DTU Management Engineering
Department of Management Engineering

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

Project's public final report

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Table of contents

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RoRoSECA project manager
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1 Purpose of this report

The purpose of this report is to describe the results of the project “Mitigating and reversing the effects of environmental legislation on Ro-Ro shipping in Northern Europe”, also known as the RoRoSECA project. The project spanned the period 15/6/2015 to 14/6/2017 and was conducted at DTU, Department of Transport (until 30/4/2016) and Department of Management Engineering (afterwards). The project’s Principal Investigator was Professor Harilaos N. Psaraftis. Major funding for this project was provided by the Danish Maritime Fund, with supplementary funding provided by the Orient’s Fund.

As detailed project results including technical reports, software and other publications are publicly available via the project’s web site[1], this report is by design synoptic and written for the non-specialist.

The rest of this report is organized as follows. Section 2 defines the problem that has been the subject of our investigation. Section 3 describes the RoRoSECA project. Section 4 describes the main results of the project.

2 Problem definition

With the introduction of new limits for the content of sulphur in marine fuels within the European Sulphur Emission Control Areas (SECAs), Ro-Ro companies operating in these SECAs will face substantial additional cost. As of 1/1/2015, IMO’s MARPOL Annex VI and EU Directive 2012/33/EU (amending Council Directive 1999/32/EC) stipulate, among other things, a 0.1% limit in the sulphur content of marine fuels, or equivalent measures limiting the percent of SOx emissions to the same amount. As low-sulphur fuel (Marine Gas Oil-MGO or Marine Diesel Oil-MDO) is substantially more expensive than Heavy Fuel Oil (HFO), there is little or no room within the Ro-Ro companies current margins to absorb such additional cost and thus significant price increases must be expected. Unlike its deep-sea counterpart, in short-sea shipping such a freight rate increase may induce shippers to use land-based alternatives (mainly road). A reverse shift of cargo would go against the EU policy to shift traffic from land to sea to reduce congestion, and might ultimately (under certain circumstances) increase the overall level of CO_2 emissions along the entire supply chain. If the shipping price is no longer competitive with road transport, this will likely have one or more of the following ramifications:

1. Shifts and congestion to road transport
2. Loss of cargo to the shipping company
3. Reduced profits or increased losses
4. (Potentially) more CO_2 in the overall supply chain
5. Increased cost of the produced goods, making these products uncompetitive as compared with sourcing from other areas, including areas outside the EU
6. The loss of business to the shipping lines as a consequence of 1, 2 and 3 above, makes the shipping routes non-viable and thus candidates for closure. A consequence is that all of the remaining cargoes on such routes will need to find alternative transport routes, most likely road.

Before 1/1/2015 arrived, gloom and doom was the prevailing mood of the industry. The sulphur problem was a serious source of concern to Ro-Ro operators in the Baltic and North Sea.

[1] www.roroseca.transport.dtu.dk

Operators such as DFDS and Stena already shut down some of their routes. The problem caused also concern to manufacturing, mining and forest industries in the area. The fear was that many of these industries might be forced to relocate because of the side-effects of such operational and regulatory changes. Such loss of business might force the marginally viable ship operators and ports out of business, channeling even more cargoes towards land-based modes.

Things turned out differently however. The significant and largely not anticipated drop in fuel prices after mid-2014 alleviated and to some extent masked the impact of the new legislation. Companies reported record profits and in many ways it was as this problem never existed. Still, the industry recognized their luck, and as fuel prices can rise again in the future, the same questions and concerns pertain.

These questions can be summarized as follows:

- What is the economic impact of the new legislation?
- What is the environmental impact of the new legislation?
- What may be possible modal shifts?
- What measures can the RoRo operator take to mitigate and reverse the situation?
- What policy measures are deemed the most appropriate?

3 The project

DTU started working on the RoRoSECA project in mid 2015. Below are the objectives of the project and its main technical work packages, as described in the project proposal.

3.1 Project's objective

The main objective of this project has been to identify and assess possible technical, operational, regulatory and financial measures for the mitigation and reversal of the negative repercussions of environmental legislation to the market shares of Ro-Ro shipping in Northern Europe.

Work on the project involved two technical work packages, labelled WP2 and WP3[2], and broken down into several tasks as described below.

3.2 WP2 Enhanced modal split and emissions models

The objective of this work package was 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 came from the Ro-Ro short sea sector in the Baltic, the North Sea, and the English Channel where land-based alternatives are a real option. In these scenarios, sulphur regulations would impact the competitiveness of maritime transport and might also ultimately increase CO_2 elsewhere in the supply chain (even though as already mentioned this may be scenario-dependent and is to be investigated anyway). It should be noted that routes' profitability can be an unstable variable as even small shifts of traffic away from the maritime mode can make a route unprofitable and subsequently shut it down. Traditional modal split models (logit or others) do not capture this fact so they will have to be appropriately enhanced. The network of DFDS Seaways was used as a test case. An investigation of the road mode was

[2] There was also WP1, the management work package, and WP4, the dissemination work package.

part of this work package, as this constitutes an essential part of the model's input. In addition, a separate module dealt with emissions and external costs calculations.

WP2 was broken down into the following 3 tasks:

3.2.1 Task 2.1 Scenario definition and data collection

Data collection involves obtaining data such as:

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

This set of data was collected for a set of 'baseline scenarios'. The scenarios were selected in collaboration with DFDS, and mainly in the context of their North Sea, Baltic and Channel networks. Each baseline scenario was defined as a route involving a short-sea leg that competes for the same cargoes with at least one alternative route that is fully land-based.

