channel crossing ferry services for passengers. Data from Shippax were not found for this Route, however Table 42 summarizes the information provided by DFDS on the last 21 months of the service (January 2013 - September 2014).

Table 42: The performance of the Esbjerg-Harwich service that led to its closure

Year	HFO price ($/ton)	Trips Total	Utilization Rate freight (%)	Passengers	Freight Rate change
2013	672	281	45.87%	79161	NA
2014 (9 months)	533	230	52.48%	74086	-0.6%

It can be seen that this route was not performing well in the last two years of its service. The freight utilization capacity was very low in comparison to other DFDS services despite the lack of direct competition with other maritime services. While the drop in fuel prices from 2013 had lowered the operating costs of the route, the freight rates were marginally lower. The utilization rate increased in 2014 for both passengers and freight, but in anticipation of the higher costs due to the SECA regulation, it came as no surprise that the route would be shut down. Despite the fact that the declining trend in fuel prices continued, to the point that MGO in 2015 was cheaper than HFO in 2014, it seems unlikely that the profitability of this route would increase to the point it would be a viable alternative. Therefore, the new sulphur limits may have hastened the shut-down decision, but for this service this seemed as an inevitable fate at the time. The conclusions from this route can be vital in year two of the RoRoSECA project, as they can allow benchmarking the what-if scenarios on possible shutting down on the examined services. While DFDS has not provided actual threshold limits that could be used to decide a service shutdown, the experience of the Harwich-Esbjerg case provides insight that low utilization rates (below the normal 75-85% observed in other services) can be critical.

[9] Source: http://www.dfdsseaways.co.uk/h-about-us/press-centre/Pages/new-sulphur-rules-cause-closure.aspx

11 Conclusions and plan ahead for WP3

This report presented the main activities undertaken in the context of Task 2.2. This section will summarize the novelty of the developed methodology, the first conclusions on the implications of the new sulphur limit on the Ro-Ro sector, and the next steps of the project.

11.1 Contribution of Task 2.2

The modelling framework developed through the RoRoSECA project can be used to explore the repercussions of maritime policy on the freight transportation sector. While there had been attempts at estimating the effects of certain policies on some services, this is the first attempt to examine in detail the effects of the new lower sulphur limits. The main objective of Task 2.2 was the development of a modal split model with suitable extensions on the modal shift models described in Psaraftis and Kontovas (2010) and Panagakos et al. (2013) that were restricted to binary cases. The report presented the programming modules and their capabilities, which improve the previous computational capabilities by:

- Allowing the modelling of more options for shippers
- Performing sensitivity analyses on key parameters influencing choice such as
  - Initial market shares
  - Cargo value
  - Depreciation rate
  - Cost structure
- Enabling the consideration of operating measures such as
  - speed reduction and modelling their implications on modal choice
  - changes in freight surcharges on cargo transported via maritime links
- Dissecting the effects of the low fuel prices observed in 2015 from the impact of the regulation
- Examining what-if scenarios on fuel price that may bear more negative effects on the Ro-Ro market
- Comparing the predicted cargo flows with the observed ones to validate the model

In addition, modules using the outputs of the simulated new market shares are allowing a cost-benefit analysis from the operator's point of view. This allows a system approach where the perspective of all stakeholders is taken into account. The modules allow comparisons of the before-after states for the ship operator, the overall system in terms of emissions, and the market shares for all available options. The main difficulties encountered in the context of Task 2.2 dealt with the quality of available data for the calibration of the modal split models. In reality, there is a vast number of alternatives between any O-D pairs. As a result, given the great uncertainty in obtaining accurate market share data information, the way forward was through simulation of data and through the conduct of sensitivity analyses on percentages for each mode around central values provided by statistical services and discussions with DFDS.

