RoRoSeCa

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DTU

Presentation of project results

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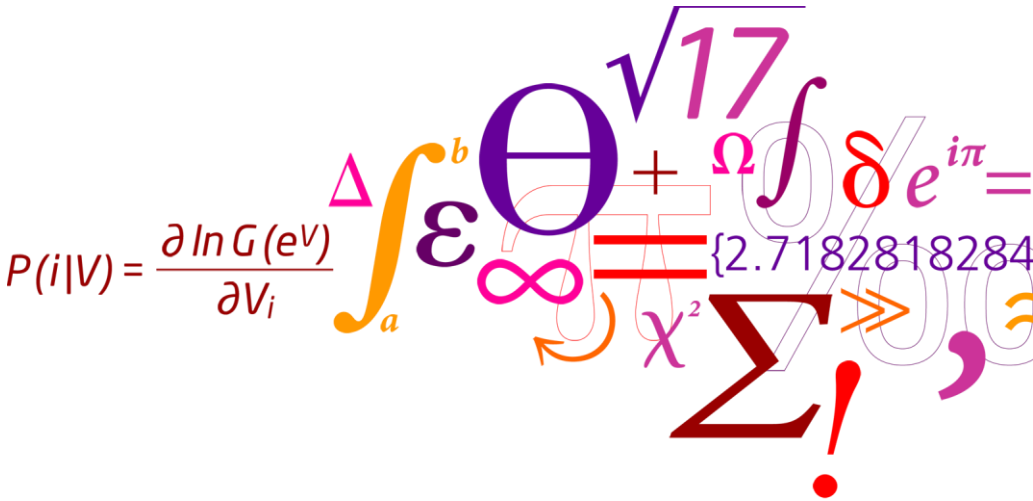


DTU Management Engineering
Department of Management Engineering

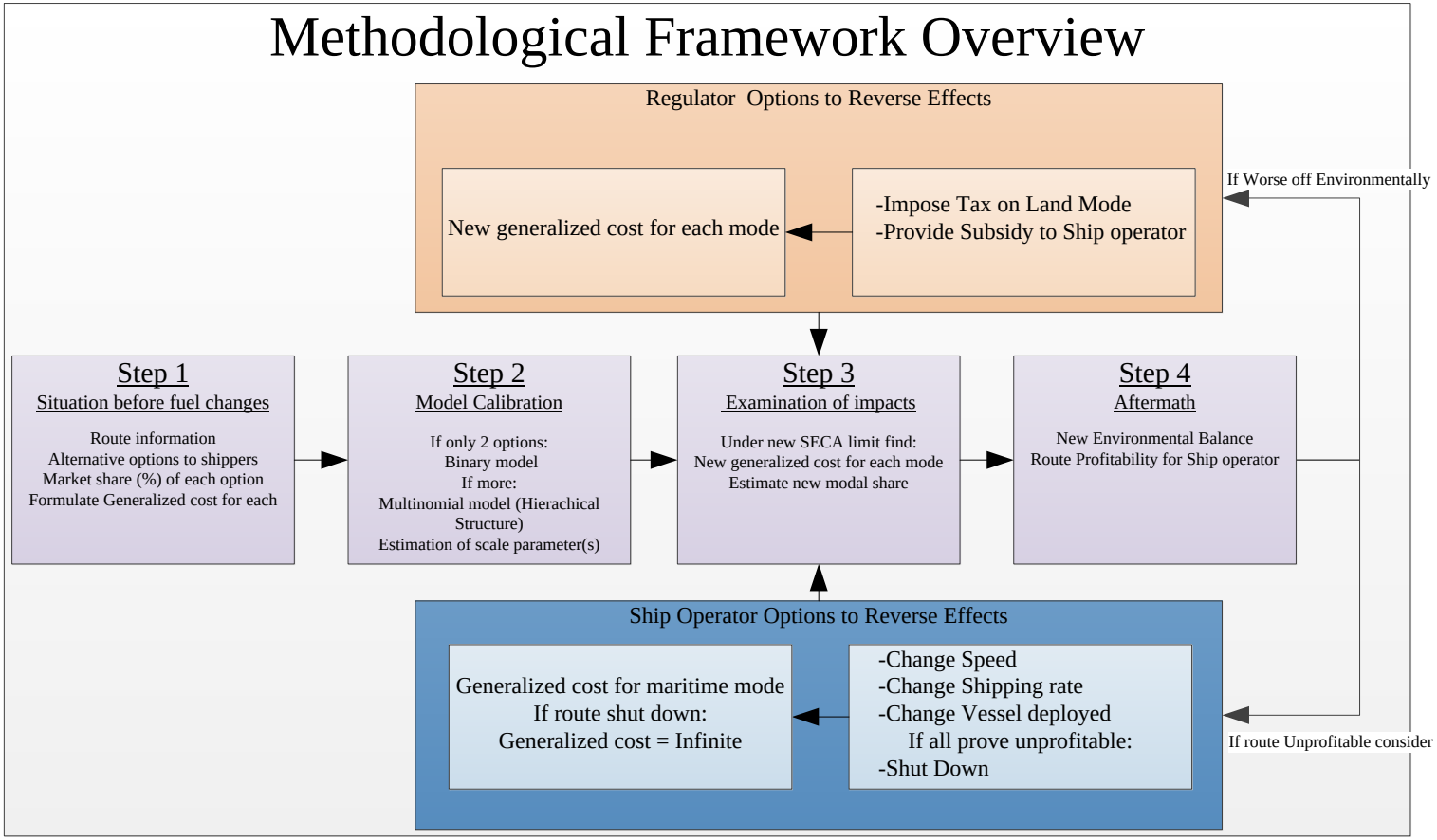
Presentation Outline

- Methodology
  - Route Selection Criteria
  - Objectives of WP3
  - Modelling modal shifts
  - Environmental efficiency
  - Profitability of a service
  - Fuel Price Scenarios
- Measures from the Ro-Ro operator
  - Speed reduction
  - Sailing frequency
  - Vessel Swapping
  - Technology
- Policy measures
  - Influencing generalized cost
  - Internalization of external costs
  - Reimbursing the BAF surcharges
  - Tax levy on landbased modes

Current DFDS network

- 18 Routes (22 links)
- ~38 vessels
- Up to 535 departures/week, 13 countries, 30 ports
- 4 main areas
  - North Sea (9 Routes, 20 vessels)
  - Baltic Sea (5 Routes, 7 vessels)
  - Cross-Channel (3 Routes, 6-7 vessels)
  - Mediterranean (1 Route, 1-2 vessels)