The following criteria were applied for the selection of scenarios:

- Geographical balance: The selected scenarios exhibit a diverse geographical coverage.
- Chain configuration: There are scenarios with short, medium and longer sea legs, while the ratio between sea and land-based legs is varying.
- Volume: The scenarios collectively cover a non-trivial fraction of DFDS Ro/Ro traffic (approximately 43% in 2014-15).
- Commodity mix: The cargoes being transported are diverse.
- Vehicles/vessels: The vehicles/vessels, too, should be as diverse as possible, particularly with respect to capacity utilization.
- Data availability: Given the usual difficulty in obtaining the necessary data, particularly those related to costs, the availability of information was a decisive factor in selecting the final subset of routes.

3.2.2 Task 2.2 Modal split model development and calibration

This task started in parallel with Task 2.1 and ran throughout Year 1. The developed modal split model was an extension of the modal split models developed earlier and took on board the following considerations:

- Model captures the fact that if a route becomes unprofitable it will shut down and its traffic will be diverted to the remaining competing modes.
- Model captures the effects of possible speed reduction on transit time and modal shares.
- Model captures the effects of Ro/Ro freight rate surcharge (bunker adjustment factor – BAF) 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, model captures effects of both capital and operational costs, including increased fuel consumption due to the scrubber.
- Model captures the impact of different values of the cargo on generalized cost and modal shares.
- Model captures 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.

For each scenario, outputs of this model include:

- Modal split (cargo flows) among the alternative routes
- Cargo capacity utilization of the maritime mode
- Cargo revenue of the maritime mode
- Profitability of the maritime mode
- Identification of problematic and non-problematic maritime routes

3.2.3 Task 2.3 Emissions and external costs calculator

A parallel effort in WP2 was the development of an emissions and external costs calculator. For any scenario examined, emissions and external costs were calculated by a modified version of the DTU/SDU SHIP-DESMO model (project 2010-56 funded by the DMF). The model modified and adapted the container model already developed, into a Ro/Ro model. In addition, an emissions and external costs calculator for the road option was provided. The advantage of using this type of model is that it is possible to carry out different parameter and sensitivity studies, such as change of speed, change of fuel and engine type, change of cargo utilization of the ship, and others. Work on this task included:

- Analysis of statistical data for Ro/Ro ships for determination of main dimensions
- Analysis of model test results
- Transformation of container ship program to Ro-Ro ship program
- Test of fuel and performance data for existing Ro-Ro ships (benchmarking of model)
- Implementation of truck calculation module
- Implementation of CEN standard
- Implementation of external costs calculation module
- Writing of documentation reports and manual

Outputs included:

- Emissions of both modes (CO_2, SO_x, NO_x, P.M., HC, other)
- External costs of both modes

3.3 WP3 Measures to mitigate or reverse modal shifts

In order to mitigate the unwarranted effects of the coming legislation, and based on the models developed in WP2, and for the set of baseline scenarios selected there, a number of measures could be considered, both by the Ro-Ro operator involved and (potentially) by policy makers.

WP3 was broken down into two tasks. Both tasks explored and assessed such measures on a 'what if' basis and identified alternatives that achieve the best possible outcome for the maritime sector, in terms of the outputs defined in WP2.

3.3.1 Task 3.1 Measures from the Ro/Ro operator

These included:

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

For each of these measures, each of which could involve several variants (eg specific speed reduction variants, specific fleet or service frequency variants, etc), and for combinations of these measures, the models of WP2 were run, and outputs as defined in Tasks 2.2 and 2.3 were produced.

3.3.2 Task 3.2 Measures from policy makers

This task complemented Task 3.1 and investigated additional potential measures that come under the 'policy' category. These included:

- Full or partial internalization of external costs, all modes
- 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 hauliers 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 and its subgroups.

Again, for each of these potential measures, each of which could involve several variants (eg how much a road tax might be), and for combinations of these measures, the models of WP2 were run, and outputs as defined in Tasks 2.2 and 2.3 were produced.

Various mixes of measures of Tasks 3.1 and 3.2 would also be considered in combination.

4 Project results

This section summarizes the project's results, per project WP and Task, as these were defined in the previous section.

4.1 WP2 Enhanced modal split and emissions models

Work on WP2 produced the following technical reports, all of which can be downloaded from the project's web site:

WP2 task	Reports
2.1 Scenario definition and data collection	Report on the outcome of Task 2.1: scenarios defined and data collected
2.2 Modal split model development and calibration	Report on the outcome of Task 2.2: modal split model development and calibration
2.3 Emissions and external costs calculator	Resistance and propulsion power for Ro-Ro ships
	Analysis of technical data of Ro-Ro ships
	Energy demand and emissions of marine engines
	Analysis of propulsion power data of Ro-Ro ships
	Energy and emission model for trucks
	External cost calculator for the SHIP-DESMO model

Summaries of these reports follow.

4.1.1 Task 2.1 Scenario definition and data collection

This task comprised of two main objectives:

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

After some analysis, 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	RoPax
Klaipeda – Karlshamn	RoPax
CROSS CHANNEL	
Dover – Calais	RoPax

The DTU team also deciced to examine one of the recently shut down routes of DFDS as DFDS confirmed that the new sulphur limits contributed to the shutting down decision. Following a short discussion, it was suggested that this route would be Esbjerg- Harwich. It was also noted that it might be useful to also consider a what-if analysis on routes not affected by the ECA regulations. To address this, DTU also examined the Marseille-Tunis route served by DFDS.

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

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

Detailed information on the numerous classes of data collected can be found in the report for Task 2.1.

4.1.2 Task 2.2 Modal Split Development and Calibration

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.

The enhanced modal split model developed 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 early 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.

