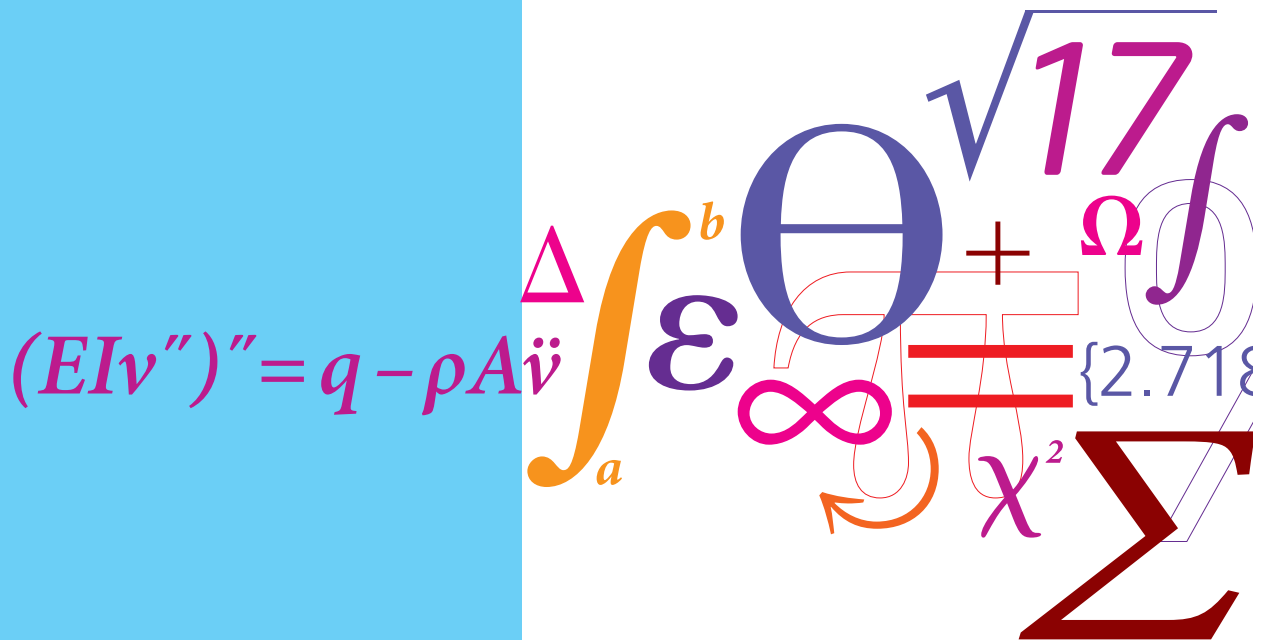


Emissions and external cost calculations for small cargo ships (1000 - 6000 DWT) compared with cargo transport by truck (Euro Norm 4 truck carrying 25 tons cargo)

Technical Report



Hans Otto Kristensen
19 February 2010

**Emissions and external cost calculations
for small cargo ships (1000 – 6000 DWT)
compared with cargo transport by truck
(Euro Norm 4 truck carrying 25 tons cargo)**

Carried out by

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Introduction

There is more and more attention on the environmental impact from ship transport compared with other transport means such as trucks. Especially in the so-called short sea shipping segment it is important to know the environmental impact from ships compared with transport by trucks as these are often used as alternative transport means – or used in conjunction with ship transport (intermodal transport chains).

In this report are shown results of emission calculations for ships and trucks and furthermore the external costs due to these two different transport modes are given, to give a more holistic view on the two transport forms.

Calculation model

A generic calculation model developed by the Department of Mechanical Engineering at The Technical University of Denmark (DTU) has been used for the calculations including exhaust gas emissions and the different types of external costs – both for ship and truck transportation. Based on the capacity of the ship, the DTU program calculates the main dimensions and other important data for the ship, such that the propulsion and auxiliary power requirement can be calculated. By specifying the sulphur content (in weight per cent) in the fuel oil and NOx requirements (Tier I, II and III) which shall be fulfilled the program is able to calculate the quantity of the different exhaust gas emissions given in gram per ton payload per km or nautical mile for the ship transport.

In a similar way - and using the same units - the energy demand and the exhaust gas emissions are calculated for transport by truck simply by specifying the cargo weight and which EURO norm the truck has to fulfil.

Based on the calculated exhaust gas emissions the external costs due to the emissions are calculated using an external cost model developed by DTU '*Transportøkonomiske enhedspriser, Version 1.2 – April 2009*'.

The energy demand and emissions for trucks are calculated by using values from the *TEMA 2000 emission model* from the Danish Ministry of Transport) supplemented and updated with emission data from the National Environmental Research Institute – University of Aarhus Denmark. (Danmarks Miljøundersøgelser). It is possible to specify 5 different EURO Norms, 2 (1996), 3 (2001), 4 (2006), 5 (2011) and 6 (2015) for trucks.

Ship particulars

4 different ship sizes have been analysed having a deadweight of 1000, 2000, 4000 and 6000 tons respectively. The particulars for these 4 ships are tabled in Appendix E, showing the output pages from the computer program. It is assumed that the payload to deadweight ratio is 0.90 i.e. the weight of the cargo is 90 % of the deadweight and by specifying the payload to deadweight ratio of 0.90, the model calculations are customised

to be valid for bulk cargo. For container cargo ships the payload to deadweight are normally lower due to the need for ballast water, some times as low as 0.65.

The calculations have been carried out for 4 scenarios as follows:

- A. 3 % sulphur content in the fuel oil, engines fulfilling IMO Tier I NO_x level and normal service speed
- B. 1 % sulphur content in the fuel oil, engines fulfilling IMO Tier I NO_x level and normal service speed
- C. 0.1 % sulphur content in the fuel oil, engines fulfilling IMO Tier I NO_x level and normal service speed
- D. 0.1 % sulphur content in the fuel oil, engines fulfilling IMO Tier I NO_x level and 10 % speed reduction compared to normal service speed

The change of sulphur content alters the SO_x and particulate emissions and the change of external costs due to these two emission products have been investigated and the results are shown in fig. 2.

Truck data

As mentioned earlier the energy demand and emission calculations for trucks are an integrated part of the total emission and external cost program for ships and trucks developed by DTU. The truck data have partly been collected from the TEMA 2000 emission model and have been supplemented with latest updated emission data from the National Environmental Research Institute – University of Aarhus Denmark. (Danmarks Miljøundersøgelser). The data from TEMA 2000 on energy demand and oil consumption have been compared with new truck data and it has been judged that the TEMA 2000 data still represents modern truck engine technology with respect to energy demand and thereby oil consumption.

In the present analysis exhaust gas emission comparisons have been carried out for a truck fulfilling EURO Norm 4, which has been valid from 2006. The cargo load on the truck is 25 tons which is found representative for a typical 'standard truck load'. The truck data are given in Appendix F.

The results are summarized in fig. 1, showing the CO₂ emissions per transport unit for two different speed levels for the cargo ships compared with truck transport. It is seen that the level of CO₂ emissions for truck transport is approximately 3 to 3.5 times higher than for ship transport at normal speed and approximately 3.5 to 4.5 higher with a speed reduction of 10 % compared to normal speed.

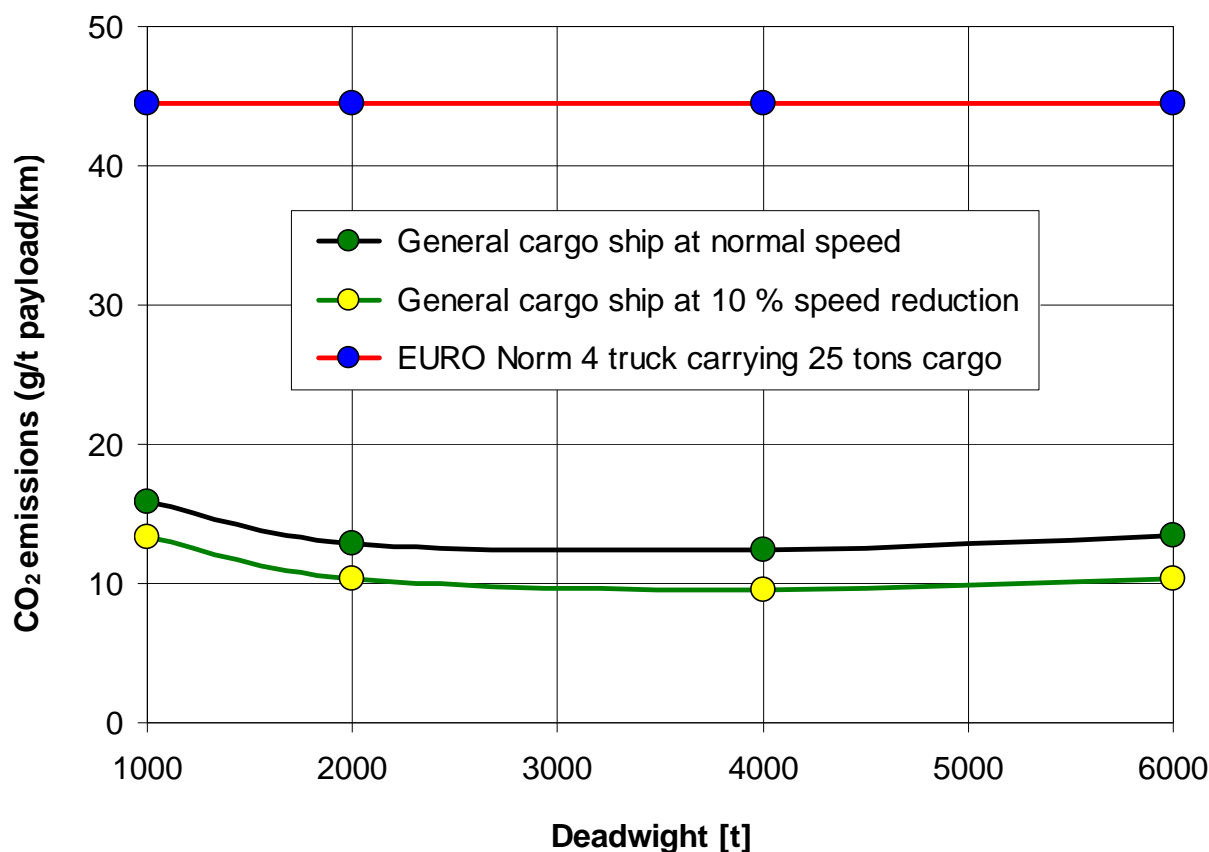


Fig. 1 CO₂ emissions for ship transport versus truck transport

External costs

The CO₂ emissions per transport unit is an environmental indicator which can be used for comparison between two transport modes as described in this report. However other emission products are also very important, such as NO_x, SO_x and particulates - the last product strongly related to the sulphur content in the oil used.

To get a total emission overview for comparison purposes it is advisable to calculate the total external costs to the society due to all the exhaust gas emissions – and finally to combine these calculations with the remaining external cost imposed by the two different transport modes. These additional costs are due to noise, congestion, accidents, infrastructure and climate change.

The external cost factors for all the above mentioned impacts used the computer program are listed in Appendix G according to DTU *‘Transportøkonomiske enhedspriser, Version 1.2 – April 2009’* and the results of the calculations are shown in fig. 2 for the different emission scenarios. It is seen that the influence of the sulphur content is pronounced such that the external cost ratio between truck transport and ship transport changes from approximately 4 with 3 % sulphur to approximately 8 for 1 % sulphur and 9 to 11 with 0.1 % sulphur and even 13 to 15 if the speed at the same time is reduced 10 %.