Objectives of WP3

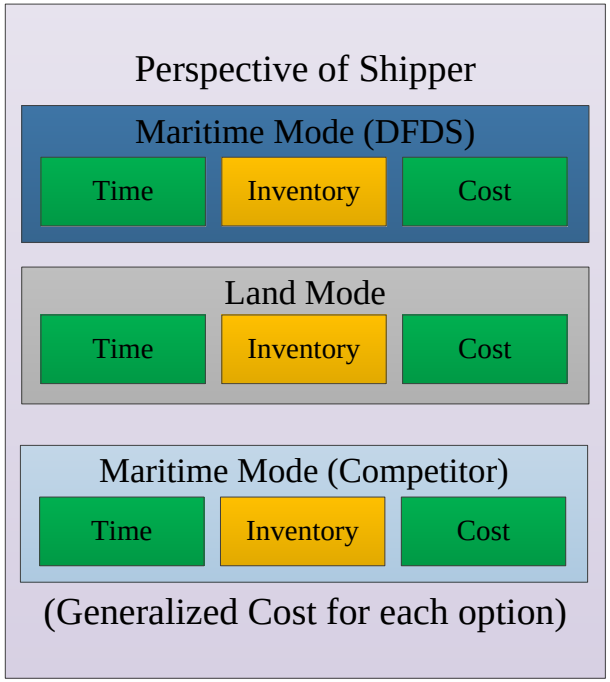


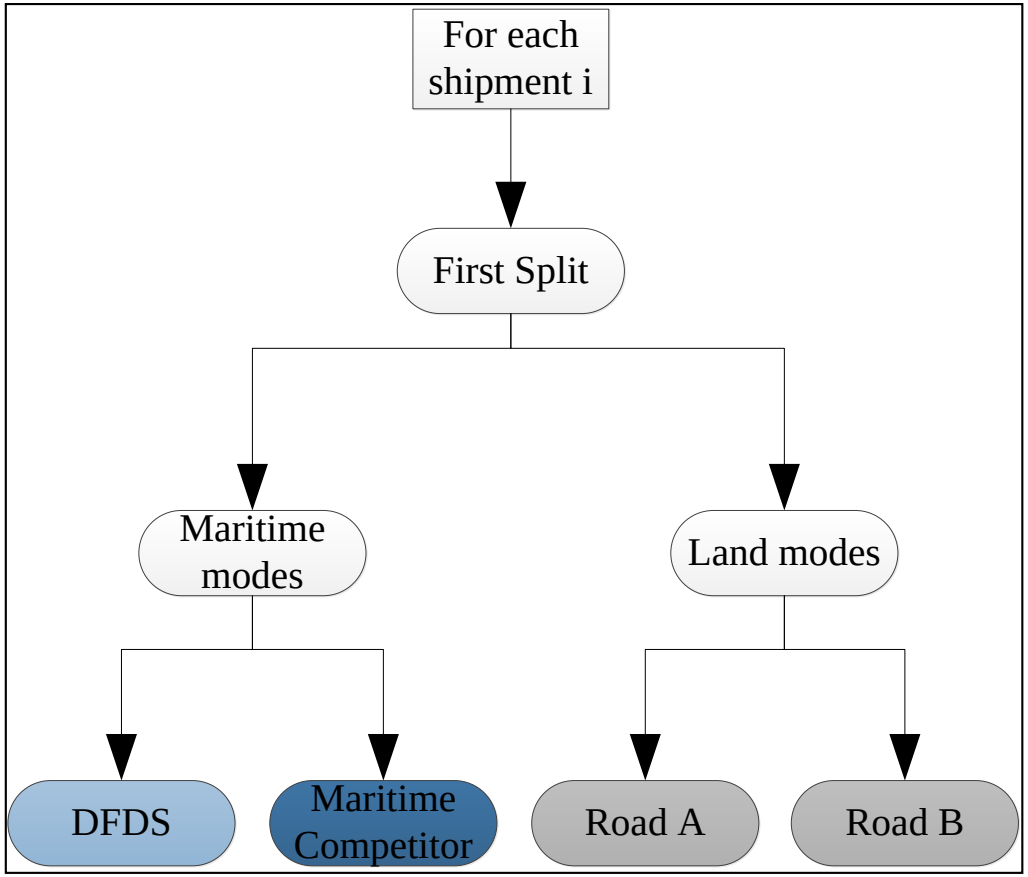
Summary of new market picture

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

Modal Shifts based on generalized cost of transport

- General Case – Hierarchical Structure

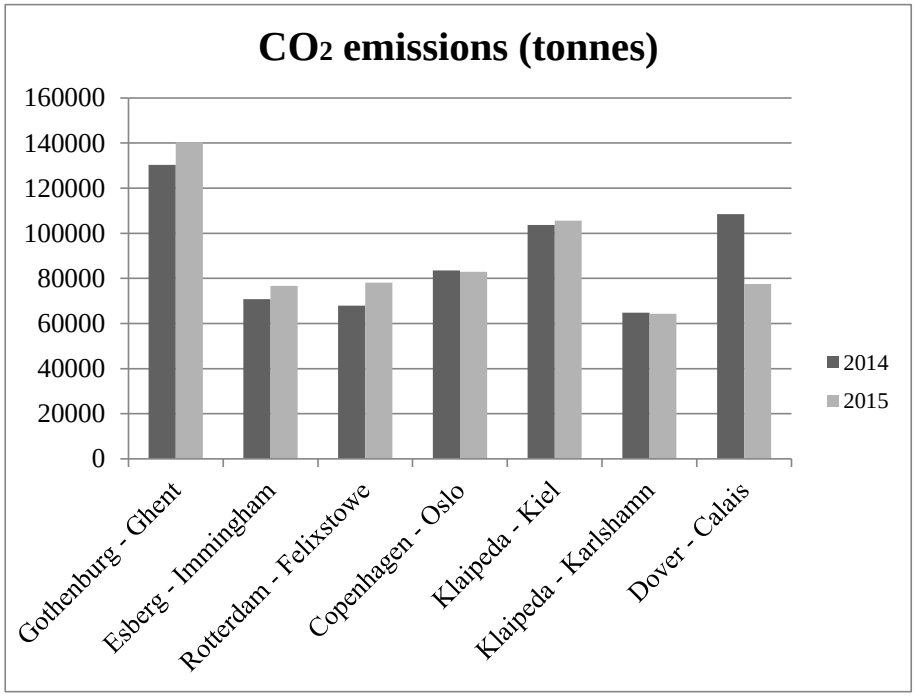


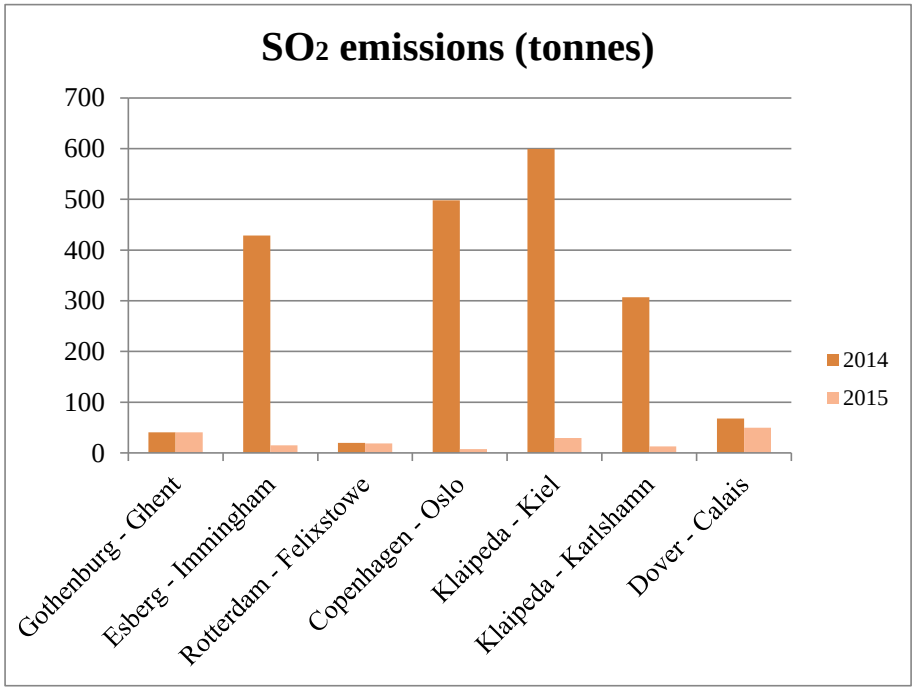


Environmental appraisal

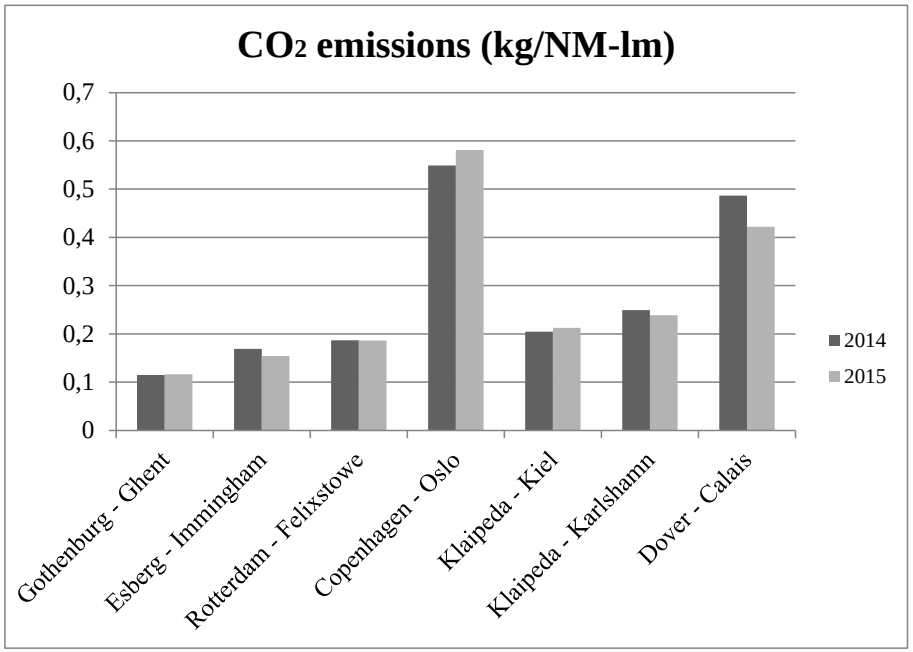
- So far emissions of fleet have been calculated for actual scenarios
- Module produces outputs of emissions per
  - lm transported
  - lm*NM transported
  - Trip
  - Year
- Next steps include calculation of emissions from competing modes
- Concerns for Ro-Pax vessels

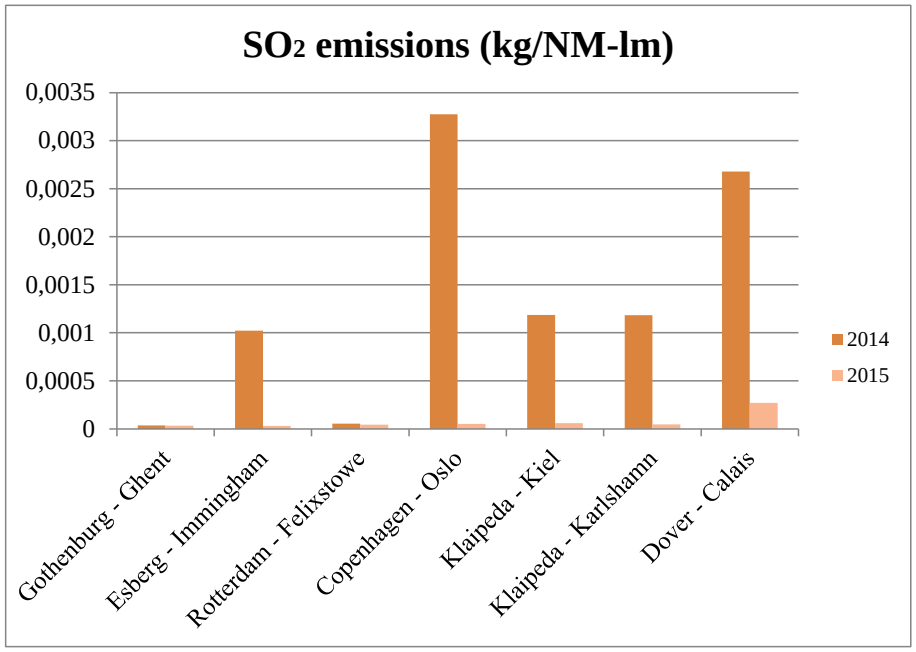
Emissions of the fleet (tonnes per year)