Given such a drop in fuel prices, the question was if one could still pick out and dissect the effect of the new sulphur regulation from the effect of the fuel price drop. The answer turned out to be yes, and the analyses performed in the context of Task 2.2 helped 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 considered 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 were:

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

Essentially, Fuel Case 1 referred 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 was a reasonable approach.

Fuel Case 2 was 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 were used to simulate the effects of the regulation as anticipated in the ex-post market and research reports.

Finally, Fuel Case 3 was another 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.

Based on the above scenarios, and even allowing for differences due to the particularities of the different routes examined, the analysis of Task 2.2 supported the following general conclusions:

The first conclusion was 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 gave the impression that the investments in scrubbers the years before the new limits might 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 identified a clear risk. Should fuel prices increase (as the trends in the first months of 2016 suggested) 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 were the objective of Work Package 3, in Year 2 of the project.

A final conclusion regarded 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.

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 was used to conduct sensitivity analyses on fuel prices that could render a service unprofitable. The Harwich-Esbjerg route which was shut down in 2014 was used as a benchmarking instance on the criteria to shut down a service.

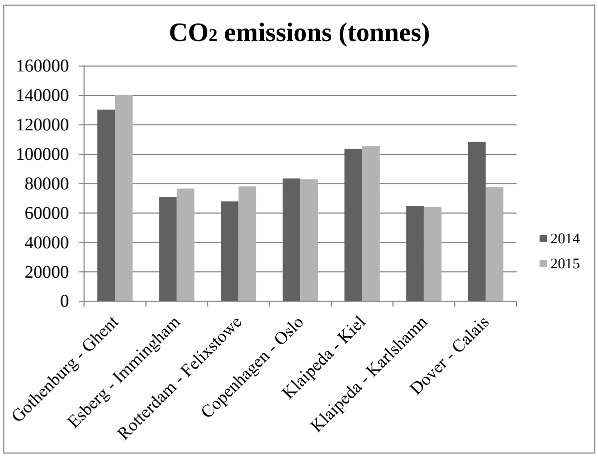
One of the main outputs within Task 2.2 was the analysis of data provided on DFDS that compared the two years (2014 and 2015) in terms of economic and environmental performance. The table below summarizes the market picture of DFDS before and after the low sulphur limit.

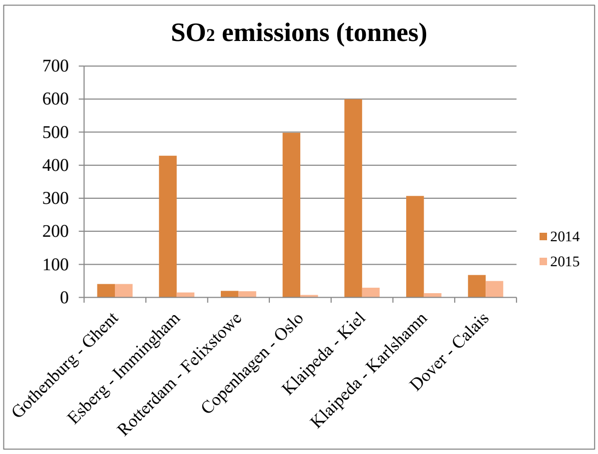
Summary of new market picture

Route	Year	Trips Total	Transported Cargo Volume change (%)	Cargo Rate change (%)	Revenue Change (%)	Annual Fuel Cost Change (%)
Gothenburg Ghent*	2014 2015	553 569	6.06	-5.62	0.09	-52.89
Esbjerg Immingham	2014 2015	512 580	19.46	-0.5	18.85	-15.29
Rotterdam Felixstowe	2014 2015	1514 1637	15.13	0.5	15.71	-24.34
Copenhagen Oslo	2014 2015	687 702	-5.82	1.58	4.28	-9.36
Klaipeda Kiel*	2014 2015	611 615	-4.64	-7.71	-8.89	-30.05
Klaipeda Karlshamn	2014 2015	717 710	3.64	-2.32	3.73	-22.99
Dover Calais	2014 2015	6210 4994	-17.66	9.36	-18.04	-50.35

This table shows that for all services the fuel cost has dropped significantly, higher for services that are using scrubber-equipped vessels. At the same time, the freight rate has decreased or remained steady for most of the routes (except Dover – Calais), thus effectively constituting maritiem services more attractice to shippers. Despite the lower freight rate, most services achieved higher revenues in 2015, in part due to the higher market share captured, and the higher number of vessel trips. Essentially, this table explains why the low sulphur limit did not affect negatively the ship operators as it was anticipated before.

On environmetnal terms, data on the actual fuel consumption of all vessels deployed in the examined seven routes were collected and analyzed. The figure below summarizes the total CO_2 and SO_2 emissions for each of the two years in absolute terms.





Emissions of the examined routes (tonnes per year)

It can be seen that in 2015 the carbon emissions have increased, a fact that can be attributed to the higher number of trips performed, as well as a potential small increase in sailing speeds in some routes due to the low fuel prices. In SO_2 terms, it is evident that the regulation has been successful in diminishing these pollutant emissions. In relative terms, the emissions intensity was found to decrease as there were higher load factors of the vessels on average.