11.2 Main findings

The first conclusion of the first year of the RoRoSECA project is that indeed most services were not affected by the new sulphur limits, and actually improved their performance. In the DFDS case studies, it is evident that the actual volumes of transported goods increased for most routes. At the same time, even for some routes that lost some cargoes (due to marginally fewer sailings), the utilized capacity has increased. However, the main reason the Ro-Ro operators seem to be coping with the new limits is the very low prices of fuel experienced throughout 2015. These prices actually suggest that the investments in scrubbers the years before the new limits were not the optimal decision.

The model runs show conform to the actual case and show small increases in the market shares of the maritime links assuming that the freight rates were lowered more in comparison to landbased modes. This however is shown to pose a risk as should fuel prices increase (as the trends in the first months of 2016 suggest) the situation may reverse. The what-if scenarios using higher MGO prices (as in 2014 levels) revealed that the maritime sector would be shrinking and losing cargoes to landbased modes.

In addition, if the regulation was not in place the fuel prices would be much lower as ships would still use HFO. The what-if analysis on using HFO prices in the 2015 levels showed that the market share of the maritime options would have increased further. Thus, the regulation has reduced the rate at which the maritime sector would have increased cargo volumes transported.

For all simulation scenarios, it is clear that the generalized cost of each option is mainly affected by the freight rates charged. The value of time is important only for very high value cargoes and high depreciation rates. As a result, the option of reducing the sailing speed for a route struggling (if fuel prices increase) is not expected to have a detrimental effect to the shipper's decision. Therefore, in Year 2 of the project such scenarios will be examined thoroughly, taking into account the potential lowering of freight rates as a counter measure to the added travel time (and also as a result of lower fuel costs). Of course these options may not be suitable for services that carry high value cargoes, and it may also be difficult for Ro-Pax services as a very long trip may be seen as undesirable by passengers. This may not be the case for cruise routes, where passengers may consider a longer trip as more desirable. To take into account the passenger's decision criteria, a series of (stated preference) surveys and interviews has to be conducted, but this is outside the scope of the RoRoSECA project.

11.2.1 Expressing emissions per lane-meter to compare Ro-Ro shipping with land-based alternatives

The analysis presented in section 10 considered the emissions generation from the vessels in the examined routes. It has to be noted that these are the emissions as calculated based on the actual fuel consumption. The results were presented in terms of emissions per lane meter, which is only used for illustrative purposes. Particularly for Ro-Pax ferries, it is very difficult to allocate emissions among cargo and passengers, as there is still no standardised way to attribute emissions to passengers. In addition, depending on the types of cargo the weight per lane meter is different, and although the weight of the cargo is not going to have a detrimental effect in the fuel consumption of the vessel the same cannot be said for road transport. As a result, the emissions per lane meter cannot be a very effective way of comparing the different modes. However, the results clearly show the effect of the regulation for what concerns the efficiency per lane meter of the ships. It is shown that for sulphur emissions this has greatly improved (except for some vessels that already had scrubber systems before 2015), and for carbon emissions it depends on the speeds used. The overall conclusion for all routes is that the utilization rate of the vessel has improved, which is also an indicator of improved environmental performance[10].

11.3 The next steps in the RoRoSECA project

The developed modelling framework is enabling a thorough examination of candidate operating, policy, and market measures that may reverse these negative effects. Work Package 2 has been essentially the quantitative backbone of the project. The aspiration was the development of sufficient computational modules that would allow the estimation of modal shifts under different realistic scenarios, and comparing the system's performance with the benchmark case. The first results of the project show that there are indeed important negative effects of the limit on the Ro-Ro sector, even if these have been masked by the very low fuel prices in 2015. In the second year, the tasks in WP3 revolve around the proposal of operating measures and regulatory policies that can mitigate and reverse the negative effects of the new sulphur limits. This is illustrated schematically in Figure 66.

[10] The SHIP DESMO models developed in the context of Task 2.3 provide information on emissions allocation, according to several methods, but this information has not yet been taken into consideration. This will be done in Year 2.