Emissions per transported unit (kg/lm-NM)

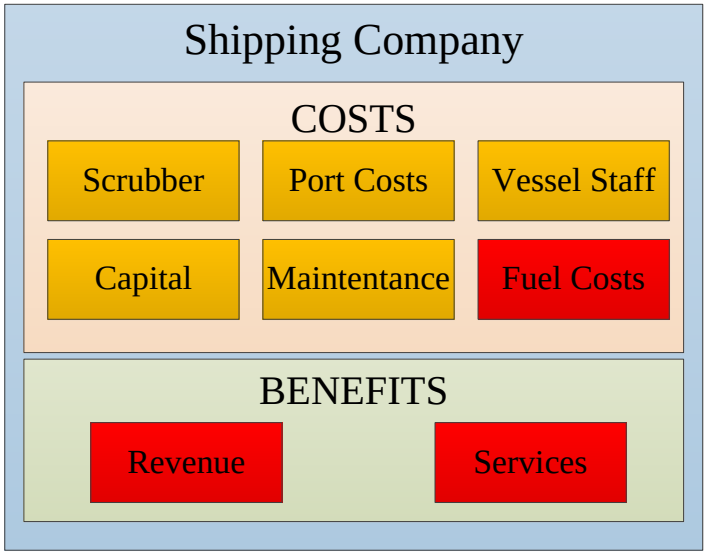




Ro-Ro Operator's profitability indicator

- Revenue Change through policy measure
  - Passenger tickets (assumed fixed)
  - Passenger spending (assumed as function of sailing time)
  - Freight Rate for Cargo (changes in BAF)

- Costs
  - Fuel (function of speed and fuel price)
  - Port (affected by policy measure)
  - Abatement technology



Fuel Price Scenarios

For all model simulation tests, the calibration was performed using data on 2014. The model predicts changes in the probability of choosing a DFDS Route for the following scenarios:

- **Fuel Case 1: What actually happened (MGO with actual prices)**
- **Fuel Case 2: What would happen if prices increase (2014 MGO)**
- **Fuel Case 3: What would happen if HFO allowed (2015 prices)**

Basic Fuel price scenarios

Scenario	HFO Price ($/ton)	MGO Price ($/ton)	Comment
Fuel Case 1	263	478	These are the actual fuel prices in 2015
Fuel Case 2	533	816	These are using the fuel prices in 2014, which were higher. This is a pessimistic scenario.
Fuel Case 3	263	(Not used)	These are using the HFO prices in 2015, so represent an optimistic scenario of very low fuel prices (or lack of regulation)

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Objectives of Task 3.1

- Extension of modal split model for WP2
- Examine proposed Ro-Ro operators measures
- Incorporate effects of speed changes on mode choice
- Assess impacts of new sailing frequency
- Consider different fleet deployment
- Implications of investments in technology

Addressing Objectives of Task 3.1

- Extension of modal split model for WP2
- Model was enhanced to show effects of Ro-Ro changes on GC, and modal shifts

- Examine proposed Ro-Ro operators measures
- Suggested measures in project and previous AC incorporated to the models. Effects on market share, Ro-Ro profitability

- Incorporate effects of speed changes on mode choice
- Speed effects on total travel time and GC

- Assess impacts of new sailing frequency
- Mainly on utilization rates

- Consider different fleet deployment
- Utilization rates, fuel consumption per NM-lm

- Implications of investments in technology
- CBA approach

Flow of Task 3.1

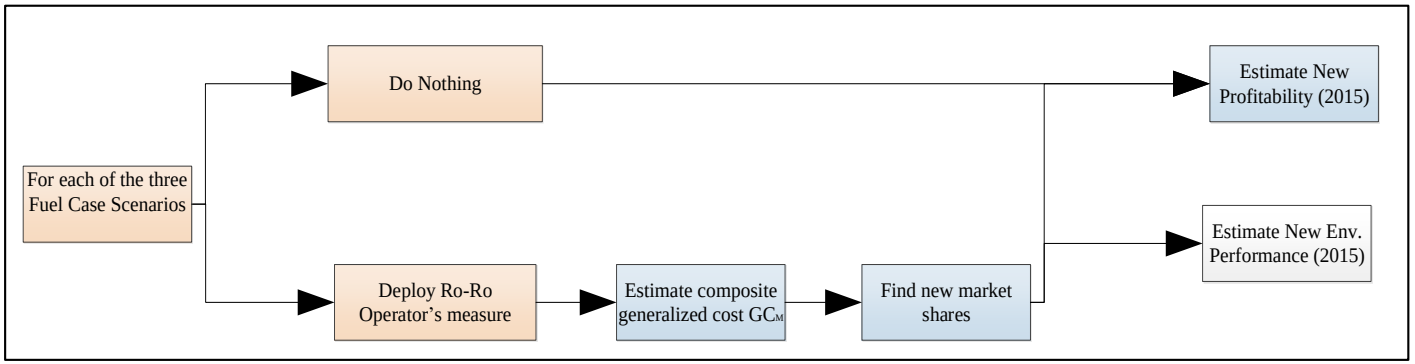
- Selection of appropriate Ro-Ro measures
- Matrix of measures
- Match measures with relevant Routes
- Discuss specifications of each measure (e.g. what speed, frequency etc.)
- Simulation for all Routes, for three fuel price scenarios
- Using calibration results of Task 2.2
- Output of Task 3.1 (Deliverable) – Month 19

The Route-Measure Matrix

Measure / Route	Speed Reduction		Sailing Frequency		Fleet and network reconfiguration	Use of LNG as fuel (CBA, no change in schedule)	Use of scrubbers in more vessels (CBA, no change in schedule)	Change in pricing policy	Cold ironing
	Current (hours)	New (hours)	Current (#/week)	New (#/week)					
Gothenburg – Ghent	32	+ 1, 2,3	Not relevant as doing well		Swap vessel with Goth-Immingham based on capacity or abatement technology. No change at schedule, or demand	Not route specific. Feasibility and CBA to be conducted on different vessel type (Ro-Ro/Ro-Pax/Pax) and size, assuming new-build.	All vessels have scrubbers	Not route specific. Either absorb BAF 0.1/1% sulphur differential Alternatively, lower cost to obtain same market share, or same revenue. Policy changes for each fuel case scenario	Not route specific. First assumption: 1 port offers facility, or both ports offer facility. Always available. CBA for one vessel will be conducted, external costs will be contrasted
Esbjerg – Immingham	18.5	+0.5,1, 2	6	5 (cut Saturday)	Swap vessels between these two routes		Now both have scrubbers (not in the past)		
Rotterdam – Felixstowe	7.5	+0.5,1	16	Not relevant (3/weekday fixed schedule)			All vessels now have scrubbers (Anglia Seaways was the last to be retrofitted)		
Copenhagen – Oslo	17	+0.5,1, 2 (more revenue onboard)	Not relevant as doing well		Not relevant, could swap with AMS-NEW		Crown has scrubber-Fit scrubber on Pearl was ruled out by DFDS		
Klaipeda – Kiel	20	-1.5 (actually happened) +0.5	7	6	Swap vessels between these two routes		All vessels have scrubbers		
Klaipeda – Karlshamn	12/13-15	+1,2	7	6			Athena was the last vessel that was retrofitted		
Dover – Calais	Not relevant due to low sailing time		75 weekday 13 Saturday 11 Sunday	75	Not relevant due to loading/unloading uniqueness of vessels		Current deployed have scrubbers (not in the past)		

Summary of Results – Ro-Ro Operators measures

The process


For each of the three Fuel Case Scenarios
Do Nothing
Deploy Ro-Ro Operator's measure
Estimate composite generalized cost GCM
Find new market shares
Estimate New Profitability (2015)
Estimate New Env. Performance (2015)

Speed Reduction

Gothenburg – Ghent

Effects of Speed on fuel consumption

Gothenburg – Ghent (Normal sailing time 32 hours)

Ship	Hours at berth	Hours sailing	Weekly fuel consumption (tonnes)	Reduction (%)
Baseline Sailing Speed **18.06 knots**				
Ship A	38	130	294.354	NA
Ship B			305.564	
Ship C			270.198	
Ship D			277.407	
Increase Trip by **1 hour**, New Sailing Speed **17.51 knots**				
Ship A	32	136	264.585	-10.11
Ship B			273.453	-10.51
Ship C			245.181	-9.26
Ship D			253.777	-8.52
Increase Trip by **2 hours**, New Sailing Speed **16.99 knots**				
Ship A	26	142	240.315	-18.36
Ship B			247.638	-18.96
Ship C			222.784	-17.55
Ship D			231.167	-16.67
Increase Trip by **3 hours**, New Sailing Speed **16.51 knots**				
Ship A	20	148	191.740	-34.86
Ship B			196.167	-35.80
Ship C			177.715	-34.23
Ship D			185.196	-33.24

Effects of Speed on cargo, revenue, fuel cost

Gothenburg – Ghent (Normal sailing time 32 hours)

Increase Trip by 1 hour, New Sailing Speed 17.51				
	Transported lm	Capacity Utilization (%)	Revenue (€)	Cost of Fuel (€)
Fuel Case 1	42309	85.99	2003326	185559
Fuel Case 2	39389	89.01	2048240	376057
Fuel Case 3	43815	79.8	1972660	180155
Increase Trip by 2 hours, New Sailing Speed 16.99				
Fuel Case 1	42287	85.87	2002281	168387
Fuel Case 2	39255	79.71	2041251	341255
Fuel Case 3	43793	88.92	1970699	163482
Increase Trip by 3 hours, New Sailing Speed 16.51				
Fuel Case 1	42265	85.82	2001233	134006
Fuel Case 2	39232	79.66	2040081	271579
Fuel Case 3	43772	88.88	1969719	130103