4.1.3 Task 2.3 Emissions and external costs calculator

Task 2.3 has produced a total of six (6) reports, covering the following topics in detail:

1. Prediction of resistance and propulsion power of Ro-Ro ships

2. Analysis of technical data of Ro-Ro ships

3. Energy demand and exhaust gas emissions of marine engines

4. Analysis of propulsion power data of Ro-Ro ships and analysis of the CEN standard 16258 for Ro-Ro ships

5. Energy and emission model for trucks

6. External cost calculator for the SHIP-DESMO model.

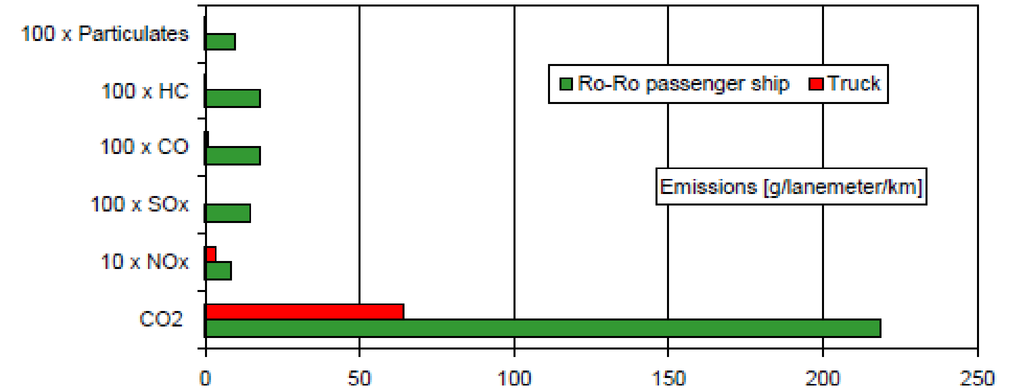
The CEN Standard 16258 describes two different allocation methods for allocation of the total ship emissions on passenger and freight transport respectively. The two methods are the so-called 1) mass method and the 2) area method. A third method might be an average allocation method, based on the mean values of the area and the mass allocation method. All three methods are used in SHIP-DESMO for allocation of energy demand, emissions and external costs on the different cargo segments, 1) rolling cargo (on trucks, trailers, mafis, etc.) and 2) the passengers including cars, campers, buses, etc.

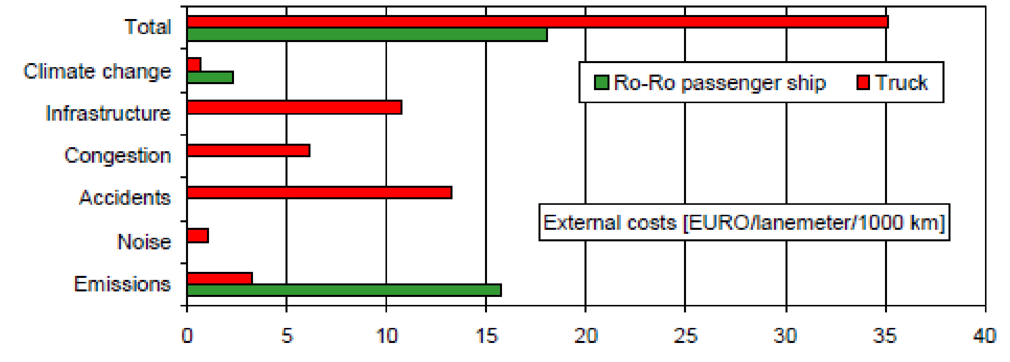
In addition, two separate SHIP-DESMO software programs have been developed, one for Ro-Ro cargo ships and one for Ro-Ro passenger ships.

The figure below is a typical output of the SHIP-DESMO Ro-Ro passenger ship software.

Example No. 1: 2000 passenger Ro-Ro passenger ship loaded with 100 % trucks and only 200 passengers (typical off season situation). Average allocation procedure

Ship data		Truck data	
Default ship (0) or ship alternative No. 1 or No. 2	0	Total weight of truck cargo (t)	18.0
Low cargo density (1) or high cargo density (2)	1	Truck weight (empty)	10.0
Passenger capacity (persons)	2000	Truck weight (loaded)	28.0
Actual number of passengers	0	Length of truck - total (m)	14.0
Total lanemeters (100 %) = LM	1337	EURO norm (2, 3, 4, 5 or 6)	4
Total number of cars (100 %)	450	Driving distance (km)	400
Actual payload/deadweight at maximum draught (pct.)	60	Driving percentage in city area	5
Rolling cargo lanemeters in pct. of total LM	100	**Car data (Euro Norm 6)**	
Bus lanemeters in pct. of total LM	0	Diesel (1) or petrol driven (2) car	2
Car and caravan lanemeters in pct. of total LM	0	Normal (1) or hybrid (2)	1
Occupied lanemeters	1337	Engine volume (0.8 - 2.2 litres)	1.8
Normal speed (knots)	22.3	Number of passengers (max. 4)	2
Actual speed (knots)	22.3	**Bus data**	
Speed change (pct.)	0	EURO norm (3 - 6)	4
Pass. comfort class (1 = low, 2 = average or 3 = high)	2	Number of passengers (max. 45)	40
Suphur content of oil (%)	0.1	**External cost level**	
NOx emissions (IMO TIER 1, 2 or 3)	3	1 = Low, 2 = Mean, 3 = High	2
Slow speed (1) or medium speed main engine (2)	2	EURO/DKK exchange rate	7.50
Sailing percentage in harbour conditions	2.0	**Emission allocation method**	
Remaining draft reserve (m) - shall be positive !	0.02	Area (1), mass (2) or average (3)	3





4.2 WP3 Measures to mitigate or reverse modal shifts

Work on WP3 produced the following technical reports, both of which can be downloaded from the project's web site:

WP3 task	Reports
3.1 Measures from the Ro-Ro operator	Report on the outcome of Task 3.1: Measures from the Ro-Ro operator
3.2 Measures from the policy makers	Report on the outcome of Task 3.2: Measures from the policy makers

Summaries of these reports follow.