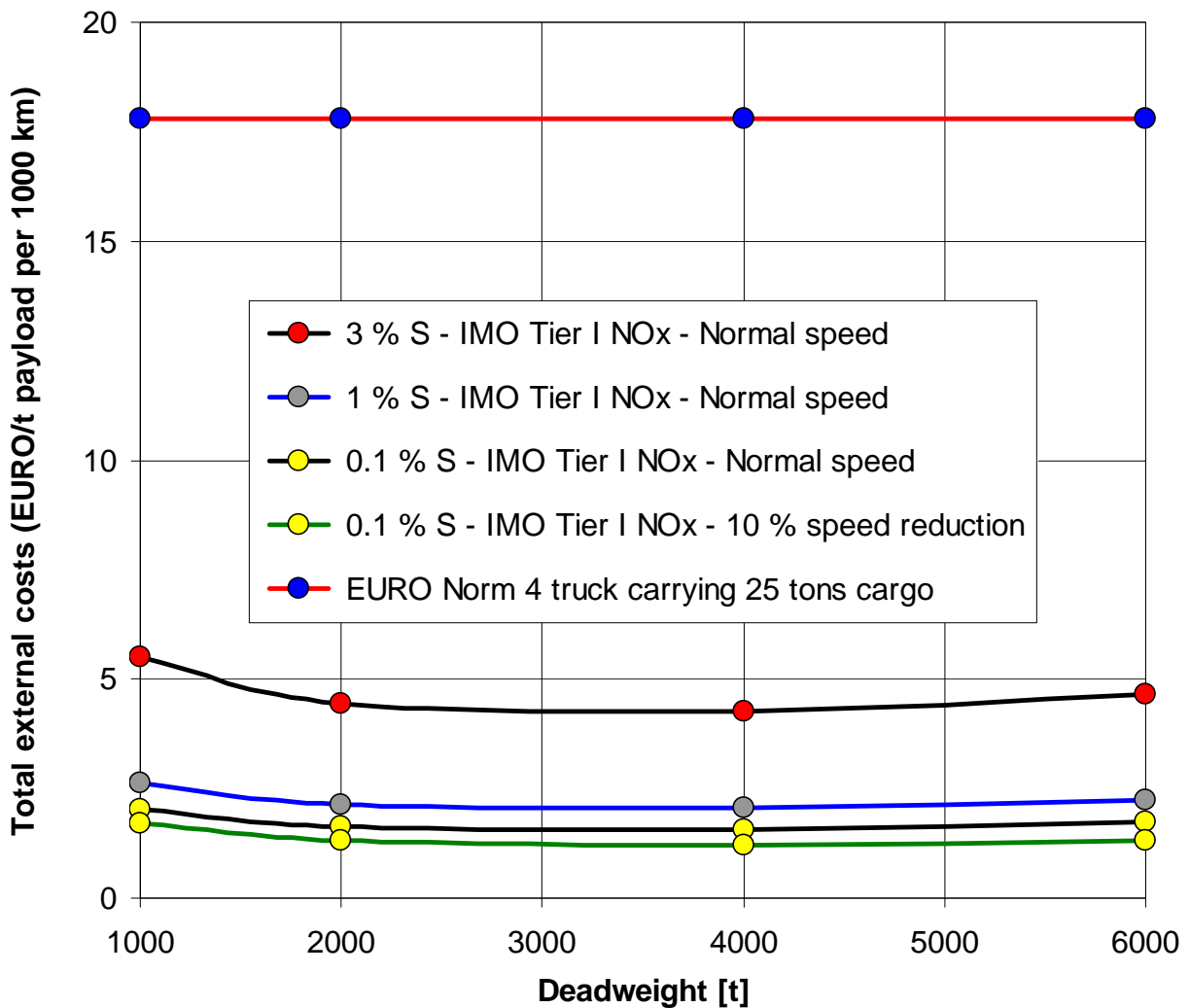


Fig. 2 Total external costs for different ship scenarios and for truck transport

Sensitivity analysis of external costs

The total external costs in fig. 2 are calculated on basis of mean cost values. To see the robustness of the calculations/comparisons, it is recommended to carry out a sensitivity analysis for the external cost calculations, using a low cost and a high cost level according to the methodology used in the external cost model from DTU: *'Transportøkonomiske enhedspriser, Version 1.2 – April 2009'*.

The sensitivity analysis has been carried out for the case with 1 % sulphur, Tier I NOx level and normal service speed, and the results of this analysis are shown in fig. 3, which show that the ratio between total external costs for truck transport and ship transport changes from approximately 8 to 4.5 and 5.5 with the high and low costs level respectively. But the total external costs due to ship transport are still clearly lower than for truck transport.

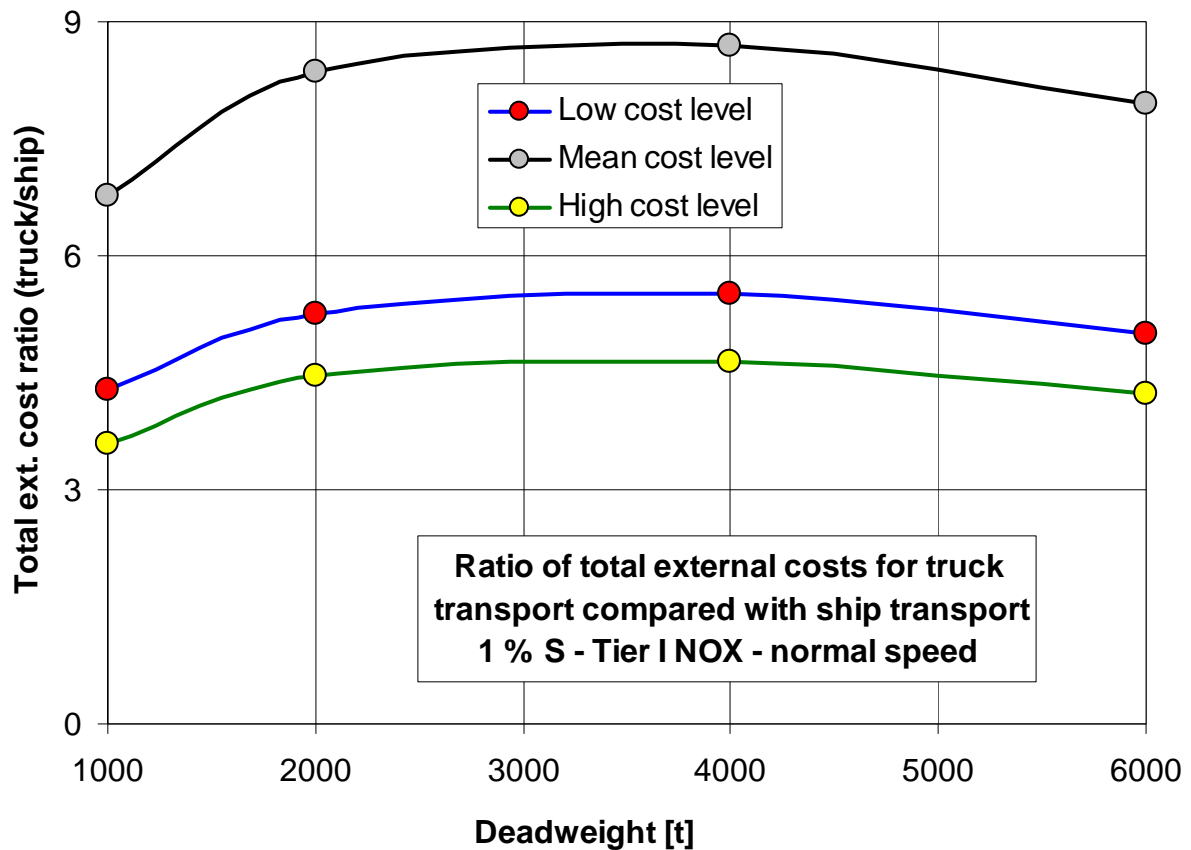


Fig. 3 Results of sensitivity analysis of external cost calculations

Conclusions

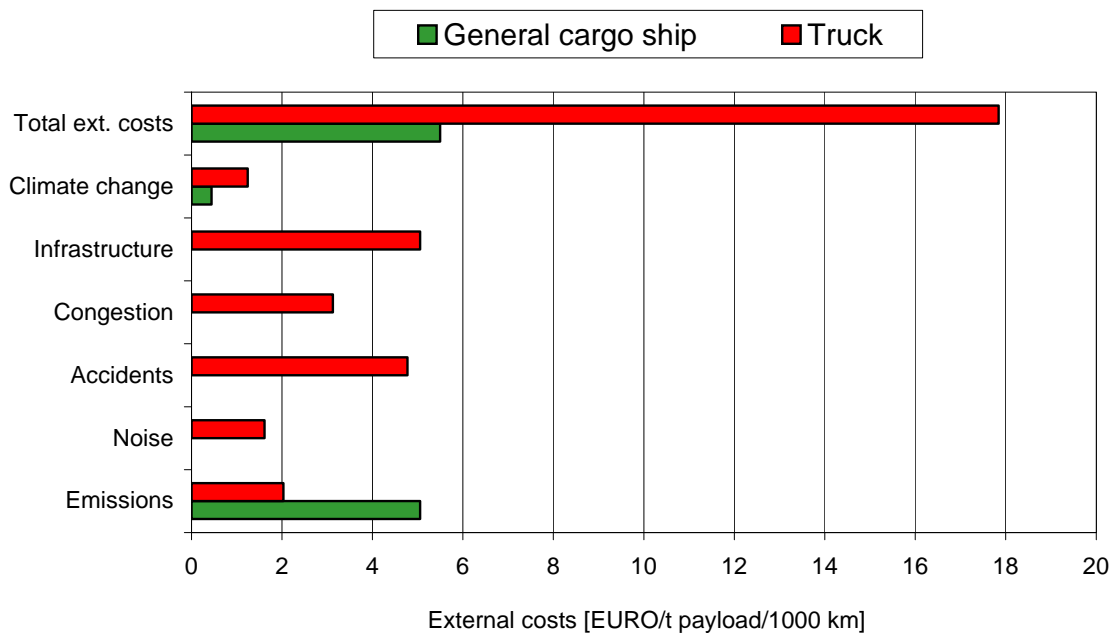
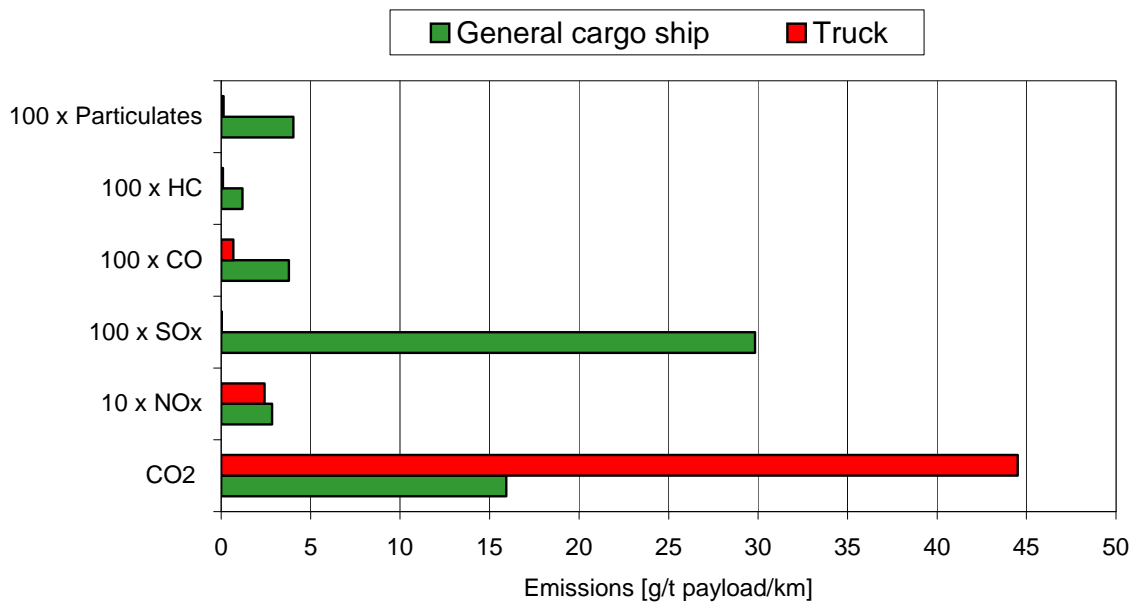
Based on a combined emission and external cost analysis for transportation with general cargo ships in the range from 1000 tons deadweight to 6000 tons deadweight compared with cargo transportation with trucks carrying 25 tons cargo, following conclusions can be made:

1. CO₂ emissions per transport unit (ton cargo x km) for truck transport are approximately 3 to 3.5 times higher than for ship transport at normal speed and approximately 3.5 to 4.5 at a speed reduction of 10 % compared to normal service speed.
2. The influence of the sulphur content on the total external costs per transport unit is pronounced. The external cost ratio between truck transport and ship transport changes from approximately 4 when using oil with 3 % sulphur content to approximately 8 when using oil with 1 % sulphur and further to approximately 10 with only 0.1 % sulphur and even further to approximately 13 if the speed additionally is reduced by 10 %.