Esbjerg – Immingham

Effects of Speed on fuel consumption

Esbjerg – Immingham (Fuel consumption per hour)

Ship	Average Fuel ME (tonnes per hour)	Average AE (tonnes per hour, cruise)	Average Fuel port (tonnes per hour, berth)
Baseline Sailing Speed 18.11 knots			
Ark Germania	**2.158**	**Included in ME**	**0.392**
Ark Dania	**2.520**		**0.400**
Increase Trip by 0.5 hour, New Sailing Speed 17.62			
Ark Germania	**1.960**	**Included in ME**	**0.392**
Ark Dania	**2.289**		**0.400**
Increase Trip by 1 hour, New Sailing Speed 17.16			
Ark Germania	**1.786**	**Included in ME**	**0.392**
Ark Dania	**2.085**		**0.400**
Increase Trip by 2 hours, New Sailing Speed 16.3			
Ark Germania	**1.492**	**Included in ME**	**0.392**
Ark Dania	**1.743**		**0.400**

Effects of Speed on fuel consumption

Esbjerg – Immingham (Fuel consumption savings)

Ship	Hours at berth	Hours sailing	Weekly fuel consumption (tonnes)	Reduction (%)
Baseline Sailing Speed 18.11 knots				
Ark Germania	60	108	257	NA
Ark Dania			296	
Increase Trip by 0.5 hour, New Sailing Speed 17.62				
Ark Germania	57	111	240	-6.47
Ark Dania			254	-14.19
Increase Trip by 1 hour, New Sailing Speed 16.53				
Ark Germania	54	114	225	-12.40
Ark Dania			238	-19.72
Increase Trip by 2 hours, New Sailing Speed 15.86				
Ark Germania	48	120	198	-22.87
Ark Dania			209	-29.38

Rotterdam – Felixstowe

Effects of Speed on fuel consumption

Rotterdam – Felixstowe (Fuel consumption per hour)

Ship	Average Fuel ME (tonnes per hour)	Average AE (tonnes per hour, cruise)	Average Fuel port (tonnes per hour, berth)
Baseline Sailing Speed 16.11 knots			
Suecia	**1.745**	**0.094**	**0.291**
Selandia	**1.836**	**0.144**	**0.350**
Anglia	**1.348**	**Included in ME**	**0.399**
Increase Trip by 0.5 hour, New Sailing Speed 14.67 knots			
Suecia	**1.250**	**0.094**	**0.291**
Selandia	**1.316**	**0.144**	**0.350**
Anglia	**0.966**	**Included in ME**	**0.399**
Increase Trip by 1 hour, New Sailing Speed 13.44 knots			
Suecia	**0.922**	**0.094**	**0.291**
Selandia	**0.970**	**0.144**	**0.350**
Anglia	**0.712**	**Included in ME**	**0.399**

Effects of Speed on fuel consumption

Rotterdam – Felixstowe (Fuel consumption savings)

Ship	Hours at berth	Hours sailing	Weekly fuel consumption (tonnes)	Reduction (%)
Baseline Sailing Speed 16.11 knots				
Suecia	88	80	172.682	NA
Selandia			189.241	
Anglia			142.978	
Increase Trip by 0.5 hour, New Sailing Speed 14.67				
Suecia	80	88	141.507	-18.05
Selandia			156.446	-17.33
Anglia			116.918	-18.23
Increase Trip by 1 hour, New Sailing Speed 13.44				
Suecia	72	96	118.425	-31.42
Selandia			132.167	-30.16
Anglia			97.110	-32.08

Copenhagen – Oslo

Effects of Speed on fuel consumption

Copenhagen – Oslo (Fuel consumption per hour)

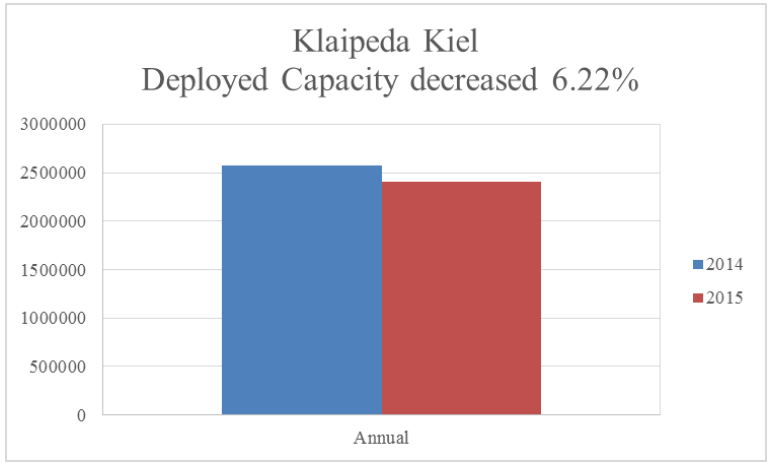
Ship	Average Fuel ME (tonnes per hour)	Average AE (tonnes per hour, cruise)	Average Fuel port (tonnes per hour, berth)
Baseline Sailing Speed 15.54 knots			
Crown Seaways	**1.750**	**0.441**	**0.380**
Pearl Seaways	**1.503**	**0.453**	**0.381**
Increase Trip by 0.5 hour, New Sailing Speed 15.11			
Crown Seaways	**1.586**	**0.441**	**0.380**
Pearl Seaways	**1.362**	**0.453**	**0.381**
Increase Trip by 1 hour, New Sailing Speed 14.70			
Crown Seaways	**1.441**	**0.441**	**0.380**
Pearl Seaways	**1.237**	**0.453**	**0.381**

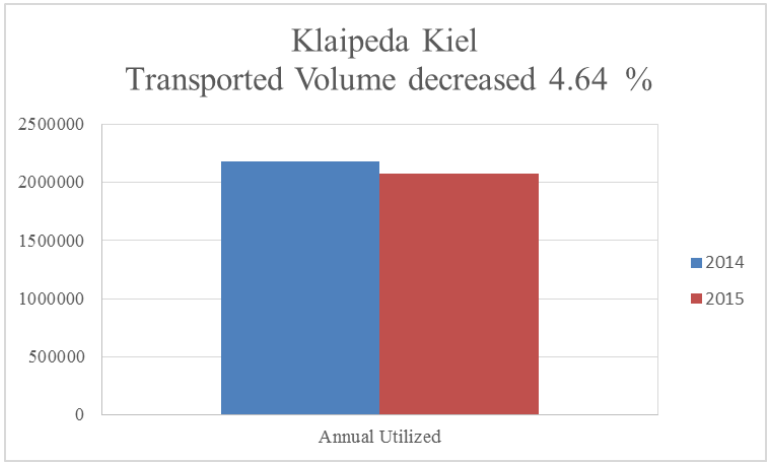
Effects of Speed on fuel consumption

Copenhagen – Oslo (Fuel consumption savings)

Ship	Hours at berth	Hours sailing	Fuel consumption (tonnes)	Reduction (%)
Baseline Sailing Speed 15.54 knots				
Crown Seaways	45.5	122.5	285.650	NA
Pearl Seaways			256.894	
Increase Trip by 0.5 hour, New Sailing Speed 15.11				
Crown Seaways	42	126	271.285	-5.03
Pearl Seaways			244.625	-4.78
Increase Trip by 1 hour, New Sailing Speed 14.70				
Crown Seaways	38.5	129.5	258.270	-9.59
Pearl Seaways			233.516	-9.10

Klaipeda – Kiel





Effects of Speed on fuel consumption

Klaipeda – Kiel (Fuel consumption per hour)

Ship	Average Fuel ME (tonnes per hour)	Average AE (tonnes per hour, cruise)	Average Fuel port (tonnes per hour, berth)
Baseline Sailing Speed 18.39 knots			
Victoria Seaways	2.139	0.159	0.456
Optima Seaways	2.664	Included in ME	0.471
Increase Trip by 0.5 hour, New Sailing Speed 17.98			
Victoria Seaways	1.988	0.159	0.456
Optima Seaways	2.476	Included in ME	0.471
Decrease Trip by 1.5 hour, New Sailing Speed 19.77			
Victoria Seaways	2.694	0.159	0.456
Optima Seaways	3.355	Included in ME	0.471

Effects of Speed on fuel consumption

Klaipeda – Kiel (Fuel consumption change)

Ship	Hours at berth	Hours sailing	Fuel consumption (tonnes)	Change (%)
Baseline Sailing Speed 18.39 knots				
Victoria Seaways	17	151	354.995	NA
Optima Seaways			410.508	
Increase Trip by 0.5 hour, New Sailing Speed 17.98				
Victoria Seaways	13.4	154.6	338.076	-4.77
Optima Seaways			389.081	-5.22
Decrease Trip by 1.5 hour, New Sailing Speed 19.77				
Victoria Seaways	27.4	140.6	413.610	16.51
Optima Seaways			484.574	18.04

Klaipeda – Karlshamn

Effects of Speed on fuel consumption

Klaipeda – Karlshamn (Fuel consumption change)

Ship	Hours at berth	Hours sailing	Fuel consumption (tonnes)	Change (%)
Baseline Sailing Speed 17.15 knots				
Athena Seaways	77	91	205.268	NA
Regina Seaways			210.671	
Increase Trip by 1 hour, New Sailing Speed 15.93				
Athena Seaways	70	98	178.696	-12.94
Regina Seaways			183.801	-12.75
Increase Trip by 2 hour, New Sailing Speed 14.87				
Athena Seaways	63	105	157.590	-23.23
Regina Seaways			162.430	-22.90