4.2.1 Task 3.1 Measures from the Ro-Ro operator

Task 3.1 examined measures that Ro-Ro operators could deploy in response to the new lower sulphur limits since January 2015. The selected measures for further analysis were the following:

- Change in sailing speed
- New sailing frequency
- Vessel swapping between compatible services
- Investments in abatement technologies versus the use of low-sulphur fuel
- Changes in pricing policy

These measures were adjusted for each of the examined services in terms of feasibility. For instance, a speed reduction beyond a certain threshold could be impossible, as there would be not enough time at the ports of call for the loading and unloading operations. Similarly, there were constraints on which vessels could be deployed at each service based on vessel type, policy requirements (subsidised scrubber-fit vessels are bound to specific route), and capacity considerations.

To assess the implications of the Ro-Ro measures on the profitability of each service, a fuel consumption module was developed taking as input actual fuel data provided by DFDS at the operating patterns used in the schedules of the company. In addition, data from the sea-trials of these vessels (at various sailing speeds) were used to model the impacts of changes in sailing speed in actual sailing conditions. It was therefore possible to estimate the fuel consumption at different combinations of sailing frequencies, speeds, vessels deployed, considering also the use of MGO or a scrubber retrofit. At the same time, certain of the examined measures would have an impact on the shippers in terms of increased (or in some rare cases of low fuel prices – reduced) sailing durations, waiting times (as a result of less frequent services), and capacity offered. To address this impact on the shipper, a computational module was created that was linking the effects of the new total travel time and cost on shippers' choice. This module was an enhancement on the modelling framework designed for WP2 and the modal split model in particular. Thus, the estimation of the new transport demand that the operator would have to satisfy was possible.

In WP3, the calibration results from WP2 were used to predict modal shifts as a result of the examined measures, and simulation was performed for three main fuel price scenarios. However, the models are developed in such a way that any potential fuel price combination (HFO vs MGO) can be readily examined. The calibration for each of the examined routes was based on data collection and simulation in the context of WP2 that concerned the year 2014 (the last year before the new sulphur limit was introduced). For each calibration, estimation of scale parameters was the main output that can be used to predict changes in market shares of each of the examined available options to the shipper.

The examined measures that ship operators can utilize to reverse and mitigate the negative effects of the regulation (particularly for high fuel price scenarios) are described below.

A small *speed reduction* in times of high fuel prices was shown to be an effective measure in reducing the operating costs of each service. There are certain constraints on the extent of increasing the sailing time of a voyage, due to the minimum requirements of at-berth operations (loading and unloading of the vessel, refuelling) as well as due to the requested times of arrival/departure from long-term clients. As a result, small increases of 0.5, 1, 2, and up to 3 hours (in longer services) were examined. The developed models allowed also the examination of a speed increase for low fuel price scenarios. Outputs of this model were the new fuel consumption (based on DFDS data, and the use of an activity based modelling methodology), the new market share due to the effects of new sailing times on mode choice of the shippers, and the resulting emissions. A snapshot of the results for the longest route (Gothenburg – Ghent) is shown in the following table.

Effects of speed on fuel consumption[3]

Ship	Hours at berth	Hours sailing	Weekly fuel consumption (tonnes)	Reduction (%)
Baseline Sailing Speed **18.06 knots**				
Ship A	38	130	xx	NA
Ship B			xx	
Ship C			xx	
Ship D			xx	
Increase Trip by **1 hour**, New Sailing Speed **17.26 knots**				
Ship A	32	136	xx	-10.11
Ship B			xx	-10.51
Ship C			xx	-9.26
Ship D			xx	-8.52
Increase Trip by **2 hours**, New Sailing Speed **16.53 knots**				
Ship A	26	142	xx	-18.36
Ship B			xx	-18.96
Ship C			xx	-17.55
Ship D			xx	-16.67
Increase Trip by **3 hours**, New Sailing Speed **15.86 knots**				
Ship A	20	148	xx	-34.86
Ship B			xx	-35.80
Ship C			xx	-34.23
Ship D			xx	-33.24

Significant fuel consumption reductions can be observed via a small increase in sailing time. This was shown to minimally affect shippers' choice for most routes, and hence the revenue of such an option will marginally decrease, while an important saving can be achieved in the operating costs. It should also be noted that such an option will reduce the time spent at berth each year, and thus result in some emissions savings at the port.

Changing the *sailing frequency* is another option for ship operators when struggling with high fuel prices (decrease number of sailings) or during unexpectedly low fuel prices and increased transport demand (increase number of sailings). This was examined for routes where a small adjustment of the weekly sailings was possible. A sample of results is shown in the following table.

[3] Confidential figures are shown by 'xx'.

Effects of new sailing frequency[4]

Esbjerg – Immingham (Normal frequency 6 sailings per week)

	New sailing frequency	New Transported lm	New capacity utilization	ΔRevenue (€)	ΔFuel Cost (€)
Fuel Case 2	5	29060	xx	-112273	-33579
Fuel Case 3	7	34475	xx	39897	16569

Klaipeda – Kiel (Normal frequency 7 sailings per week)

	New sailing frequency	New Transported lm	New capacity utilization	ΔRevenue	ΔFuel Cost
Fuel Case 1	6	26900	xx	-32419	-28172
Fuel Case 2	6	25950	xx	-25082	-57093

Dover – Calais (Normal frequency 99 sailings per week)

	New sailing frequency	New Transported lm	New capacity utilization	ΔRevenue	ΔFuel Cost
Fuel Case 1	75	131724	xx	-56039	-58844
Fuel Case 2	75	130760	xx	-74580	-119255

The results show that for the high fuel price scenarios, the loss of revenue is occasionally comparable with the reduction in operating costs. In certain cases (e.g. Esbjerg – Immingham) the reduction in revenue is higher than the fuel savings, and unless the reduction in other costs (salaries, port fees, depreciation of vessel) is higher than this difference, the company would be worse off by reducing the service. In low fuel prices, it is advisable for most routes to increase the sailing frequency in order to also improve the load factor of the vessels.