Appendix A

3 % S – IMO Tier I NOx level – Normal speed

Ship data		Truck data	
Design deaweight (t)	1000	Number of containers per truck	2
Payload/deadweight at design draught (%)	90	Weight per container (t/TEU)	12,5
Capacity utilization (pct.)	100	Length of truck - total (m)	18
Design payload (t)	900	EURO norm (2, 3, 4, 5 or 6)	4
Normal speed (knots)	9,7	Suphur content of oil (%)	0,001
Speed reduction (pct.)	0	Driving distance (km)	400
Actual ship speed (knots)	9,7	Driving percentage in city area	5
Suphur content of oil (%)	3,0	External cost level	
NOx emissions (IMO TIER 1, 2 or 3)	1	1 = Low, 2 = Mean, 3 = High	2
Slow speed (1) or medium speed main engine (2)	2	Ship (EURO/t payload/1000 km)	5,50
Sailing percentage in harbour conditions	2	Truck (EURO/t truck load/1000 km)	17,8



Emissions (g/t payload/km)

Ship		Truck	
CO ₂	15,9	CO ₂	44,5
10 x NOx	2,84	10 x NOx	2,43
100 x SOx	29,83	100 x SOx	0,03
100 x CO	3,79	100 x CO	0,7
100 x HC	1,18	100 x HC	0,10
100 x Particulates	4,03	100 x Particulates	0,14

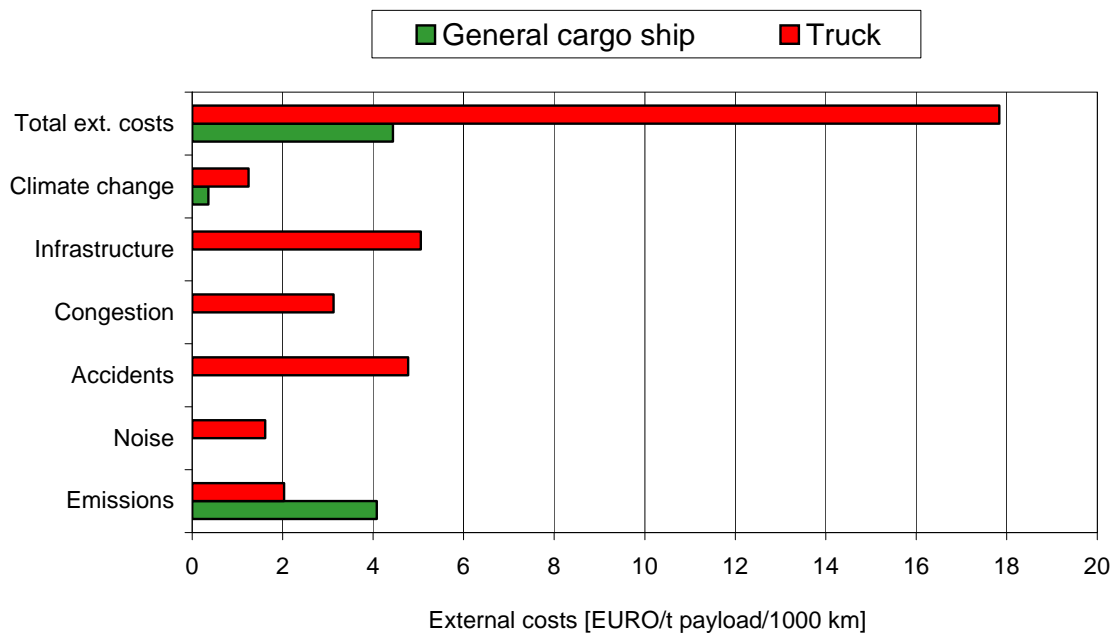
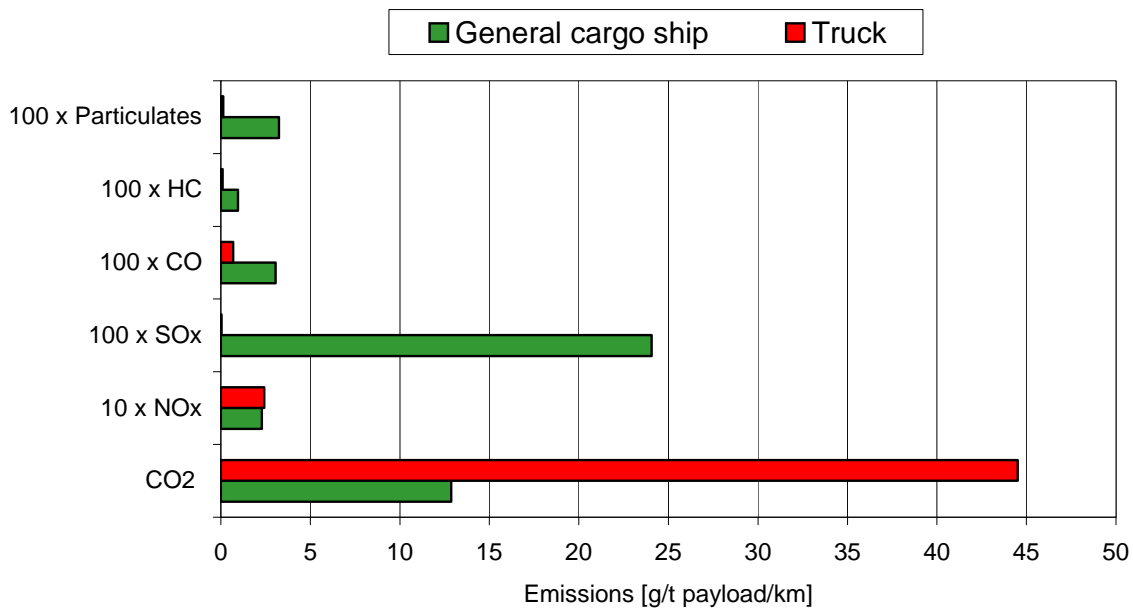
External costs (EURO/t payload/1000 km)

Ship		Truck	
Emissions	5,05	Emissions	2,03
Noise	0	Noise	1,61
Accidents	0	Accidents	4,78
Congestion	0	Congestion	3,12
Infrastructure	0	Infrastructure	5,05
Climate change	0,45	Climate change	1,24
Total ext. costs	5,50	Total ext. costs	17,8

External costs (EURO/t payload/1000 km)

Ship		Truck	
CO ₂	0,47	CO ₂	1,31
NOx	0,74	NOx	0,64
SOx	1,591	SOx	0,0015
CO	0,00001	CO	0,00000
HC	0,008	HC	0,001
Particulates	2,24	Particulates	0,09
Total	5,05	Total	2,03

Ship data		Truck data	
Design deaweight (t)	2000	Number of containers per truck	2
Payload/deadweight at design draught (%)	90	Weight per container (t/TEU)	12,5
Capacity utilization (pct.)	100	Length of truck - total (m)	18
Design payload (t)	1800	EURO norm (2, 3, 4, 5 or 6)	4
Normal speed (knots)	10,3	Suphur content of oil (%)	0,001
Speed reduction (pct.)	0	Driving distance (km)	400
Actual ship speed (knots)	10,3	Driving percentage in city area	5
Suphur content of oil (%)	3,0	External cost level	
NOx emissions (IMO TIER 1, 2 or 3)	1	1 = Low, 2 = Mean, 3 = High	2
Slow speed (1) or medium speed main engine (2)	2	Ship (EURO/t payload/1000 km)	4,44
Sailing percentage in harbour conditions	2	Truck (EURO/t truck load/1000 km)	17,8



Emissions (g/t payload/km)

Ship		Truck	
CO ₂	12,9	CO ₂	44,5
10 x NOx	2,29	10 x NOx	2,43
100 x SOx	24,07	100 x SOx	0,03
100 x CO	3,06	100 x CO	0,7
100 x HC	0,96	100 x HC	0,10
100 x Particulates	3,25	100 x Particulates	0,14

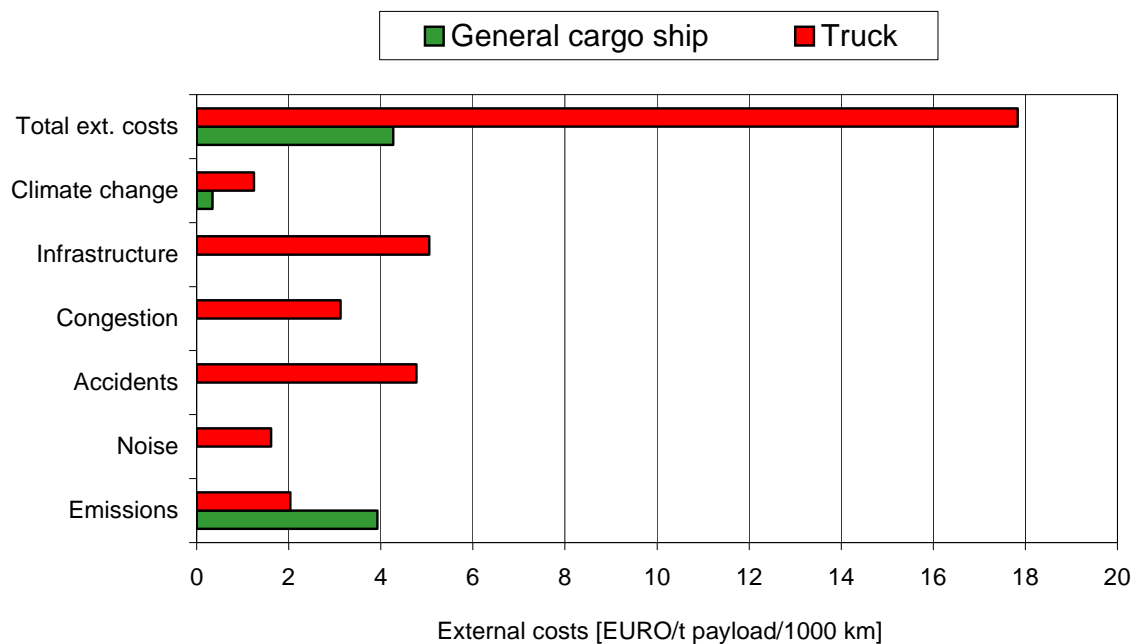
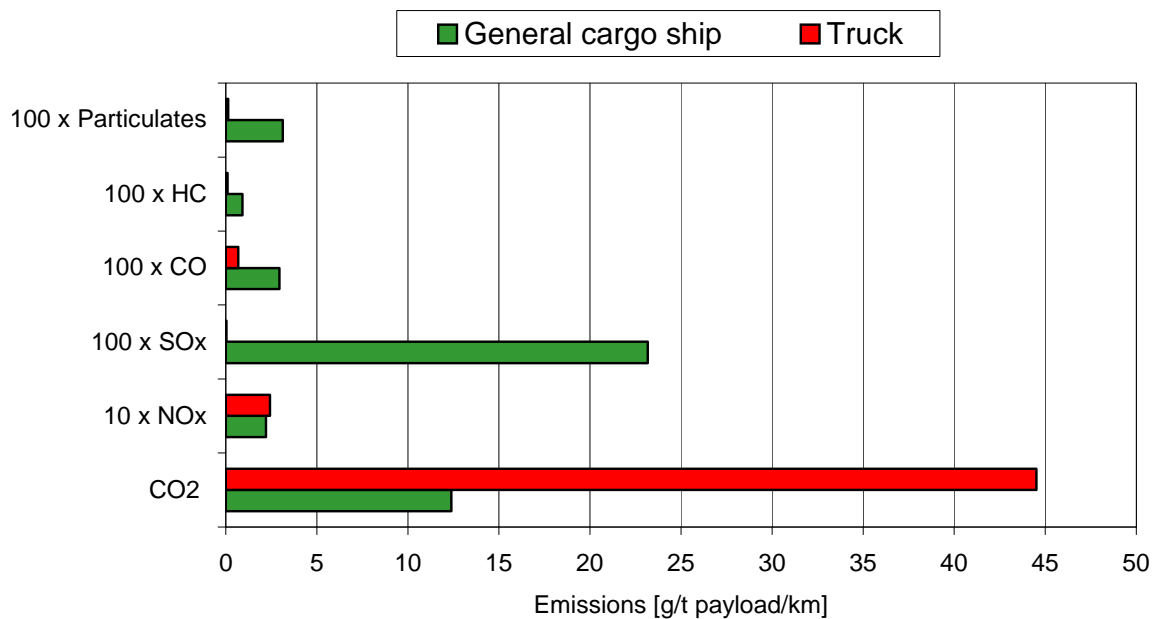
External costs (EURO/t payload/1000 km)