New sailing frequency

Esbjerg – Immingham (Baseline 6 sailing per week)

	New sailing frequency	New Transported lm	New capacity utilization	ΔRevenue (€)	ΔFuel Cost (€)
Fuel Case 2	5	29060	96.86	-112273	-33579
Fuel Case 3	7	34475	82.02	39897	16569

Klaipeda – Kiel (Baseline frequency: 7 per week)

	New sailing frequency	New Transported lm	New capacity utilization	ΔRevenue	ΔFuel Cost
Fuel Case 1	6	26900	97.36	-32419	-28172
Fuel Case 2	6	25950	96.19	-25082	-57093

Klaipeda – Karlshamn (Baseline frequency: 7 per week)

	New sailing frequency	New Transported lm	New capacity utilization	ΔRevenue	ΔFuel Cost
Fuel Case 1	6	26141	87.38	-4699	-13169
Fuel Case 2	6	24453	81.73	-5985	-26688

Vessel swapping (for 1 week)

Gothenburg – Ghent (Illustrative, some crude assumptions)

	Capacity utilization	ΔFuel Cost (€)
Fuel Case 1	92.08	4662
Fuel Case 2	85.49	9447
Fuel Case 3	95.36	4526

Rotterdam – Felixstowe

	Capacity utilization (%)	ΔFuel Cost (€)
Fuel Case 1	79.52	10331
Fuel Case 2	82.85	20938
Fuel Case 3	75.78	10030

Dover – Calais

New sailing frequency

Dover – Calais (Baseline frequency: 99 per week)

	New sailing frequency	New Transported lm	New capacity utilization	ΔRevenue	ΔFuel Cost
Fuel Case 1	75	131724	94.63	-56039	-58844
Fuel Case 2	75	130760	88.25	-74580	-119255

General measures

- Scrubber in more vessels

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

General measures

- LNG as fuel

HFO (€/ton)	*MGO (€/ton)*	*LNG (€/ton)*	*Annual LNG Savings (M€)*	*LNG Payback period (years)*
135	304	250	727121	23
237	480	485	605132	35
590	880	610	2788661	4.9
803	1212	740	4443090	2.5

Conclusions on measures by Ro-Ro operator

- Slow steaming reduces fuel consumption (low speed - less hours at port)
- Constraints on allowed increase of sailing time
- In 2016 certain routes actually sped up
- Frequency of sailing service can be used to improve load factors
- Mainly on very frequent services. On 6/7 sailings per week, some flexibility
- Vessel swapping can help with load factors
- Investing in scrubbers critically depends on fuel prices, and level of subsidies

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Task 3.2: Policy measures

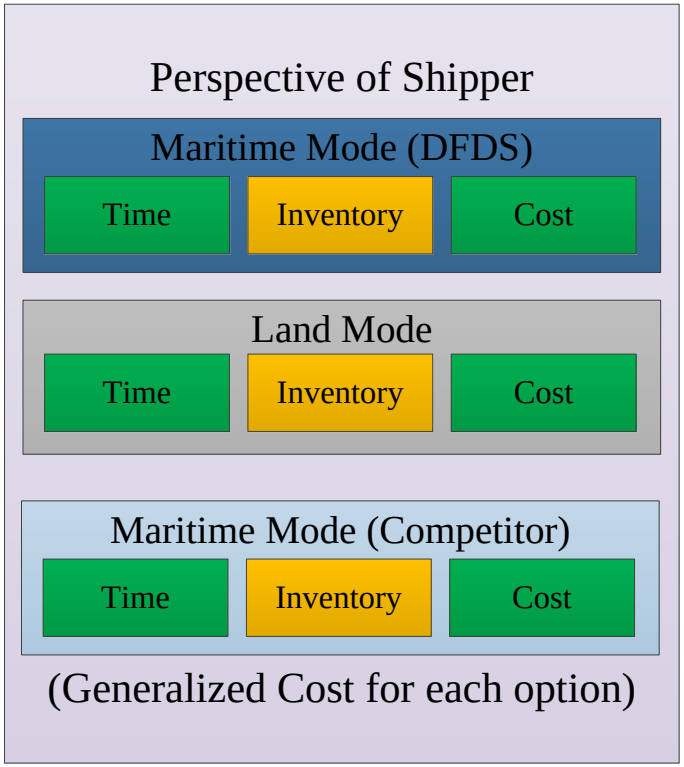
- Following identification of negative effects of the new limit

- Consider the following policy measures to reverse/mitigate these effects

  - Full or partial internalization of external costs, all modes
  - Easing of port dues/fairway dues for relevant shipping
  - ECO bonus-like system, with refund to freight haulers boarding a vessel
  - Subsidies for environmental investments (LNG, scrubbers, others)
  - Additional tax on landbased modes
  - Other policy measures?

Perspective of the Shipper

- Neutralize the relative increase of the freight rates from maritime modes
- By either covering the additional cost as a consequence of the low-sulphur requirment
- Increasing similarly the cost of unaffected competing modes



Objectives of Task 3.2

- Quantify external costs for all modes
- Estimate cost of bunker adjustment factor surcharges on shippers
- Retrieve port fees/fairway dues for the examined routes
- Impacts of new policies on the competitive border with land-based modes
- Impact of proposed policies on mode share

Addressing Objectives of Task 3.2

- Quantify external costs for all modes
- Methodology to be presented..

- Estimate cost of bunker adjustment factor surcharges on shippers
- Module that is based on historic data and DFDS – BAF rule

- Retrieve port fees/fairway dues for the examined routes
- Based on port tariffs and online sources. Fraction of cost for Ro-Ro Operator

- Impacts of new policies on the competitive border with land-based modes
- Runs on Network model – to be presented

- Impact of proposed policies on mode share
- Runs on modal split models after each intervention

Flow of Task 3.2

- Selection of appropriate policy measures
- Estimation of external costs of transport
- Formulate cost functions for each measure
- Simulation for all Routes, for three fuel price scenarios
- Modal shifts using calibration results of Task 2.2
- Output of Task 3.2 (Deliverable) – Month 25

External costs: types and sources of information

Types of external costs
- Air pollution
- Climate change
- Noise
- Accidents
- Congestion
- Infrastructure

Sources of information
- COWI/DTU (Danish Ministry of Transport, Building and Housing)
- External Costs Handbook (EU Commission)

COWI/DTU (Danish Ministry of Transport)

Unit value of emissions (2016 prices)						
DKK/kg	Urban			Rural		
	Low	Medium	High	Low	Medium	High
CO2	0.0542	0.0821	0.0821	0.0542	0.0821	0.0821
PM2,5	250.6315	1,748.8991	11,812.8500	34.9406	243.8143	1,646.8316
NOx	4.5318	53.2263	408.8154	0.0326	53.2263	375.3265
SO2	57.2518	241.1759	1,146.5725	10.6948	208.5430	1,259.7542
CO	0.0045	0.0242	3.0998	0.0000	0.0087	1.1089
HC	0.5841	2.9200	16.7287	0.5220	2.4788	14.5675

Urban: A built-up area where the distance between the buildings is not more than 200 metres, unless the interruption is due to public facilities, parks, cemeteries, etc.(UN definition of urban areas).

COWI/DTU (Danish Ministry of Transport)

Marginal external costs (2016 prices)								MEDIUM VALUES		
DKK/Km		Capacity	Air pollution	Climate change	Noise	Accidents	Congestion	Infrastructure	Health	TOTAL
Bicycle (only urban)		1 pers	0.0000	0.0000	0.0000	0.8771	0.0000	0.0000	-2.5717	-1.6946
Passenger car	Gasoline	4 pers	0.0124	0.0149	0.0534	0.2320	0.3762	0.0108		0.6998
	Diesel	4 pers	0.0498	0.0124	0.0534	0.2320	0.3762	0.0108		0.7347
	Electrical	4 pers	0.0107	0.0060	0.0200	0.2320	0.3762	0.0108		0.6558
Van	Gasoline	1.5 t	0.0249	0.0268	0.0741	0.1831	0.5223	0.0174		0.8486
	Diesel	1.5 t	0.1183	0.0226	0.0741	0.1831	0.5223	0.0174		0.9378
Truck	Diesel	23.2 t	0.5102	0.0813	0.1087	1.3852	0.6445	1.1296		3.8595
Bus	Diesel	46 pers	0.9537	0.0886	0.2358	0.5154	0.7034	0.6199		3.1167
Passenger train	Electrical	481 pers	0.8272	0.4967	0.3492	2.5603				4.2334
	Diesel	270 pers	3.0057	0.3610	0.3492	2.5603				6.2762
Freight train	Electrical	659 t	1.5972	0.8931	2.0054	2.9633				7.4590
	Diesel	496 t	13.7206	1.0116	2.0054	2.9633				19.7008
Passenger plane	Jet	120 pers	6.6564	2.1276						8.7840
	Turboprop	60 pers	1.0563	0.4649						1.5212
Coastal vessel		2,000 t	147.6309	2.1518						149.7828
Containership		3,500 t	379.9367	5.5379						385.4746

Average load per truck (tons)	9.4

Truck, Low values	0.8586	1 : 4.5
Truck, Medium values	3.8595	1 : 1
Truck, High values	9.3142	2.4 : 1

Handbook, Air pollution

Damage costs of main pollutants from transport, in € per tonne (2010)