Another approach is to *swap vessels* between compatible routes. Under this measure, the company may take advantage of the variety in nominal capacity of vessels serving similar routes. The following table shows an example of savings if two vessels were to be swapped during 1 week of operation, without changing anything else in the services.

[4] Confidential figures are shown by ‘xx’.

Effects of vessel swapping[5]

Gothenburg – Ghent (Illustrative, some crude assumptions)

	Capacity utilization	ΔFuel Cost (€)
Fuel Case 1	xx	-4662
Fuel Case 2	xx	-9447
Fuel Case 3	xx	-4526

Esbjerg – Immingham

	Capacity utilization	ΔFuel Cost (€)
Fuel Case 1	xx	-11033
Fuel Case 2	xx	-22358
Fuel Case 3	xx	-10711

It can be shown that through this measure some fuel cost savings can be achieved for the route. Also, the capacity utilization (confidential) can be improved by assigning a vessel with a more appropriate nominal capacity for each route.

Finally, the option of *retrofitting another vessel with scrubber systems* was considered. Considering one of the vessels in the network that is still running on low-sulphur fuel (the one with the highest installed power), and for a variety of fuel price differentials, a simple CBA was performed to estimate the payback period of the investment. A summarized version of results is shown in the following table.

Payback period of scrubbers

Fuel prices	*HFO (€/ton)*	*MGO (€/ton)*	*Annual Savings (M€)*	*Payback period (years)*
December 2015	135	304	1.21	4.3
October 2015	237	480	1.731	2.9
November 2014	590	880	1.998	2.4
February 2014	803	1212	2.825	1.3

The increased payback period due to the very low fuel prices observed in 2015, showed that under such circumstances it may be better to wait, especially in anticipation of the glbal sulphur cap in 2020. The latter, may result in more efficient and affordable technologies in scrubber systems being available, as well as more subsidies being available. A speculative analysis on the use of LNG showed that due to the high uncertainty regarding its price, and the much higher capital costs in comparison to scurbbers, it may also be better to wait until the LNG technology matures for Ro-Ro shipping.

The main findings of Task 3.1 can be summarized to the following key takeaways:

[5] Confidential figures are shown by 'xx'.

- The significant fuel savings through slow steaming (both during cruise, and at port; low speed - less hours at port) can help in times of high fuel prices with relatively small market share loss.
- The effect of time in the generalized cost of transport is far less important than the actual freight rate that the shipper is paying. Therefore, speed can play a very important role in case of very high fuel prices.
- The flexibility on changes in sailing duration is limited by the required loading/unloading times that pose operational constraints.
- It was observed that for very low fuel price scenarios it may be better to increase sailing speed, something that was observed in 2016 in one of the examined routes (Klaipeda – Kiel which is the examined service that competes more with landbased options)
- Changes in sailing frequency can be effective in improving the cargo loading utilization of the vessels, and would have a smaller effect on modal choice. In times of high fuel prices this could be a viable alternative to speed reductions particularly in services that have medium (e.g. 6-7 weekly services) or high frequencies (e.g. in routes such as Dover – Calais).
- A reduced sailing frequency could lead to undesirably high utilization rates (averages of 95% were observed in the analysis) that could compromise the reliability of the service (e.g. some cargoes would not be picked up).
- An increased sailing frequency (for low fuel price scenarios) could lead to lower utilization rates and thus higher emissions per transported unit than a small speed increase. Therefore, changes in sailing frequency require more cautious planning from the ship operators.
- Vessel swapping can also be effective in harmonizing the load factors at each route in case of a predicted change in transport demand. There are some constraints on which vessel is able of sailing which service, but for certain cases the differences in nominal cargo capacity for the different ships can prove useful in improving the load factors.
- Investing in scrubber systems is critically dependent on fuel prices and the relative differential between MGO and HFO. It was shown that following the unexpectedly low fuel prices, the payback period of such investments was significantly delayed in comparison to what was anticipated in 2013 and early 2014. However, the provision of subsidies for such investments can help with their economic feasibility.
- The role of scrubber systems is expected to change following the global sulphur cap coming in 2020, as more mature technologies are expected to be available at that time. This may have a more limited effect on Ro-Ro shipping that is already sailing within SECAs, but it is expected to change their payback period due to different fuel price differentials.
- The use of Liquefied Natural Gas (LNG) as fuel is more risky as an abatement investment in comparison to scrubber systems for Ro-Ro shipping. The main arguments are revolving around the uncertainty of LNG prices, the higher investment costs for LNG retrofits, and the lack of infrastructure at this stage (LNG bunkering ports).
- Technologies such as cold ironing are less relevant within SECAs as the ship operator must comply with low-sulphur requirements at all activity phases and not only at berth. In addition, due to the current low fuel prices the price differential between MGO and the

electricity cost from the grid is smaller, constituting the payback period of cold ironing longer.

4.2.2 Task 3.2 Measures from policy makers

The following policies were examined in the context of Task 3.2:

- Full or partial internalization of external costs, all modes
- 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.