Ship		Truck	
Emissions	4,08	Emissions	2,03
Noise	0	Noise	1,61
Accidents	0	Accidents	4,78
Congestion	0	Congestion	3,12
Infrastructure	0	Infrastructure	5,05
Climate change	0,36	Climate change	1,24
Total ext. costs	4,44	Total ext. costs	17,8

External costs (EURO/t payload/1000 km)

Ship		Truck	
CO ₂	0,38	CO ₂	1,31
NOx	0,60	NOx	0,64
SOx	1,284	SOx	0,0015
CO	0,00001	CO	0,00000
HC	0,007	HC	0,001
Particulates	1,81	Particulates	0,09
Total	4,08	Total	2,03

Ship data		Truck data	
Design deaweight (t)	4000	Number of containers per truck	2
Payload/deadweight at design draught (%)	90	Weight per container (t/TEU)	12,5
Capacity utilization (pct.)	100	Length of truck - total (m)	18
Design payload (t)	3600	EURO norm (2, 3, 4, 5 or 6)	4
Normal speed (knots)	11,7	Suphur content of oil (%)	0,001
Speed reduction (pct.)	0	Driving distance (km)	400
Actual ship speed (knots)	11,7	Driving percentage in city area	5
Suphur content of oil (%)	3,0	External cost level	
NOx emissions (IMO TIER 1, 2 or 3)	1	1 = Low, 2 = Mean, 3 = High	2
Slow speed (1) or medium speed main engine (2)	2	Ship (EURO/t payload/1000 km)	4,27
Sailing percentage in harbour conditions	2	Truck (EURO/t truck load/1000 km)	17,8



Emissions (g/t payload/km)

Ship		Truck	
CO ₂	12,4	CO ₂	44,5
10 x NO _x	2,21	10 x NO _x	2,43
100 x SO _x	23,17	100 x SO _x	0,03
100 x CO	2,94	100 x CO	0,7
100 x HC	0,92	100 x HC	0,10
100 x Particulates	3,13	100 x Particulates	0,14

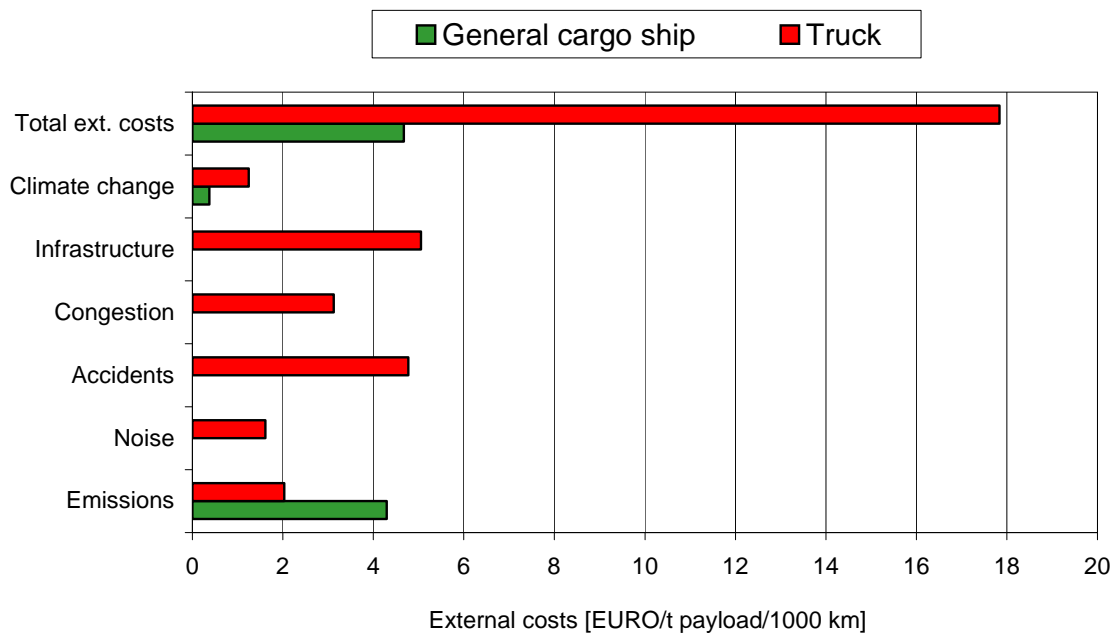
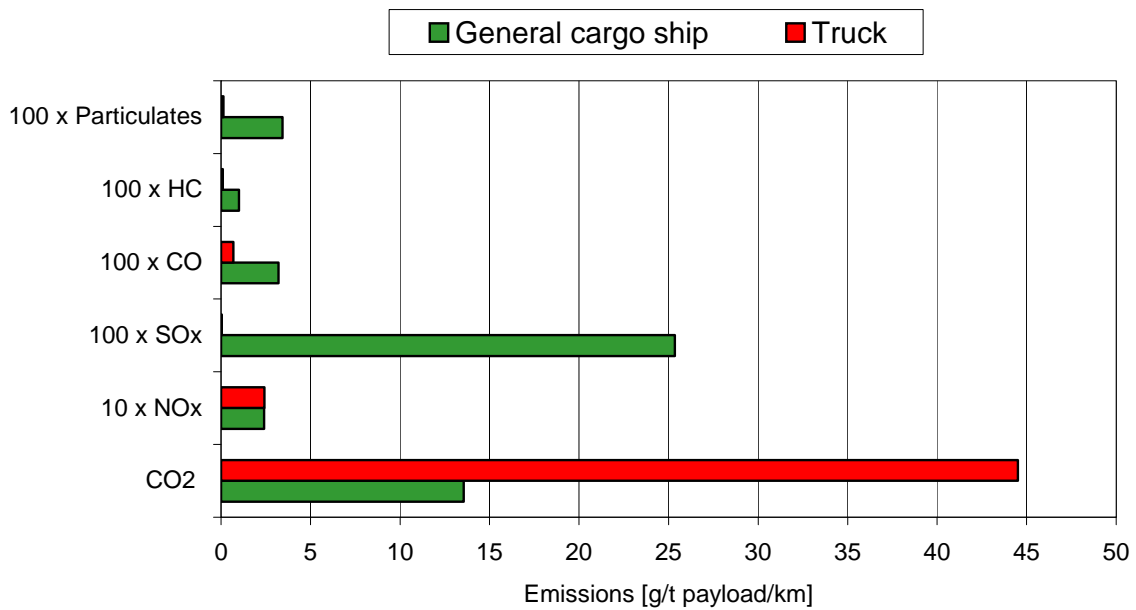
External costs (EURO/t payload/1000 km)

Ship		Truck	
Emissions	3,93	Emissions	2,03
Noise	0	Noise	1,61
Accidents	0	Accidents	4,78
Congestion	0	Congestion	3,12
Infrastructure	0	Infrastructure	5,05
Climate change	0,35	Climate change	1,24
Total ext. costs	4,27	Total ext. costs	17,8

External costs (EURO/t payload/1000 km)

Ship		Truck	
CO ₂	0,36	CO ₂	1,31
NO _x	0,58	NO _x	0,64
SO _x	1,236	SO _x	0,0015
CO	0,00001	CO	0,00000
HC	0,006	HC	0,001
Particulates	1,74	Particulates	0,09
Total	3,93	Total	2,03

Ship data		Truck data	
Design deaweight (t)	6000	Number of containers per truck	2
Payload/deadweight at design draught (%)	90	Weight per container (t/TEU)	12,5
Capacity utilization (pct.)	100	Length of truck - total (m)	18
Design payload (t)	5400	EURO norm (2, 3, 4, 5 or 6)	4
Normal speed (knots)	13,6	Suphur content of oil (%)	0,001
Speed reduction (pct.)	0	Driving distance (km)	400
Actual ship speed (knots)	13,6	Driving percentage in city area	5
Suphur content of oil (%)	3,0	External cost level	
NOx emissions (IMO TIER 1, 2 or 3)	1	1 = Low, 2 = Mean, 3 = High	2
Slow speed (1) or medium speed main engine (2)	2	Ship (EURO/t payload/1000 km)	4,67
Sailing percentage in harbour conditions	2	Truck (EURO/t truck load/1000 km)	17,8



Emissions (g/t payload/km)

Ship		Truck	
CO ₂	13,5	CO ₂	44,5
10 x NO _x	2,42	10 x NO _x	2,43
100 x SO _x	25,36	100 x SO _x	0,03
100 x CO	3,22	100 x CO	0,7
100 x HC	1,01	100 x HC	0,10
100 x Particulates	3,43	100 x Particulates	0,14

External costs (EURO/t payload/1000 km)

Ship		Truck	
Emissions	4,30	Emissions	2,03
Noise	0	Noise	1,61
Accidents	0	Accidents	4,78
Congestion	0	Congestion	3,12
Infrastructure	0	Infrastructure	5,05
Climate change	0,38	Climate change	1,24
Total ext. costs	4,67	Total ext. costs	17,8

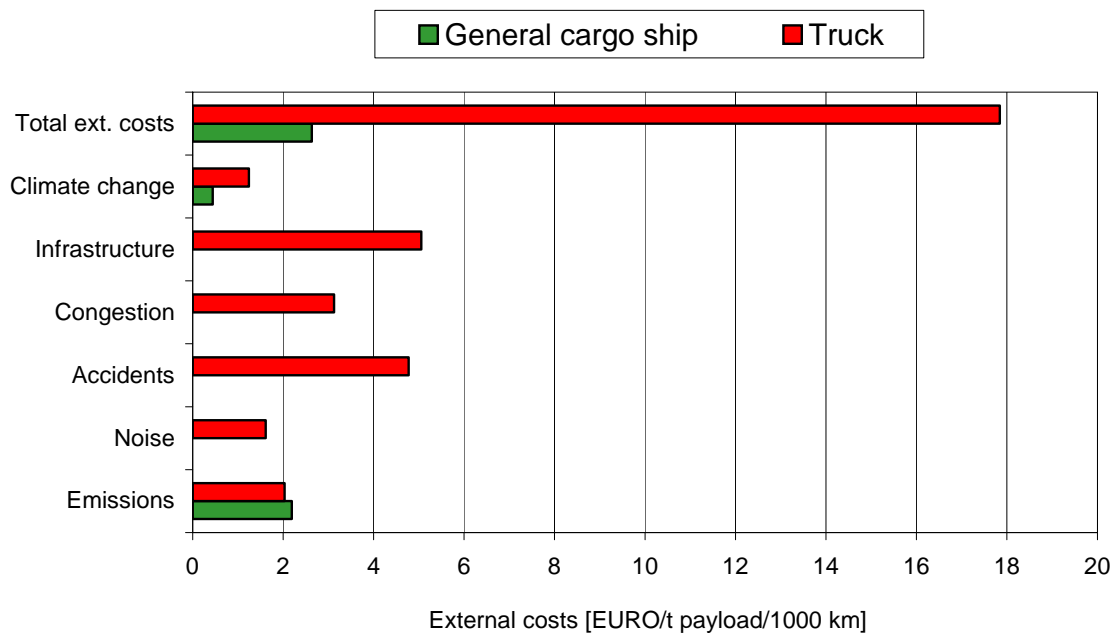
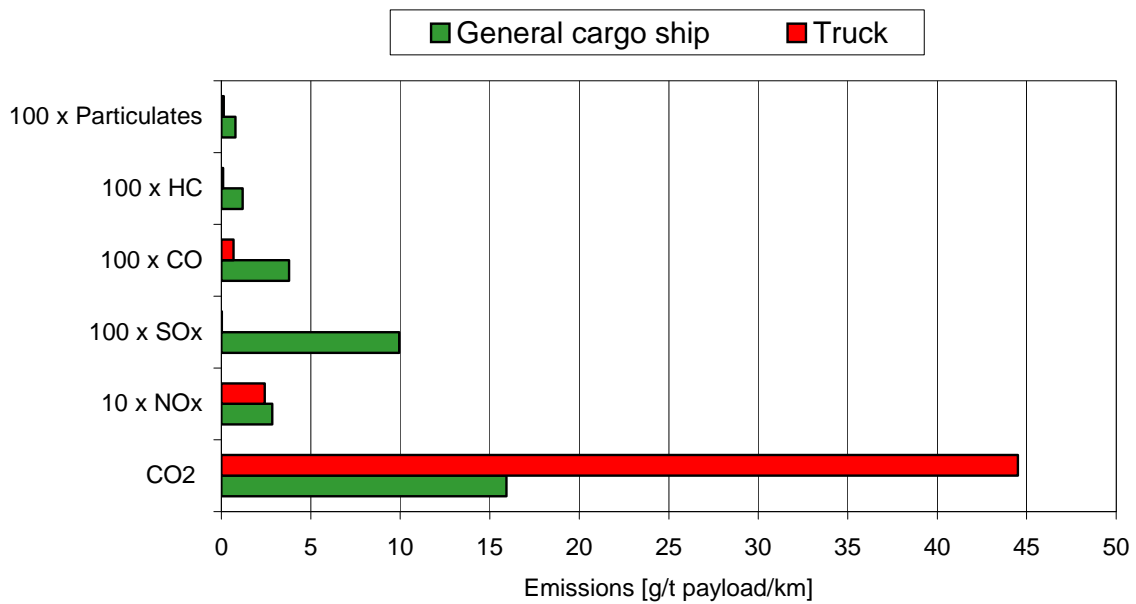
External costs (EURO/t payload/1000 km)