Urban: 1,500 residents/km^2
Suburban: 300 -"-
Rural: <150 -"-

	$PM_{2.5}$			NO_x	NMVOC	SO_2
Country	**Rural**	**Suburban**	**Urban**			
Austria	37766	67839	215079	17285	2025	12659
Belgium	34788	60407	207647	10927	3228	13622
Bulgaria	34862	65635	212875	14454	756	12598
Croatia	31649	61539	208779	15149	1819	12317
Cyprus	25040	51200	198440	6465	1122	12594
Czech Republic	43028	68427	215667	15788	1648	14112
Germany	48583	73221	220461	17039	1858	14516
Denmark	13275	40760	188000	6703	1531	7286
Estonia	15359	49948	197188	5221	1115	8441
Spain	14429	48012	195252	4964	1135	7052
Finland	8292	43997	191237	3328	781	4507
France	33303	64555	211795	13052	1695	12312
Greece	19329	50605	197845	3851	854	8210
Hungary	47205	74641	221881	19580	1569	14348
Ireland	16512	47420	194660	5688	1398	6959
Italy	24562	50121	197361	10824	1242	9875
Lithuania	23068	55535	202775	10790	1511	10945
Luxembourg	45688	71308	218548	18612	3506	15103
Latvia	19528	53638	200878	8109	1499	10000
Malta	NA	NA	98132	1983	1007	6420
Netherlands	29456	48352	195592	11574	2755	16738
Poland	47491	74215	221455	13434	1678	14435
Portugal	18371	49095	196335	1957	1048	4950
Romania	56405	84380	231620	22893	1796	17524
Sweden	14578	50210	197450	5247	974	5389
Slovenia	39633	67670	214910	16067	1975	12422
Slovakia	54030	79270	226510	21491	1709	17134
United Kingdom	14026	47511	194751	6576	1780	9192
EU average	**28108**	**70258**	**270178**	**10640**	**1566**	**10241**

Sea region	**NMVOC**	**NOx**	**$PM_{2.5}$**	**SO_2**
Baltic Sea	1100	4700	13800	5250
Black Sea	500	4200	22550	7950
Mediterranean Sea	750	1850	18500	6700
North Sea	2100	5950	25800	7600
Remaining North-East Atlantic	700	2250	5550	2900

Handbook, Air pollution

Marginal external air pollution costs (in 2010 prices)

Mode	Determinants	Min value	Max value
Road (€ct/vkm)	• Country • Vehicle type (LDV petrol, LDV diesel, rigid truck, articulated truck) • Size (<=7.5t, 7.5-12t, 12-14t, 14-20t, 20-26t, 26-28t, 28-32t, >32t) • EURO-class (0 to VI) • Road type (urban, suburban, interurban, motorway)	0.1 [FI, rigid HGV, <=7.5t, EURO VI, motorway]	52.1 [NL, articulated truck, 50-60t, EURO 0, urban]
Rail (€ct/locomotive-km)	• Country • Type of train (diesel, electric) • Region (urban, suburban, rural)	12.4 [FI, electric, rural]	506.5 [DE, diesel, rural]
Maritime (€/1000 tkm)	• Type of ship (crude oil tanker, product tanker, general cargo, bulk carrier) • Size of ship (feeder, handysize, handymax) • Region (Baltic Sea, Black Sea, North Sea, Mediterranean Sea, Remaining North-East Atlantic)	0.45 [crude oil tanker, 80-120 kt, N-E Atlantic]	9.09 [product tanker, 0-5 kt, North Sea]

Handbook, Climate change

- Central value: €90 per tonne
- Range of values: €48 - €168 per tonne
- GHG consist of CO2 (GWP=1), CH4 (GWP=25) and N2O (GWP=298)

Fuel	kg CO_2 per litre of fuel	g CH_4 per litre of fuel	g N_2O per litre of fuel	Climate change cost, €ct per litre of fuel
Gasoline	2.25	0.81	0.26	21.1
Diesel (road and rail)	2.66	0.14	0.14	24.3
Marine diesel oil	2.99	0.27	0.08	27.2
Jet kerosene	2.86	0.02	0.08	26.0
LPG (50% propane + 50% butane)	1.77	1.74	0.01	16.3
CNG (methane)	1.57	2.58	0.08	14.9

Handbook, Climate change

Marginal external climate change costs (in 2010 prices)

Mode	Determinants	Min value	Max value
Road (€ct/vkm)	• Vehicle type (LDV petrol, LDV diesel, HGVs) • Size (<=7.5t, 7.5-16t, 16-32t, >32t) • EURO-class (0 to V) • Road type (urban, rural, motorway)	2.3 [HGV, <=7.5t, EURO V, rural]	13.2 [HGV, >32t, EURO 0, urban]
Rail (€ct/locomotive-km)	• Type of train (diesel, electric) • Region (urban, non-urban)	0.0 [electric, urban]	126.31 [diesel, non-urban]
Maritime (€/1000 tkm)	• Type of ship (crude oil tanker, product tanker, general cargo, bulk carrier) • Size of ship (feeder, handysize, handymax)	0.5 [crude oil tanker, 80-120 kt] & [bulk carrier, handymax]	4.1 [product tanker, 0-5 kt]

Handbook, Noise

Marginal external noise costs (in 2010 prices)

Mode	Determinants	Min value	Max value
Road (€/1000 vkm)	• Country • Vehicle type (LDV, HGV) • Time of day (day, night) • Traffic type (dense, thin) • Region (urban, suburban, rural)	0.4 [LV, HGV, day, dense, rural]	52.1 [NL, HGV, night, thin, urban]
Rail (€/1000 vkm)	• Country • Type of train (passenger, freight) • Time of day (day, night) • Traffic type (dense, thin) • Region (urban, suburban, rural)	13.1 [LV, freight, day, dense, suburban]	2634.1 [NL, freight, night, urban]

Urban: 3,000 residents/km of road length
Suburban: 700 -"-
Rural: 500 -"-

Handbook, Accident

Marginal accident costs (in 2010 prices)

Mode	Determinants	Min value	Max value
Road (€ct/vkm)	• Country • Vehicle type (car, HGV, motorcycle) • Road type (motorway, other non-urban, urban)	0.2 [FI, HGV, motorway]	3.0 [BE, HGV, motorway]
Rail (€/1000 vkm)	N/A	0.2	

Handbook, Congestion

Efficient marginal congestion costs (in 2010 prices)

Mode	Determinants	Min value	Max value
Road (€ct/vkm)	• Country • Vehicle type (rigid truck, articulated truck) • Region (metropolitan, urban, rural) • Road type (motorway, main road, other road) • Flow conditions (free flow, near capacity, over capacity)	0.0 [all countries, rigid truck, metropolitan, motorway, free flow]	937.0 [NL, articulated truck, metropolitan, other road, over capacity]
Rail (€/1000 tkm)	N/A	0.2	

Metropolitan: > 250,000 people
Urban: > 10,000 people
Rural: all other

Congestion band	Volume / Capacity
1 : free flow	v/c < 0.25
2	0.25 < v/c < 0.5
3	0.5 < v/c < 0.75
4 : near capacity	0.75 < v/c < 1
5 : over capacity	v/c > 1

Handbook, Infrastructure

Marginal infrastructure costs (in 2010 prices)

Mode	Determinants	Min value	Max value
Road (€ct/vkm)	• Country • Vehicle type (LDV, HGV) • Size (<=3.5t, 3.5-7.5t, 7.5-12t, 12-18t, 18-26t, 26-32t, 32-40t, 40-50t, 50-60t, 44t) • Number of axles (2, 3, 4, 5, 6, 8, 9) • Road type (motorways, other trunk roads, other roads)	0.0 [all countries, HGV, 3.5-7.5t, 2 axles, motorways]	163.7 [SE, HGV, 44t, 5 axles, other roads]
Rail (€/vkm)	N/A	0.2 – 0.7 (indicative only)	

Road types: According to the classification of the German road accounts

Road class	Class definition
Motorways	Federal motorways or municipal roads with freight traffic share > 6%
Other trunk roads	Federal roads or municipal roads with freight traffic share > 3 % and ≤ 6 %
Other roads	Municipal and district roads or municipal roads with freight traffic share ≤ 3 %

Marginal external costs (DKK/km)

Denmark
truck
diesel
23.2t
(2016 prices)

Type	Source	Low	Medium	High
Air pollution	COWI/DTU	0.0180	0.5102	3.6045
	EU Handbook (est.)	0.0166	N/A	1.7546
Climate change	COWI/DTU	0.0536	0.0813	0.0813
	EU Handbook (est.)	0.4573	N/A	0.8814
Noise	COWI/DTU	0.0543	0.1087	0.2174
	EU Handbook (est.)	0.0075	N/A	3.7843
Accidents	COWI/DTU	0.3034	1.3852	1.8234
	EU Handbook (est.)	0.0582	N/A	0.0915
Congestion	COWI/DTU	0.1468	0.6445	1.8931
	EU Handbook (est.)	0.0000	N/A	48.6950
Infrastructure	COWI/DTU	0.2824	1.1296	1.6944
	EU Handbook (est.)	0.2079	0.4989	2.7773

Marginal external costs (DKK/km)

Denmark freight train electrical 659t (2016 prices)

Type	Source	Low	Medium	High
Air pollution	COWI/DTU	0.0650	1.5972	10.3818
	EU Handbook (est.)	N/A	1.6548	N/A
Climate change	COWI/DTU	0.5891	0.8931	0.8931
	EU Handbook (est.)	N/A	0.0000	N/A
Noise	COWI/DTU	0.6685	2.0054	6.0161
	EU Handbook (est.)	0.2528	N/A	20.8925
Accidents	COWI/DTU	0.5927	2.9633	7.6058
	EU Handbook (est.)	N/A	0.0017	N/A