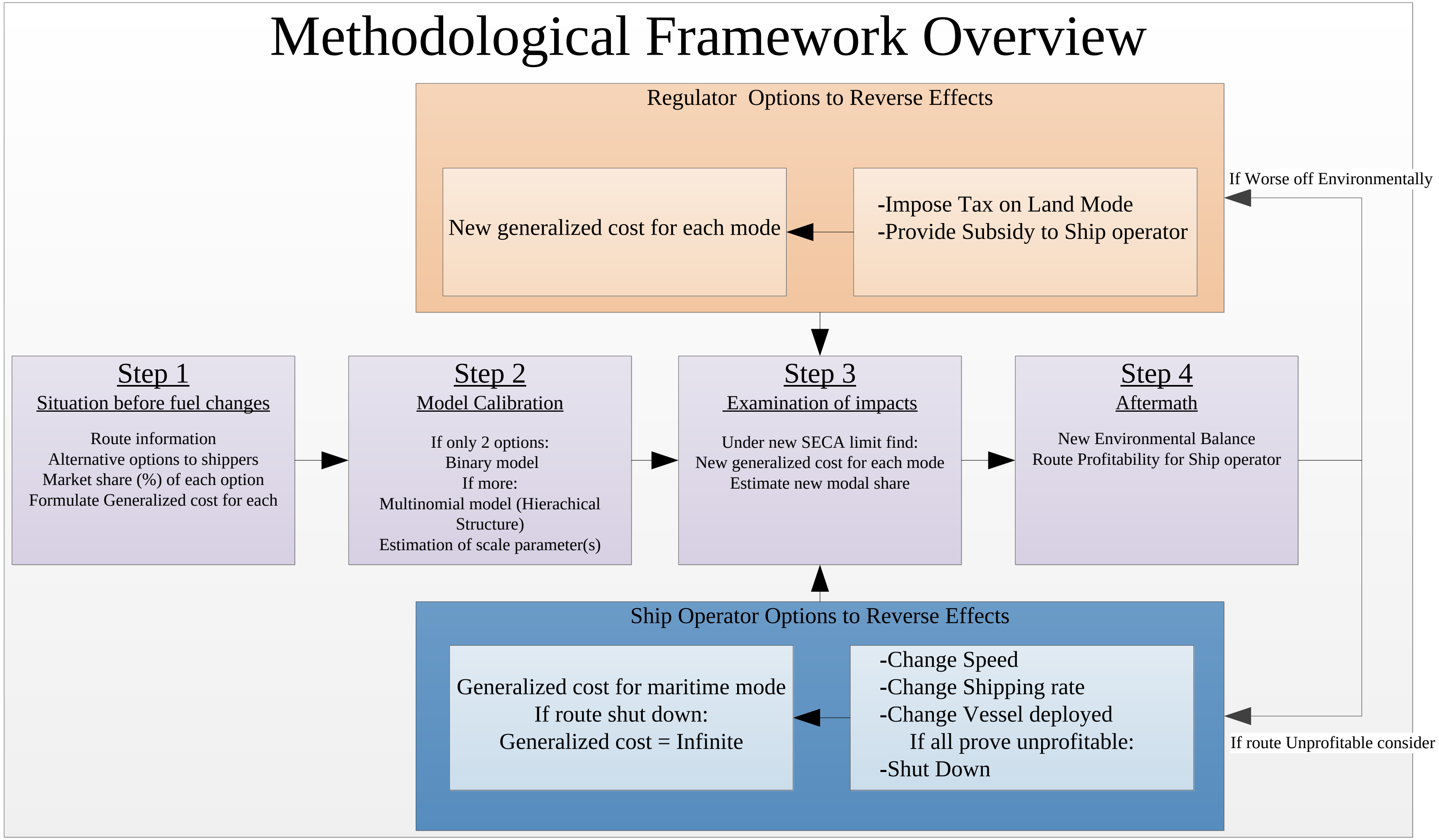


Figure 66: The modellng framework of the RoRoSECA project

Essentially, Task 2.2 considered the first two steps of the process; namely the situation before the fuel changes and the model calibration. However, during the first year of the project the 3rd step (examination of impacts) was also considered, and the computational modules for Step 4 (Aftermath) were developed. These were used to identify the negative impacts of the regulation, which due to the low fuel prices experience, occasionally in the form of missed opportunities to further expand the market shares of the sector. In year 2, a series of measures from the regulator's and the ship operator's perspective will be examined to see whether the negative effects can be reversed. The ship operator measures include the following:

- Speed reduction

This option will increase the sailing time in the maritime leg, and at the same time significantly reduce the fuel costs of the company. In terms of variables affected in the modal split model, speed reduction will affect the generalized travel cost of this option for the shipment. The effects of a discount in the price for shipment will be examined as a means to mitigate a potential modal shift due to the extra travel time.

- Fuel surcharges

This measure may be used to either increase or decrease the surcharge for the Sulphur regulation imposed on shippers. It will directly affect the generalized cost per shipment (see equation 1), and the generated revenue per voyage. The new environmental balance of the system and the new economic balance of the company will be explored.

- Frequency of service

This company policy will affect the travel time experienced by the shipper due to the change in the average waiting time. From the company's perspective, this option may change the capacity of each vessel and therefore make a specific voyage more or less profitable, but changing at the same time the number of voyages performed in a year. This will change the economic balance of the company, and may also lead to a modal shift.

- Invest in new technology

This could be a decision to invest in dual cycle engines capable of using LNG as fuel, or retrofitting a vessel with a scrubber (for vessels that currently run on MGO) and assess whether that will make the route more profitable for the company. In theory, if that decision will not change the price charged per shipment carried and the time of voyage, there will not be a modal shift because of this decision. However, the profitability of the company may change.

The regulatory options will consider:

- Imposing a tax levy on road modes

This option will seek to revert the negative modal shifts by effectively increasing the freight rates for land based modes. This will in-turn increase the generalized cost of the associated option in the modelling stage, and as a result constitute the landbased option less desirable. The implications of a potential lesser demand for transport must also be considered; e.g. if all modes are becoming more expensive perhaps the overall transport demand will also decrease.

- Provision of subsidies for investment costs in green technologies

This measure is similar to the subsidies that were given from the European Commission to help ship operators retrofit their vessels with scrubber systems. A systematic review of alternative technologies that could fall under a similar concept will be conducted, and the implications of such measures in the route profitability of the ship operator will be examined.

- The concept of Eco-Bonus

This measure is based on providing a refund to haulers that are choosing to use a Ro-Ro service and thus reduce their road distance travelled. In terms of the model, this is equivalent to lowering the freight rates of the maritime link by an appropriate percentage which is to be explored. It is noteworthy that there is a similar project on the concept of Eco-Bonus currently co-investigated by partners in a parallel Motorways of the Sea project[11].

- Easing of port dues/fairway dues/ ice dues for relevant shipping

This family of measures will consider the effects of lowering the aforementioned fees for shipping that is affected by the regulation. While these initiatives will not have an effect on the pricing policy that the operators is using to charge the shippers, it may affect the economy of the ship operator and help them reduce the fees due to lower operating costs.

- Full or partial internalization of external costs

Part of the outputs of Task 2.3 is the calculation of the external costs associated with each transport mode available in each scenario. A possible inclusion of the external costs in a ‘the polluter pays’ approach, the developed model will be used to assess its possible impacts. Essentially, the external costs will be an added variable to the formulation of the generalized costs, and it is expected that major modal shifts will be observed depending on the environmental performance of each mode. Considering the importance of utilization capacity in the estimation of emissions generated per lane-meter, such a measure may stimulate improved fleet deployment practices for ship operators and haulers.

- Any additional policy measures recommended by the European Sustainable Shipping Forum (ESSF) and its subgroups

[11] Liaisons with chief investigator from the French Development Ministry have been made, and the RoRoSECA project will be in contact to explore synergies.

This is essentially an open question to examine additional measures that may be recommended by the ESSF.

The finalized list of measures to be examined for each of the Tasks 3.1 and 3.2 will be decided after consultation with the Advisory Committee of the RoRoSECA project.

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