Ship		Truck	
CO ₂	0,40	CO ₂	1,31
NO _x	0,63	NO _x	0,64
SO _x	1,353	SO _x	0,0015
CO	0,00001	CO	0,00000
HC	0,007	HC	0,001
Particulates	1,90	Particulates	0,09
Total	4,30	Total	2,03

Appendix B

1 % S – IMO Tier I NOx level – Normal speed

Ship data		Truck data	
Design deaweight (t)	1000	Number of containers per truck	2
Payload/deadweight at design draught (%)	90	Weight per container (t/TEU)	12,5
Capacity utilization (pct.)	100	Length of truck - total (m)	18
Design payload (t)	900	EURO norm (2, 3, 4, 5 or 6)	4
Normal speed (knots)	9,7	Suphur content of oil (%)	0,001
Speed reduction (pct.)	0	Driving distance (km)	400
Actual ship speed (knots)	9,7	Driving percentage in city area	5
Suphur content of oil (%)	1,0	External cost level	
NOx emissions (IMO TIER 1, 2 or 3)	1	1 = Low, 2 = Mean, 3 = High	2
Slow speed (1) or medium speed main engine (2)	2	Ship (EURO/t payload/1000 km)	2,63
Sailing percentage in harbour conditions	2	Truck (EURO/t truck load/1000 km)	17,8



Emissions (g/t payload/km)

Ship		Truck	
CO ₂	15,9	CO ₂	44,5
10 x NO _x	2,84	10 x NO _x	2,43
100 x SO _x	9,94	100 x SO _x	0,03
100 x CO	3,79	100 x CO	0,7
100 x HC	1,18	100 x HC	0,10
100 x Particulates	0,79	100 x Particulates	0,14

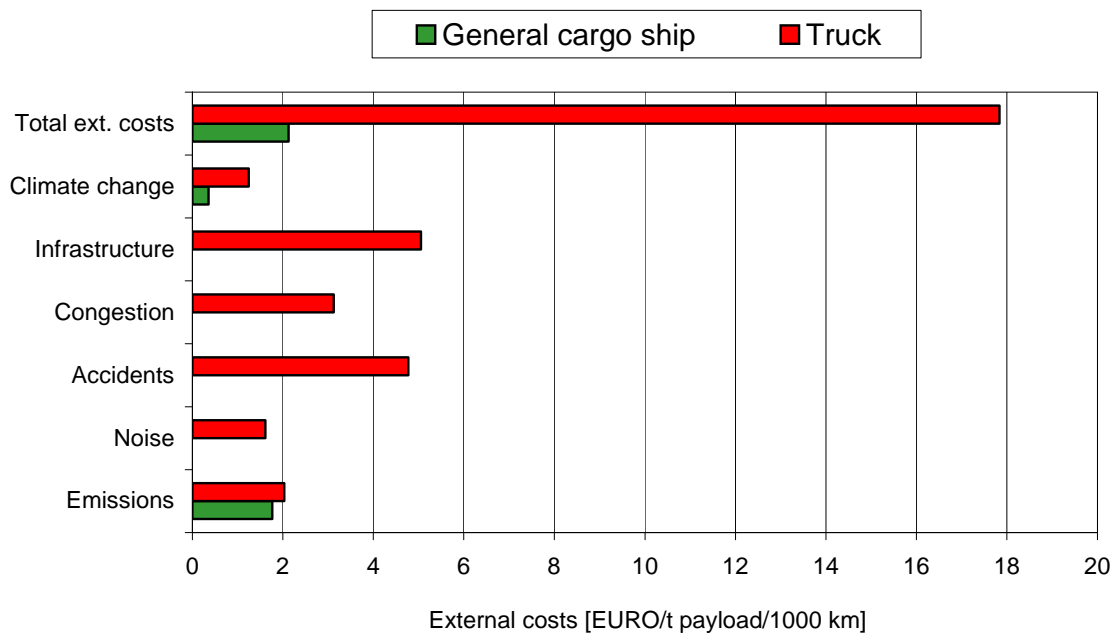
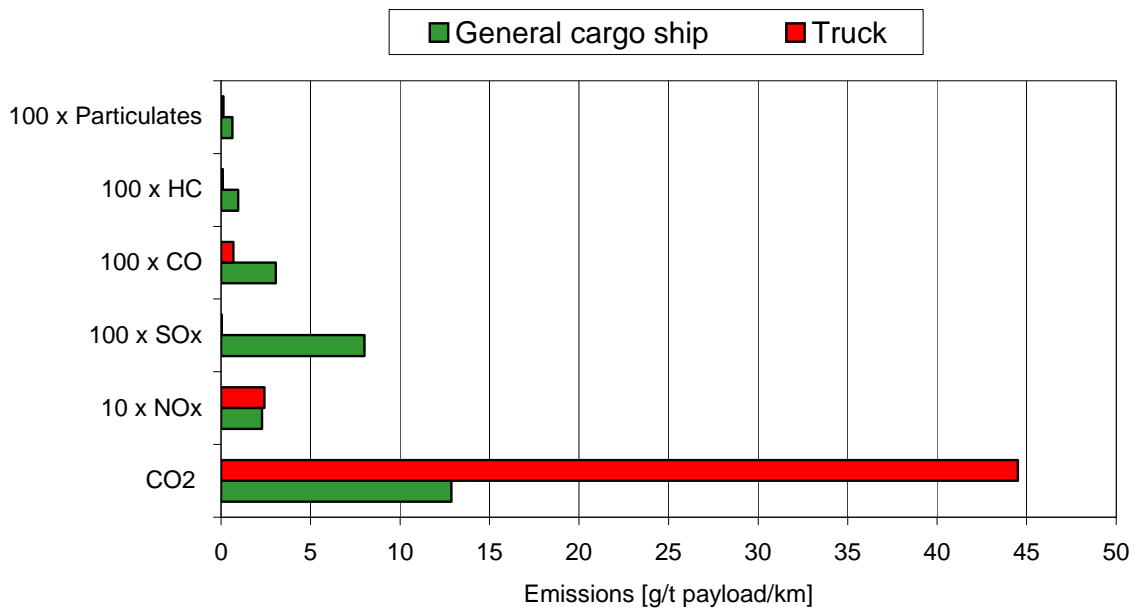
External costs (EURO/t payload/1000 km)

Ship		Truck	
Emissions	2,19	Emissions	2,03
Noise	0	Noise	1,61
Accidents	0	Accidents	4,78
Congestion	0	Congestion	3,12
Infrastructure	0	Infrastructure	5,05
Climate change	0,45	Climate change	1,24
Total ext. costs	2,63	Total ext. costs	17,8

External costs (EURO/t payload/1000 km)

Ship		Truck	
CO ₂	0,47	CO ₂	1,31
NO _x	0,74	NO _x	0,64
SO _x	0,530	SO _x	0,0015
CO	0,00001	CO	0,00000
HC	0,008	HC	0,001
Particulates	0,44	Particulates	0,09
Total	2,19	Total	2,03

Ship data		Truck data	
Design deaweight (t)	2000	Number of containers per truck	2
Payload/deadweight at design draught (%)	90	Weight per container (t/TEU)	12,5
Capacity utilization (pct.)	100	Length of truck - total (m)	18
Design payload (t)	1800	EURO norm (2, 3, 4, 5 or 6)	4
Normal speed (knots)	10,3	Suphur content of oil (%)	0,001
Speed reduction (pct.)	0	Driving distance (km)	400
Actual ship speed (knots)	10,3	Driving percentage in city area	5
Suphur content of oil (%)	1,0	External cost level	
NOx emissions (IMO TIER 1, 2 or 3)	1	1 = Low, 2 = Mean, 3 = High	2
Slow speed (1) or medium speed main engine (2)	2	Ship (EURO/t payload/1000 km)	2,13
Sailing percentage in harbour conditions	2	Truck (EURO/t truck load/1000 km)	17,8



Emissions (g/t payload/km)

Ship		Truck	
CO ₂	12,9	CO ₂	44,5
10 x NO _x	2,29	10 x NO _x	2,43
100 x SO _x	8,02	100 x SO _x	0,03
100 x CO	3,06	100 x CO	0,7
100 x HC	0,96	100 x HC	0,10
100 x Particulates	0,64	100 x Particulates	0,14

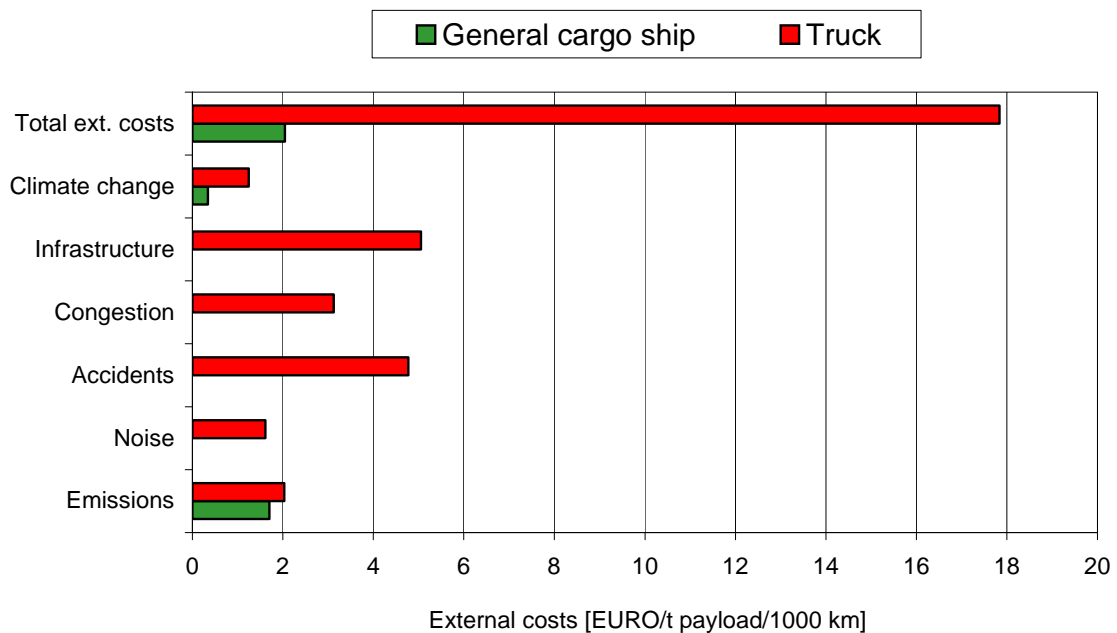
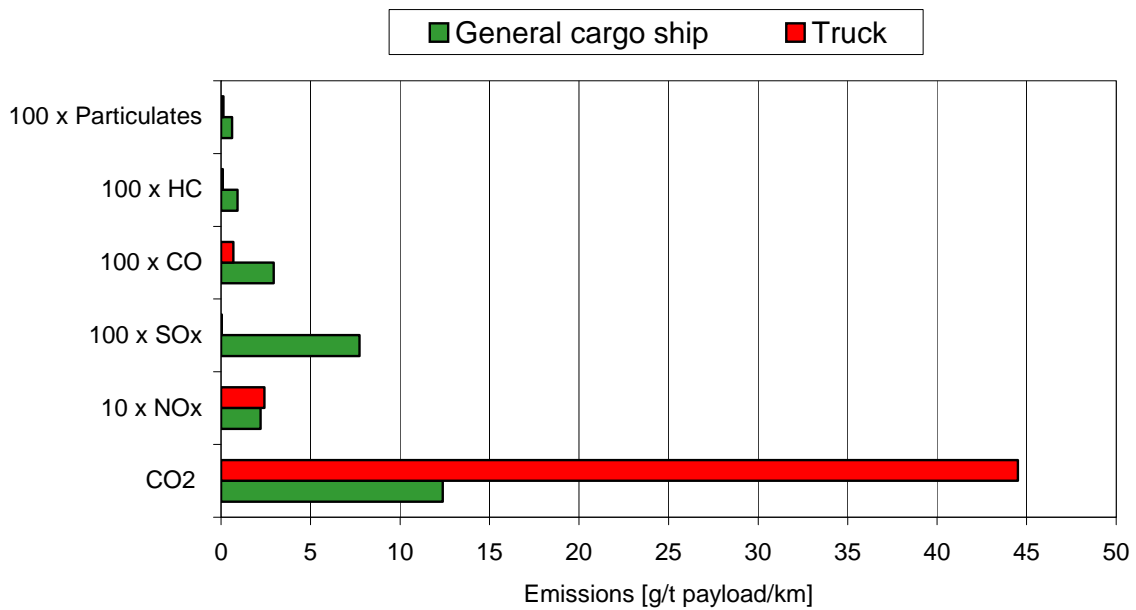
External costs (EURO/t payload/1000 km)