Denmark freight train diesel 496t (2016 prices)

Type	Source	Low	Medium	High
Air pollution	COWI/DTU	0.4425	13.7206	96.7266
	EU Handbook (est.)	N/A	15.6912	N/A
Climate change	COWI/DTU	0.6672	1.0116	1.0116
	EU Handbook (est.)	N/A	10.5032	N/A
Noise	COWI/DTU	0.6685	2.0054	6.0161
	EU Handbook (est.)	0.2528	N/A	20.8925
Accidents	COWI/DTU	0.5927	2.9633	7.6058
	EU Handbook (est.)	N/A	0.0017	N/A

Marginal external costs (DKK/km)

Denmark coastal vessel 2,000 dwt (2016 prices)

Type	Source	Low	Medium	High
Air pollution	COWI/DTU	7.2789	147.6309	935.9007
	EU Handbook (est.)	42.7412	N/A	58.0416
Climate change	COWI/DTU	1.4192	2.1518	2.1518
	EU Handbook (est.)	N/A	23.2831	N/A

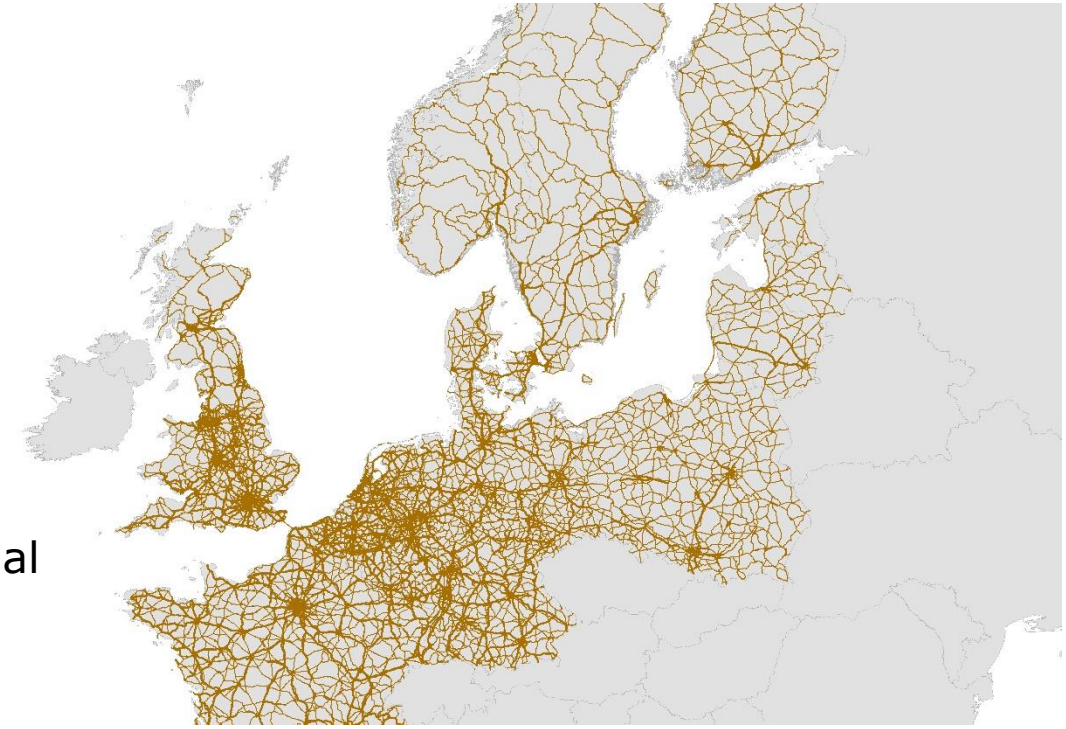
Conclusions on external costs

- Ro-Ro vessels are not covered by the official studies
- Estimates of external costs vary widely
- Need to be consistent

The digital network

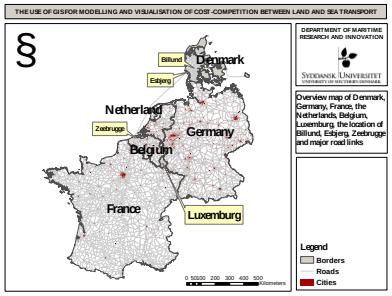
- Transport cost calculated for 1 truck with trailer (1 FEU)
- Driving cost on each road link (incl. Maut)
- Toll on fixed links (Great Belt, Øresundsbron)
- Fare on Eurotunnel
- Fares on sea links

- Initial calculations for 2 external cost scenarios:
  - No internalization for road transport and full internalization for sea transport
  - Full internalization for both road and sea transport

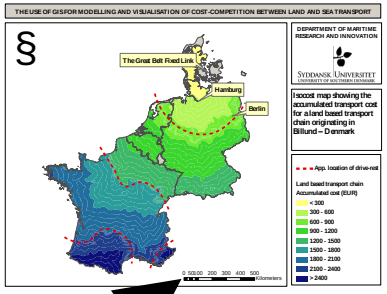


Modelling the transport cost

Intermodal
Digital network



Map of transport costs
Road transport



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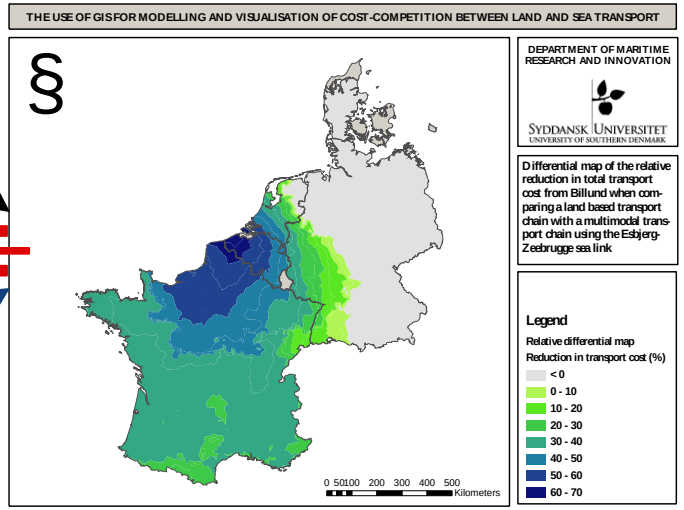
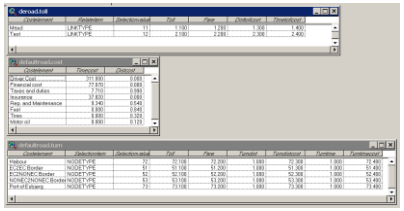
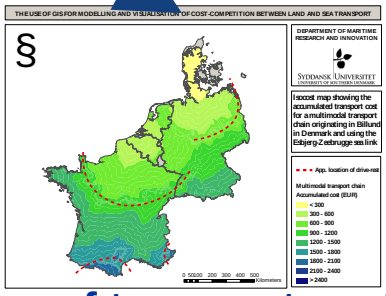
Visualisation of cost difference





User specified costs



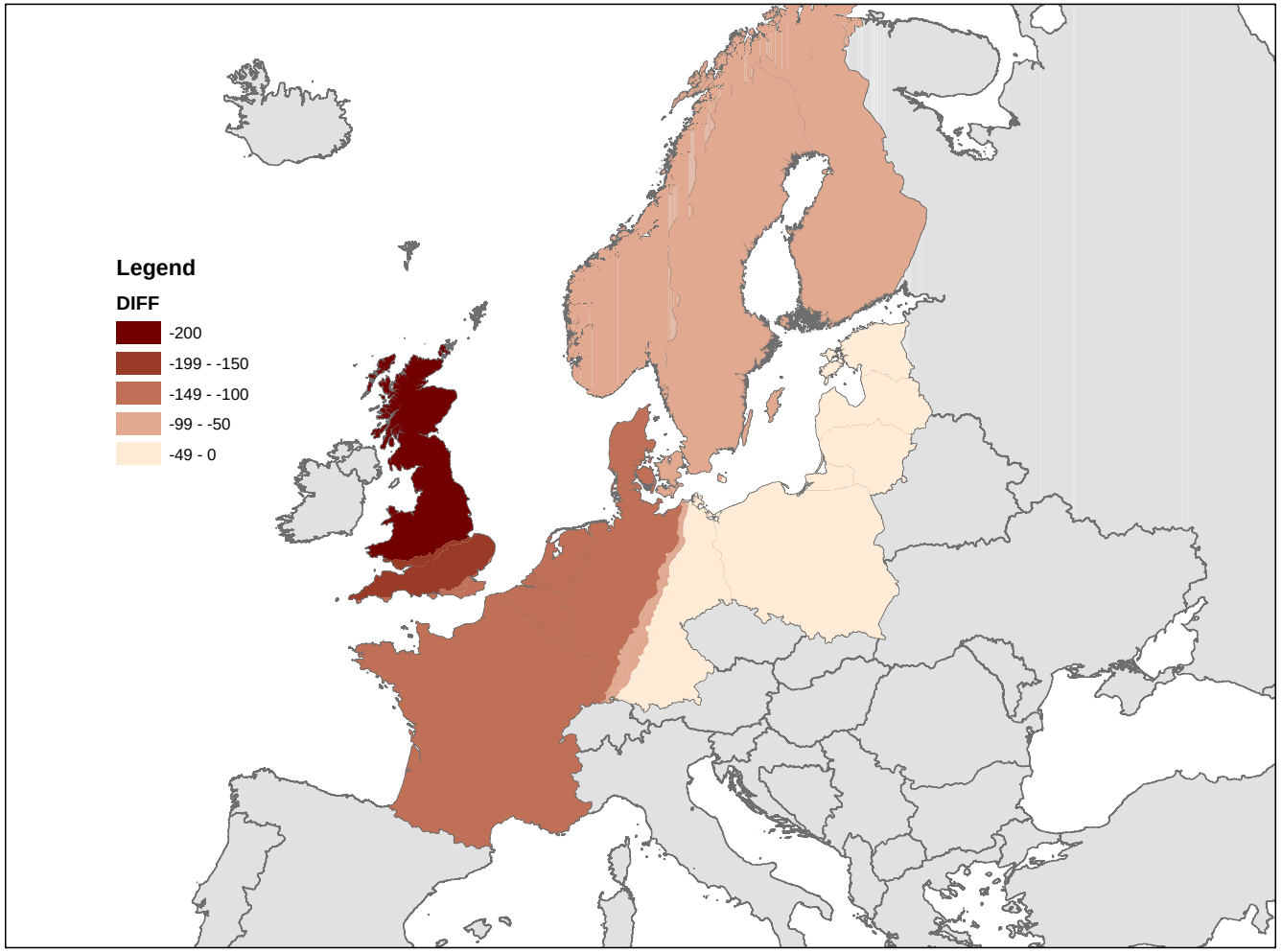
Map of transport costs
Intermodal transport