To examine these policies, the following modules were developed:

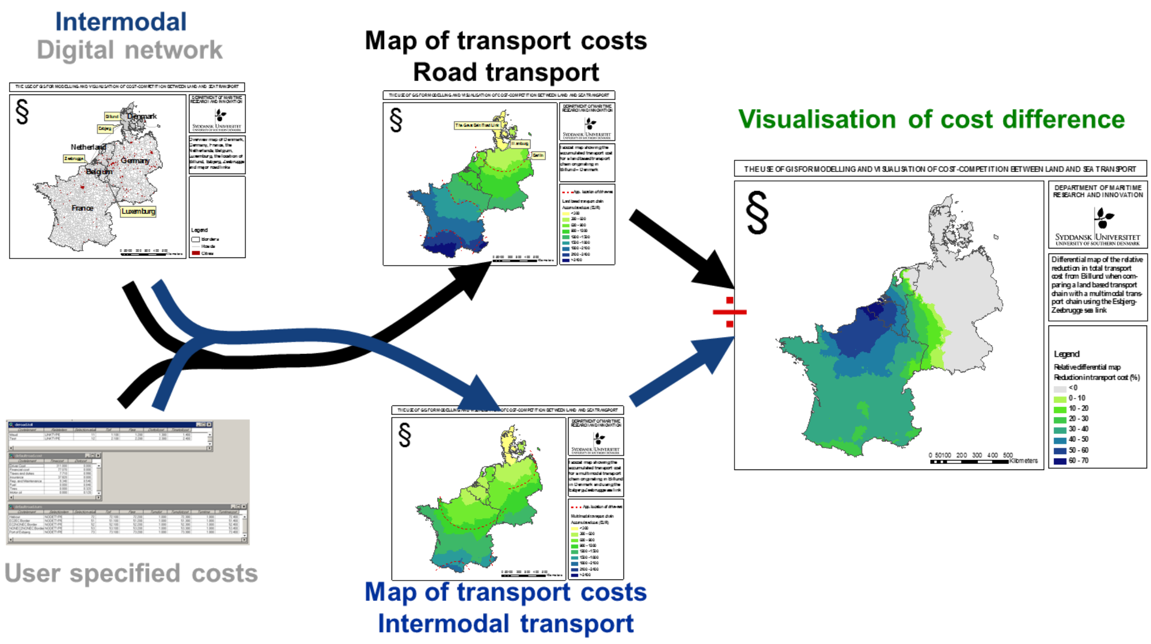
- An interface with the modal split module developed in Task 2.2
- The KPI module that estimates key performance indicators for the Ro-Ro operator
- The BAF surcharge calculator
- The fuel consumption modules that estimate costs and emissions under the new measures
- The economy module for the policy measure that estimates the total cost
- The external cost calculator

The external costs considered air pollution, climate change, noise, accidents, congestion, and infrastructure. In order to identify the relevant values, a literature survey was conducted and data from two main sources were used; the COWI/DTU study, and the external costs handbook of the EU Commission. A sample of the values used is shown in the next table.

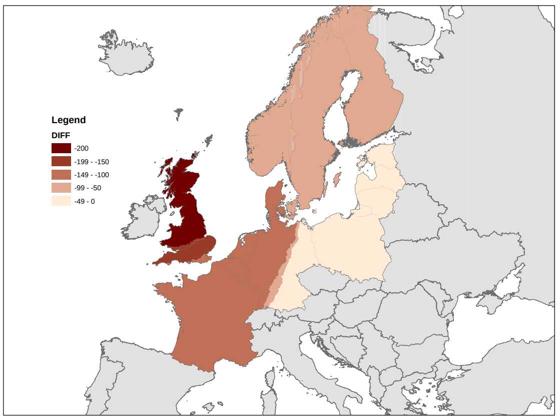
Unit values of global and local pollutants in € per kg (2015 prices)

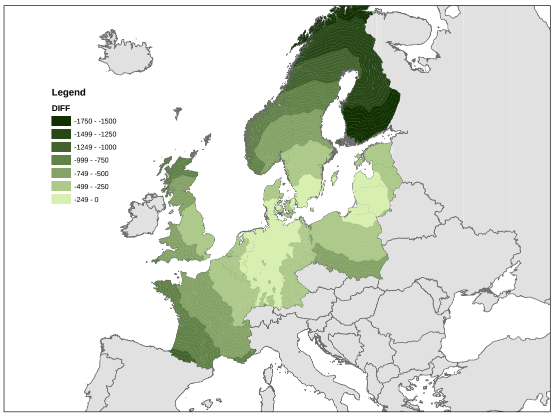
Pollutant	2014 Handbook (EU)			COWI/DTU study (DK)			Present study (EU)		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
CO_2	0.0589	0.1104	0.2061	0.0070	0.0106	0.0106	0.0070	0.1104	0.2061
$PM_{2.5}$		50.1542		4.6390	52.3539	1,568.3829	4.6390	50.1542	1,568.3829
NOx		13.4744		0.0043	7.0668	54.2781	0.0043	13.4744	54.2781
SO_2		12.9691		1.4199	28.1214	167.2566	1.4199	12.9691	167.2566

These values were used to quantify the external costs of all transport modes in the examined networks. For the landbased options, the digital network was used to estimate the cost and travel times of each shipment, and to allow the visualization of the impacts of a potential internalization of external costs in one or more transportation modes. This is possible through the estimation of the total travel cost from one point of origin to all potential destiantions in the network, before and after a change. The next figure shows the process of visualising the cost difference when enabling/disabling a sea link (Gothenburg – Ghent).



A more detailed result is shown in the next figure, where the cost of travelling from Klaipeda is calculated after internalizing only the sea transport (left map) and after internalizing both sea and road transport (right map).





The darker colored areas are indicating a higher cost saving when using a maritime mode. In the right hand map, the lesser lighted areas indicate that a full internalization of all transportation modes could lead to increased use of maritime modes.