Ship		Truck	
Emissions	1,77	Emissions	2,03
Noise	0	Noise	1,61
Accidents	0	Accidents	4,78
Congestion	0	Congestion	3,12
Infrastructure	0	Infrastructure	5,05
Climate change	0,36	Climate change	1,24
Total ext. costs	2,13	Total ext. costs	17,8

External costs (EURO/t payload/1000 km)

Ship		Truck	
CO ₂	0,38	CO ₂	1,31
NO _x	0,60	NO _x	0,64
SO _x	0,428	SO _x	0,0015
CO	0,00001	CO	0,00000
HC	0,007	HC	0,001
Particulates	0,35	Particulates	0,09
Total	1,77	Total	2,03

Ship data		Truck data	
Design deaweight (t)	4000	Number of containers per truck	2
Payload/deadweight at design draught (%)	90	Weight per container (t/TEU)	12,5
Capacity utilization (pct.)	100	Length of truck - total (m)	18
Design payload (t)	3600	EURO norm (2, 3, 4, 5 or 6)	4
Normal speed (knots)	11,7	Suphur content of oil (%)	0,001
Speed reduction (pct.)	0	Driving distance (km)	400
Actual ship speed (knots)	11,7	Driving percentage in city area	5
Suphur content of oil (%)	1,0	External cost level	
NOx emissions (IMO TIER 1, 2 or 3)	1	1 = Low, 2 = Mean, 3 = High	2
Slow speed (1) or medium speed main engine (2)	2	Ship (EURO/t payload/1000 km)	2,05
Sailing percentage in harbour conditions	2	Truck (EURO/t truck load/1000 km)	17,8



Emissions (g/t payload/km)

Ship		Truck	
CO ₂	12,4	CO ₂	44,5
10 x NO _x	2,21	10 x NO _x	2,43
100 x SO _x	7,72	100 x SO _x	0,03
100 x CO	2,94	100 x CO	0,7
100 x HC	0,92	100 x HC	0,10
100 x Particulates	0,61	100 x Particulates	0,14

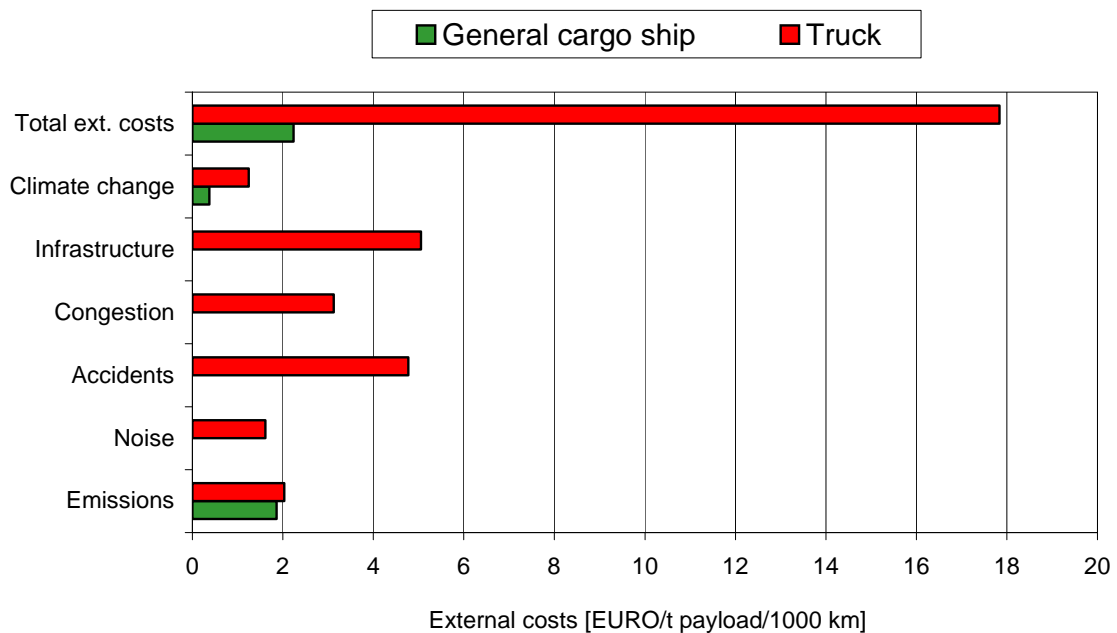
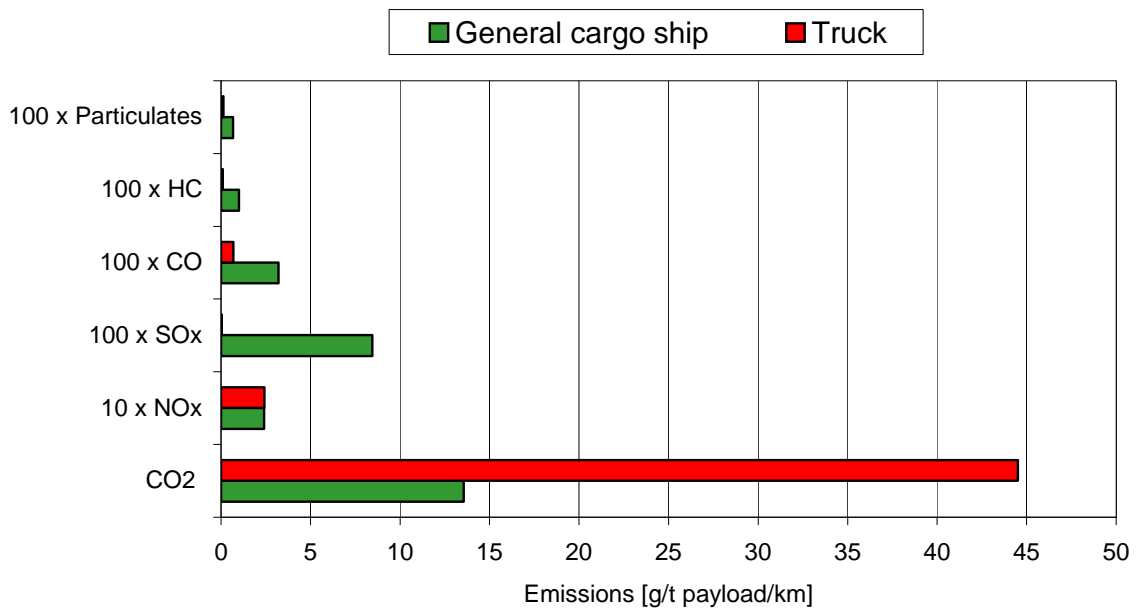
External costs (EURO/t payload/1000 km)

Ship		Truck	
Emissions	1,70	Emissions	2,03
Noise	0	Noise	1,61
Accidents	0	Accidents	4,78
Congestion	0	Congestion	3,12
Infrastructure	0	Infrastructure	5,05
Climate change	0,35	Climate change	1,24
Total ext. costs	2,05	Total ext. costs	17,8

External costs (EURO/t payload/1000 km)

Ship		Truck	
CO ₂	0,36	CO ₂	1,31
NO _x	0,58	NO _x	0,64
SO _x	0,412	SO _x	0,0015
CO	0,00001	CO	0,00000
HC	0,006	HC	0,001
Particulates	0,34	Particulates	0,09
Total	1,70	Total	2,03

Ship data		Truck data	
Design deaweight (t)	6000	Number of containers per truck	2
Payload/deadweight at design draught (%)	90	Weight per container (t/TEU)	12,5
Capacity utilization (pct.)	100	Length of truck - total (m)	18
Design payload (t)	5400	EURO norm (2, 3, 4, 5 or 6)	4
Normal speed (knots)	13,6	Suphur content of oil (%)	0,001
Speed reduction (pct.)	0	Driving distance (km)	400
Actual ship speed (knots)	13,6	Driving percentage in city area	5
Suphur content of oil (%)	1,0	External cost level	
NOx emissions (IMO TIER 1, 2 or 3)	1	1 = Low, 2 = Mean, 3 = High	2
Slow speed (1) or medium speed main engine (2)	2	Ship (EURO/t payload/1000 km)	2,24
Sailing percentage in harbour conditions	2	Truck (EURO/t truck load/1000 km)	17,8



Emissions (g/t payload/km)

Ship		Truck	
CO ₂	13,5	CO ₂	44,5
10 x NO _x	2,42	10 x NO _x	2,43
100 x SO _x	8,45	100 x SO _x	0,03
100 x CO	3,22	100 x CO	0,7
100 x HC	1,01	100 x HC	0,10
100 x Particulates	0,67	100 x Particulates	0,14

External costs (EURO/t payload/1000 km)

Ship		Truck	
Emissions	1,86	Emissions	2,03
Noise	0	Noise	1,61
Accidents	0	Accidents	4,78
Congestion	0	Congestion	3,12
Infrastructure	0	Infrastructure	5,05
Climate change	0,38	Climate change	1,24
Total ext. costs	2,24	Total ext. costs	17,8