External costs

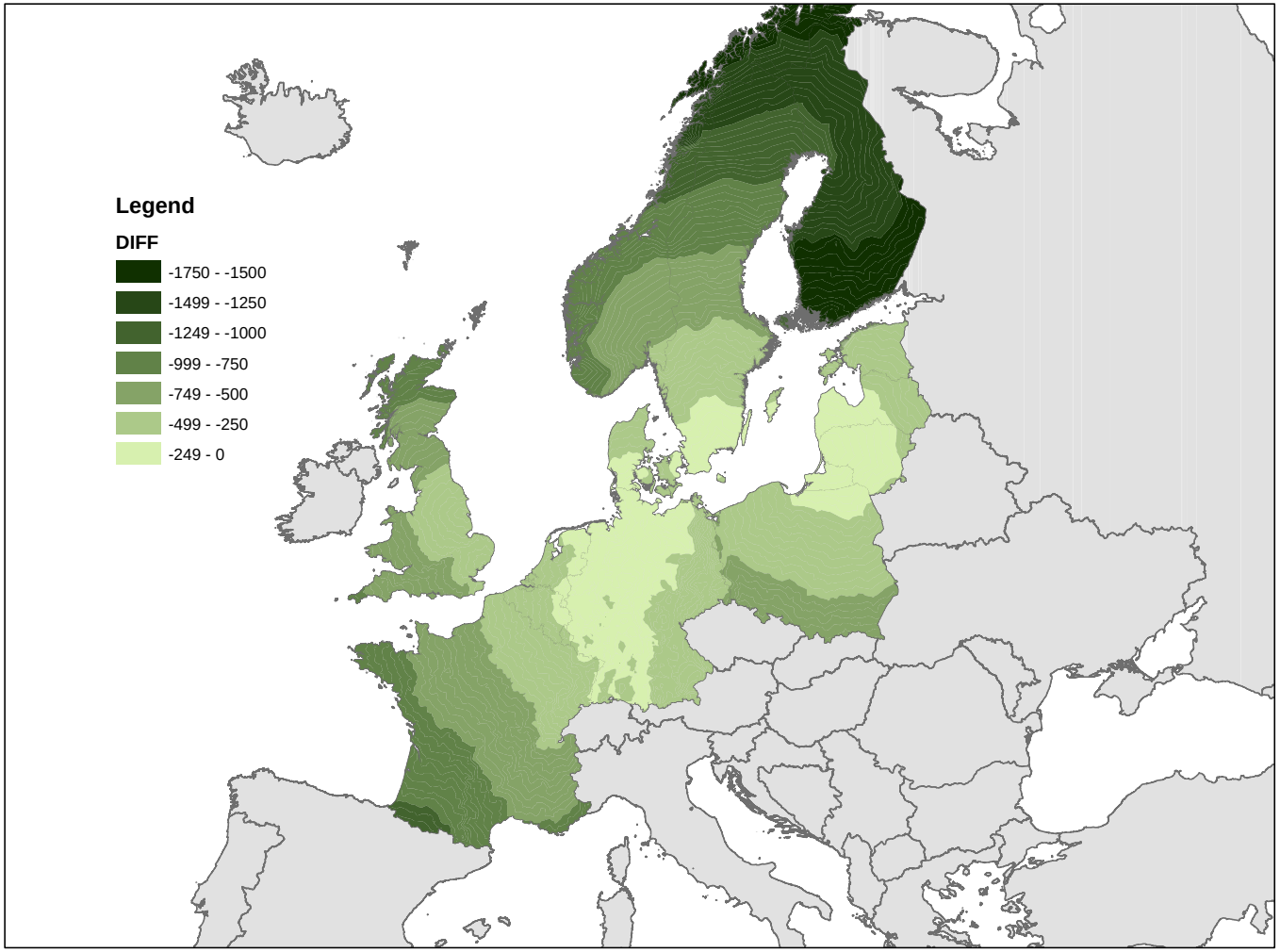
RoRo line	Direct Cost (EUR/trip) 2015	SECA Cost (EUR/trip) 2010
Gothenburg – Ghent	758	72
Esbjerg – Immingham	653	100
Rotterdam – Felixstowe	287	33
Copenhagen – Oslo	435	267
Klaipeda – Kiel	556	118
Klaipeda – Karlshamn	583	82
Dover - Calais	148	4

External cost/Road type	Average (EUR/km)
Congestion (main roads, near capacity)	0.41
Accidents (motorway, EU Average)	0.012
Air Pollution (sub-urban)	0.08
Noise (Day, Urban, Dense)	0.081
Climate (Average)	0.07
Infrastructure (HGV 26 - 32 t, 4 axles, all roads)	0.066
Sum	**0.719**

Change in cost from Klaipeda with full internalisation on sea transport



Change in cost from Klaipeda with full internalisation on sea and road transport



Summary of Results – Policy measures

Example of External Costs of emissions only (2015)

- For the DFDS routes, the external costs of emissions per lanemeter transported
- Using CO_2 (across route), SO_x and NO_x (port only)

Route	Freight Rate (€/lm) – 2015	External Cost of emissions (€/lm)
Gothenburg – Ghent	47.4	4.48
Esbjerg – Immingham	40.8	6.25
Rotterdam – Felixstowe	17.97	2.01
Copenhagen – Oslo	27.2	16.71*
Klaipeda – Kiel	34.8	7.35*
Klaipeda – Karlshamn	36.5	5.14*
Dover – Calais	9.3	0.23*

* Ships that also carry Passengers. Emissions attributed fully to cargo

Reimbursing the BAF

Route	Freight Rate (€/lm) – 2015	BAF surcharge		
		FC1	FC2	FC3
Gothenburg – Ghent	47.4	1.37	5.13	-2.57
Esbjerg – Immingham	40.8	1.19	4.30	-2.07
Rotterdam – Felixstowe	17.97	0.44	1.58	-0.76
Copenhagen – Oslo	27.2	1.19	4.30	-2.07
Klaipeda – Kiel	34.8	1.76	6.34	-3.04
Klaipeda – Karlshamn	36.5	1.01	3.65	-1.75
Dover – Calais	9.3	0.33	1.20	-0.59

- Esbjerg – Immingham (FC1)
  - If BAF was paid by policy
  - 2.22% increase in transport
  - Total Cost of 1.8M€ (for 2015)

Additional tax on landbased modes

- To cause a similar increase in the generalized cost of transport of competing modes
- Will also increase cost of maritime modes (the road parts)
- Use of GIS tool to show heatmaps on their effects

Adding a Landbased Tax Levy

- The amount depends
  - on road distance travelled
  - BAF surcharge on maritime leg
  - Average cargo value

- Klaipeda – Kiel (FC1)
  - Route that practically competes only with landbased modes
  - Maritime freight rate was decreased compared to 2014
  - Would have been further decreased without the regulation
  - The landbased cost of transport should increase by 7.05% (affecting also maritime option)

Conclusions on policy measures

- Freight Rate is the most important component for the shipper
- Requirements for policy measures to mitigate potential modal shifts
- For a policy measure to be succesful, the BAF effect needs to be mitigated
- Typical annual costs for full mitigation is 2M€ per route
- Policies sensitive to fuel price. E.g. FC2 the same route could cost more than 4M€
- BAF, eco-bonus, external costs have similar effects
- Q: who pays?

Global conclusion of project

- **RoRo shipping got lucky on SECAs**
- **But needs to be on the alert**

Possible users and uses of the tools developed in the RoRoSECA project

A. USERS

- RoRo operators
- Intermodal operators
- Other short sea shipping companies operating in ECAs
- Maritime policy makers incl. the EU

Possible users and uses of the tools developed in the RoRoSECA project

B. USES

- Estimate emissions and external costs
- Evaluate possible modal shifts in ECAs
- Evaluate possible modal shifts when 0.5% global S cap applies in 2020
- Assess the merits of alternative mitigation measures
- Assess the merits of alternative mitigation policies
- Identify routes that exhibit risk of being non-viable
- Assist operators and policy makers perform “what if” analyses of alternative scenarios
- Assist operators and policy makers select among alternatives

Thank you