The constructed modelling framework was tested for the aforementioned policy measures, that either increase the cost of competing land-based options, or reduce elements of the generalized cost of transport for the maritime options. The performed runs allow additionally the examination of the actual monetary cost that the low-sulphur requirement has on the shippers through the additional BAF surcharges due to the fuel price differentials. The examined policies that would provide a monetary incentive to the shipper that uses a maritime mode would require a significant capital investment from the policy maker, but would be successful in reversing the negative effects of the low-sulphur fuel requirements within SECAs. Other options could be a provision of certain subsidies to the affected (within SECAs) operators, either through a repayment of part of the port fees, or a partial payment towards retrofit costs.

It has to be noted that the estimated policy costs for each of the available options are calculated for each of the DFDS routes, and there would be a variability for the respective costs for policies targeting other ship operators. While some of these costs may seem low, ranging between a few million € annually, it has to be taken into account that there are numerous more Ro-Ro services that are affected in a similar manner. Therefore, the results of this work can be more useful if an actual available budget is known to the user of the developed methods. For example, the first implementation of the ECO-bonus system in Italy had an available budget of 230 million € for a two year period. The annual costs of the examined policies for only the seven DFDS routes range from 24, up to 103 million € (for a high fuel price scenario where the goal is increasing the modal share of maritime options). An important question for each of the examined measures is which body can (or should) provide the required funds for such policies. The necessary funds can of course be reduced, if ship operator's measures are also deployed in cases of high fuel prices, as with the available options examined in Task 3.1. A combined effort by all of the affected stakeholders can ensure that the short sea shipping sector operating in SECAs will endure should fuel prices return to their previous high levels.

4.3 Overall conclusions and transferability of the developed tools

The RoRoSECA project sought to answer the question of whether it is possible, through the use of operational practices or policy instruments, to mitigate and revert the negative effects of the low-sulphur fuel requirements within SECAs. Prior to the introduction of the sulphur limit, a rather gloomy picture was portrayed by the industry and the media with anticipated losses of market shares to the point that certain services would be shut down. This was particularly crucial for short sea shipping, due to the higher level of competition with alternative transport modes (primarily road). This would be against the EU policies that seek to move traffic from land to sea in order to reduce congestion and emissions. However, the record low fuel prices observed in the end of 2014 and until today resulted in a completely different outcome. As a result, the low fuel prices led to record breaking revenues for ship operators, and largely masked the negative effects of the regulation.

The models developed in the RoRoSECA project constituted possible the dissection of the effects of the regulation from the very low fuel prices observed in 2015. This would not have been possible without the inputs of DFDS, and the provision of very important (and frequently highly confidential) data, that facilitated the understanding of their impacts of the regulation.

This project has been the first attempt to examine in detail the impacts of the new limits, and the main conclusions of WP2 and WP3 can be summarized in the following key takeaways:

- Maritime shares increased due to the unexpectedly low fuel prices
- Maritime shares would have increased further if HFO were still allowed
- Maritime shares would drop if fuel levels returned to 2014 levels
- The freight rate is the most important component for the shipper, as opposed to transit time, which was deemed not so important

On operators measures to reverse the negative effects of the regulation, the following options are relevant

- Slow steaming reduces fuel consumption and hence emissions, but reducing speed is limited by logistical constraints. At high fuel prices it can help with balancing costs and revenue for the severely affected services that heavily compete with landbased options. In 2016 certain routes actually sped up.
- Frequency of sailing service can be used to improve load factors of a vessel, mainly on very frequent services. On 6/7 sailings per week, some flexibility can be achieved through changes in the number of sailings.
- Vessel swapping can also be used to help with load factors, taking advantage of the variability of nominal capacities offered in the (usually) diverse fleet of a Ro-Ro operator.
- Investing in scrubbers critically depends on fuel prices, and level of subsidies

The above measures show that the operator has some options to adjust in the new setting, particularly in case of fuel prices returning at previous levels. However, this may not be sufficient, and policy measures may be required to mitigate potential modal shifts. For a policy measure to be successful, essentially it is a question of how to mitigate the effects of the BAF surcharges due to the low sulphur requirements. In summary for Task 3.2:

- There is a requirement for policy measures to mitigate potential modal shifts
- For a policy measure to be successful, the BAF effect needs to be mitigated
- Typical annual costs for full mitigation is 2M€ per route, but can increase fast for high fuel prices scenarios as policies are sensitive to fuel price.
- Repayment of the BAF, ECO-bonus like systems, and internalization of external costs have similar effects.
- If policy and operators' measures are combined, it is possible to cause a modal shift from landbased options to maritime.

Potential users of the models developed by DTU include Ro-Ro operators, intermodal operators, other short sea shipping companies operating in ECAs, and maritime policy makers including the EU. Possible uses of these models include:

- Estimation of emissions and external costs
- Evaluation of possible modal shifts in ECAs
- Evaluation of possible modal shifts when 0.5% global S cap applies in 2020
- Assessment of the merits of alternative mitigation measures
- Assessment of the merits of alternative mitigation policies
- Identification of routes that exhibit risk of being non-viable
- Assistance of operators and policy makers to perform "what if" analyses of alternative scenarios
- Assistance of operators and policy makers to select among alternatives

The tools are transferable in the sense that additional policies that have effects on the economic and environmental balance of the short sea shipping sector can be readily tested, provided their effects are identifiable. For example, the impacts of the global sulphur cap on affected services can also be tested through the enhanced modal split model, provided that predictions on fuel prices are generated. The model can also be used in case a similar intervention on landbased modes is imposed (for example through speed limits, or banning trucks in certain areas).