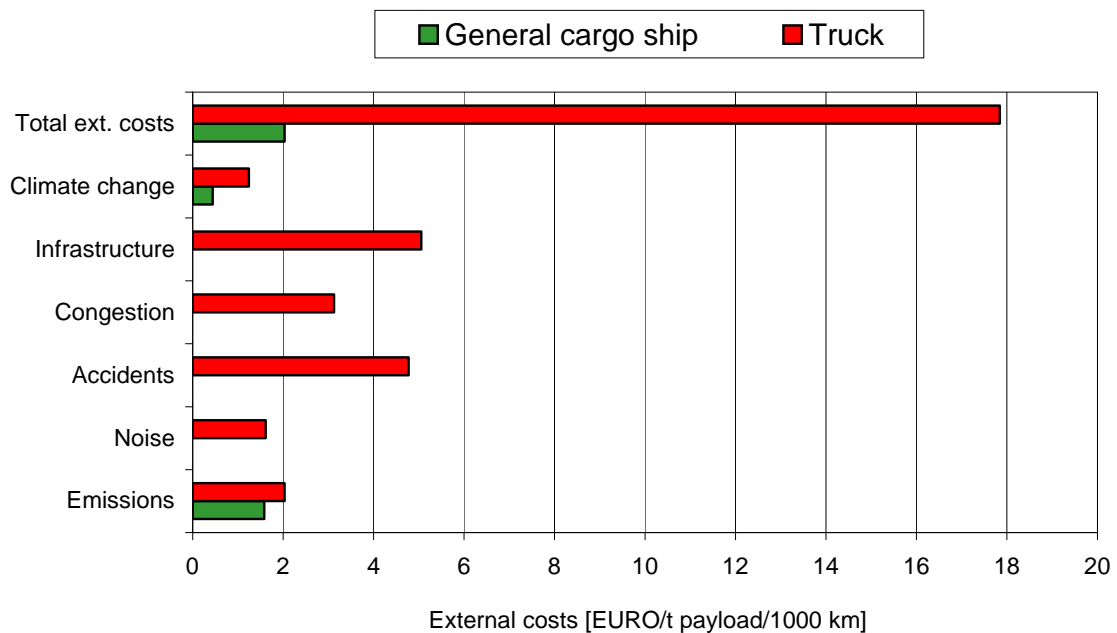
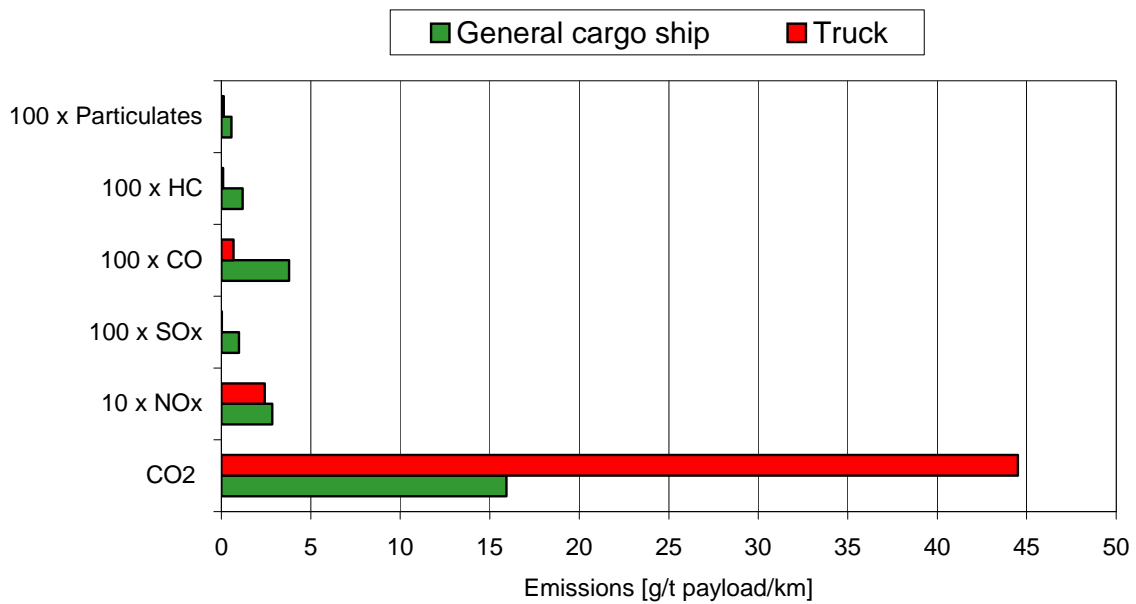
External costs (EURO/t payload/1000 km)

Ship		Truck	
CO ₂	0,40	CO ₂	1,31
NO _x	0,63	NO _x	0,64
SO _x	0,451	SO _x	0,0015
CO	0,00001	CO	0,00000
HC	0,007	HC	0,001
Particulates	0,37	Particulates	0,09
Total	1,86	Total	2,03

Appendix C

0.1 % S – IMO Tier I NOx level – Normal speed

Ship data		Truck data	
Design deaweight (t)	1000	Number of containers per truck	2
Payload/deadweight at design draught (%)	90	Weight per container (t/TEU)	12,5
Capacity utilization (pct.)	100	Length of truck - total (m)	18
Design payload (t)	900	EURO norm (2, 3, 4, 5 or 6)	4
Normal speed (knots)	9,7	Suphur content of oil (%)	0,001
Speed reduction (pct.)	0	Driving distance (km)	400
Actual ship speed (knots)	9,7	Driving percentage in city area	5
Suphur content of oil (%)	0,1	External cost level	
NOx emissions (IMO TIER 1, 2 or 3)	1	1 = Low, 2 = Mean, 3 = High	2
Slow speed (1) or medium speed main engine (2)	2	Ship (EURO/t payload/1000 km)	2,03
Sailing percentage in harbour conditions	2	Truck (EURO/t truck load/1000 km)	17,8



Emissions (g/t payload/km)

Ship		Truck	
CO ₂	15,9	CO ₂	44,5
10 x NO _x	2,84	10 x NO _x	2,43
100 x SO _x	0,99	100 x SO _x	0,03
100 x CO	3,79	100 x CO	0,7
100 x HC	1,18	100 x HC	0,10
100 x Particulates	0,56	100 x Particulates	0,14

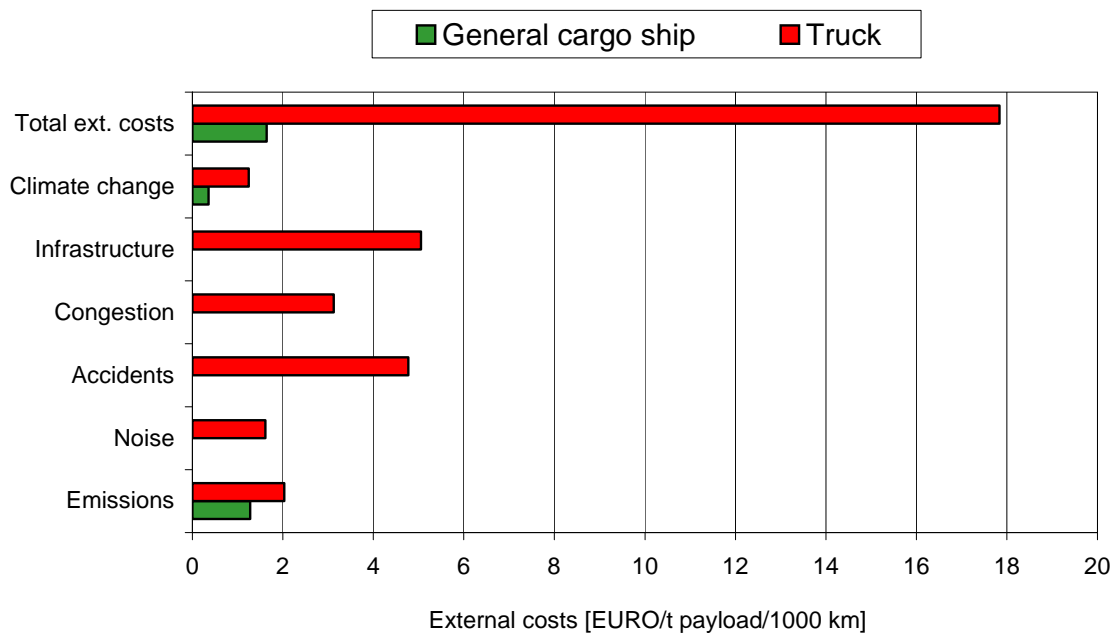
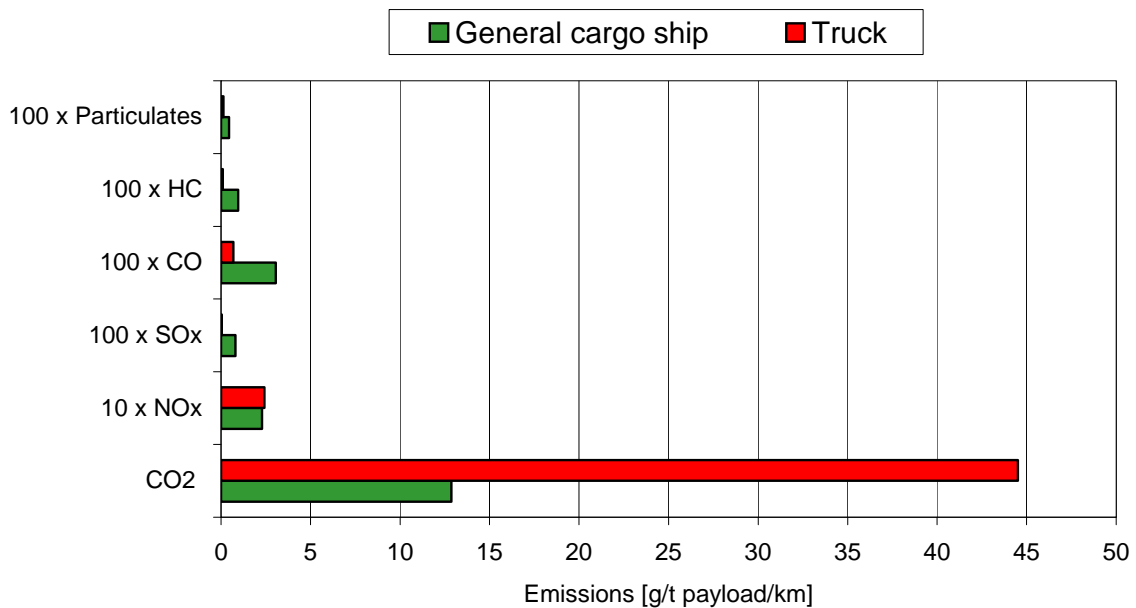
External costs (EURO/t payload/1000 km)

Ship		Truck	
Emissions	1,59	Emissions	2,03
Noise	0	Noise	1,61
Accidents	0	Accidents	4,78
Congestion	0	Congestion	3,12
Infrastructure	0	Infrastructure	5,05
Climate change	0,45	Climate change	1,24
Total ext. costs	2,03	Total ext. costs	17,8

External costs (EURO/t payload/1000 km)

Ship		Truck	
CO ₂	0,47	CO ₂	1,31
NO _x	0,74	NO _x	0,64
SO _x	0,053	SO _x	0,0015
CO	0,00001	CO	0,00000
HC	0,008	HC	0,001
Particulates	0,31	Particulates	0,09
Total	1,59	Total	2,03

Ship data		Truck data	
Design deaweight (t)	2000	Number of containers per truck	2
Payload/deadweight at design draught (%)	90	Weight per container (t/TEU)	12,5
Capacity utilization (pct.)	100	Length of truck - total (m)	18
Design payload (t)	1800	EURO norm (2, 3, 4, 5 or 6)	4
Normal speed (knots)	10,3	Suphur content of oil (%)	0,001
Speed reduction (pct.)	0	Driving distance (km)	400
Actual ship speed (knots)	10,3	Driving percentage in city area	5
Suphur content of oil (%)	0,1	External cost level	
NOx emissions (IMO TIER 1, 2 or 3)	1	1 = Low, 2 = Mean, 3 = High	2
Slow speed (1) or medium speed main engine (2)	2	Ship (EURO/t payload/1000 km)	1,64
Sailing percentage in harbour conditions	2	Truck (EURO/t truck load/1000 km)	17,8



Emissions (g/t payload/km)

Ship		Truck	
CO ₂	12,9	CO ₂	44,5
10 x NO _x	2,29	10 x NO _x	2,43
100 x SO _x	0,80	100 x SO _x	0,03
100 x CO	3,06	100 x CO	0,7
100 x HC	0,96	100 x HC	0,10
100 x Particulates	0,45	100 x Particulates	0,14

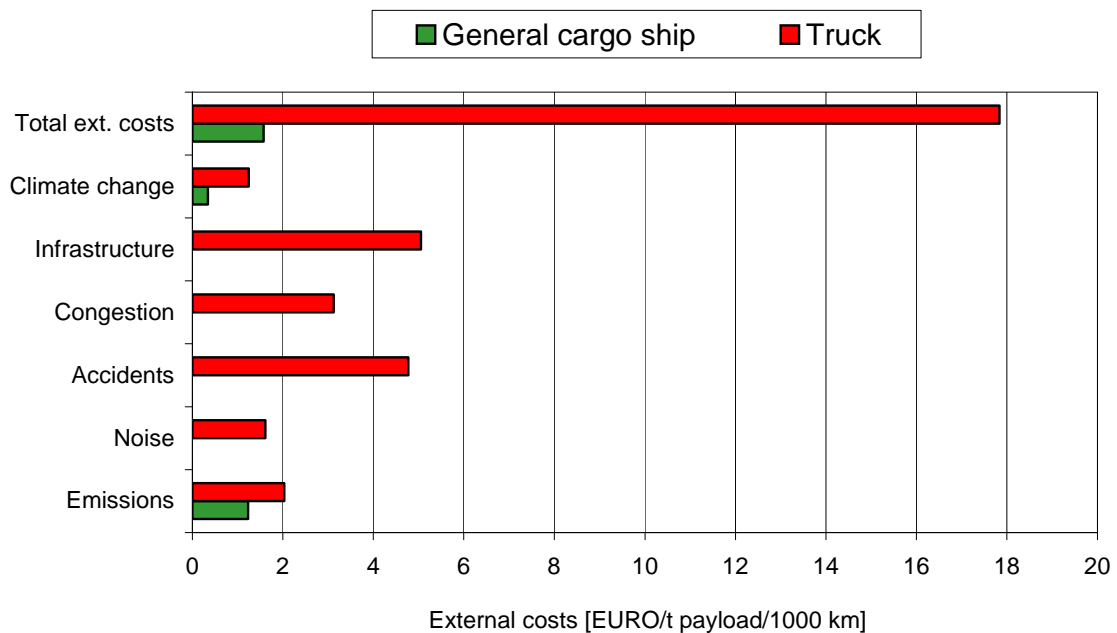
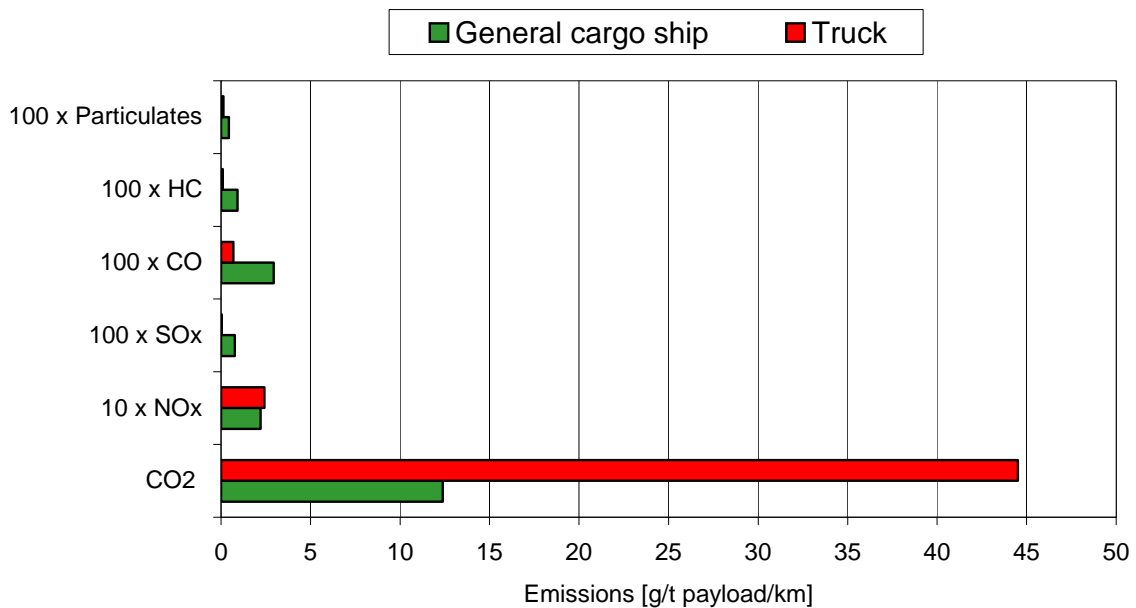
External costs (EURO/t payload/1000 km)

Ship		Truck	
Emissions	1,28	Emissions	2,03
Noise	0	Noise	1,61
Accidents	0	Accidents	4,78
Congestion	0	Congestion	3,12
Infrastructure	0	Infrastructure	5,05
Climate change	0,36	Climate change	1,24
Total ext. costs	1,64	Total ext. costs	17,8

External costs (EURO/t payload/1000 km)

Ship		Truck	
CO ₂	0,38	CO ₂	1,31
NO _x	0,60	NO _x	0,64
SO _x	0,043	SO _x	0,0015
CO	0,00001	CO	0,00000
HC	0,007	HC	0,001
Particulates	0,25	Particulates	0,09
Total	1,28	Total	2,03

Ship data		Truck data	
Design deaweight (t)	4000	Number of containers per truck	2
Payload/deadweight at design draught (%)	90	Weight per container (t/TEU)	12,5
Capacity utilization (pct.)	100	Length of truck - total (m)	18
Design payload (t)	3600	EURO norm (2, 3, 4, 5 or 6)	4
Normal speed (knots)	11,7	Suphur content of oil (%)	0,001
Speed reduction (pct.)	0	Driving distance (km)	400
Actual ship speed (knots)	11,7	Driving percentage in city area	5
Suphur content of oil (%)	0,1	External cost level	
NOx emissions (IMO TIER 1, 2 or 3)	1	1 = Low, 2 = Mean, 3 = High	2
Slow speed (1) or medium speed main engine (2)	2	Ship (EURO/t payload/1000 km)	1,58
Sailing percentage in harbour conditions	2	Truck (EURO/t truck load/1000 km)	17,8



Emissions (g/t payload/km)

Ship		Truck	
CO ₂	12,4	CO ₂	44,5
10 x NO _x	2,21	10 x NO _x	2,43
100 x SO _x	0,77	100 x SO _x	0,03
100 x CO	2,94	100 x CO	0,7
100 x HC	0,92	100 x HC	0,10
100 x Particulates	0,44	100 x Particulates	0,14

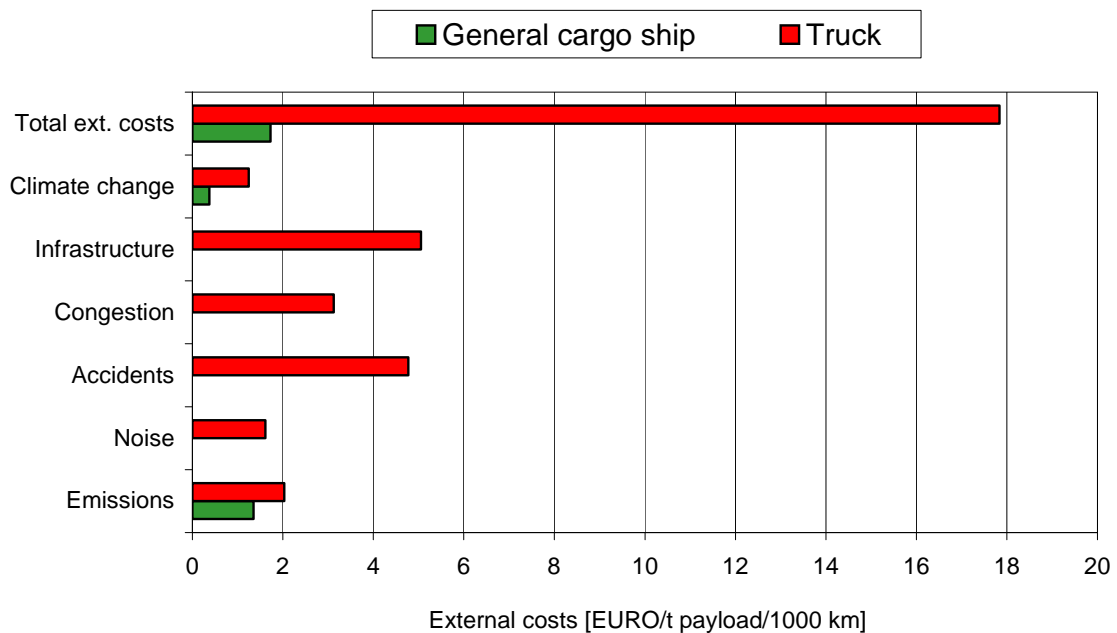
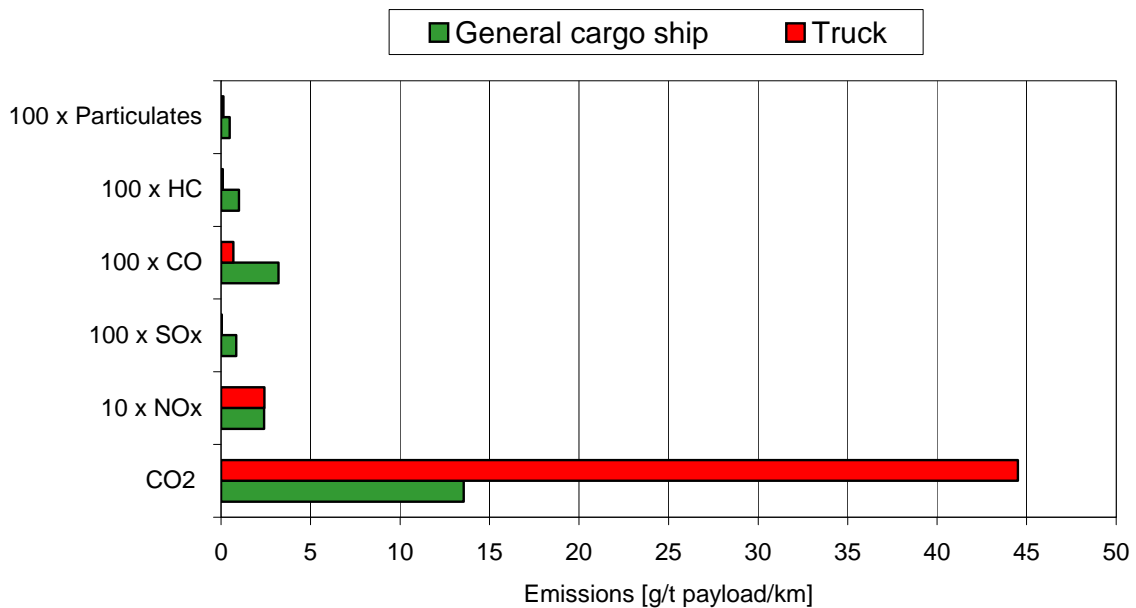
External costs (EURO/t payload/1000 km)

Ship		Truck	
Emissions	1,23	Emissions	2,03
Noise	0	Noise	1,61
Accidents	0	Accidents	4,78
Congestion	0	Congestion	3,12
Infrastructure	0	Infrastructure	5,05
Climate change	0,35	Climate change	1,24
Total ext. costs	1,58	Total ext. costs	17,8

External costs (EURO/t payload/1000 km)

Ship		Truck	
CO ₂	0,36	CO ₂	1,31
NO _x	0,58	NO _x	0,64
SO _x	0,041	SO _x	0,0015
CO	0,00001	CO	0,00000
HC	0,006	HC	0,001
Particulates	0,24	Particulates	0,09
Total	1,23	Total	2,03

Ship data		Truck data	
Design deaweight (t)	6000	Number of containers per truck	2
Payload/deadweight at design draught (%)	90	Weight per container (t/TEU)	12,5
Capacity utilization (pct.)	100	Length of truck - total (m)	18
Design payload (t)	5400	EURO norm (2, 3, 4, 5 or 6)	4
Normal speed (knots)	13,6	Suphur content of oil (%)	0,001
Speed reduction (pct.)	0	Driving distance (km)	400
Actual ship speed (knots)	13,6	Driving percentage in city area	5
Suphur content of oil (%)	0,1	External cost level	
NOx emissions (IMO TIER 1, 2 or 3)	1	1 = Low, 2 = Mean, 3 = High	2
Slow speed (1) or medium speed main engine (2)	2	Ship (EURO/t payload/1000 km)	1,73
Sailing percentage in harbour conditions	2	Truck (EURO/t truck load/1000 km)	17,8



Emissions (g/t payload/km)

Ship		Truck	
CO ₂	13,5	CO ₂	44,5
10 x NO _x	2,42	10 x NO _x	2,43
100 x SO _x	0,85	100 x SO _x	0,03
100 x CO	3,22	100 x CO	0,7
100 x HC	1,01	100 x HC	0,10
100 x Particulates	0,48	100 x Particulates	0,14

External costs (EURO/t payload/1000 km)

Ship		Truck	
Emissions	1,35	Emissions	2,03
Noise	0	Noise	1,61
Accidents	0	Accidents	4,78
Congestion	0	Congestion	3,12
Infrastructure	0	Infrastructure	5,05
Climate change	0,38	Climate change	1,24
Total ext. costs	1,73	Total ext. costs	17,8

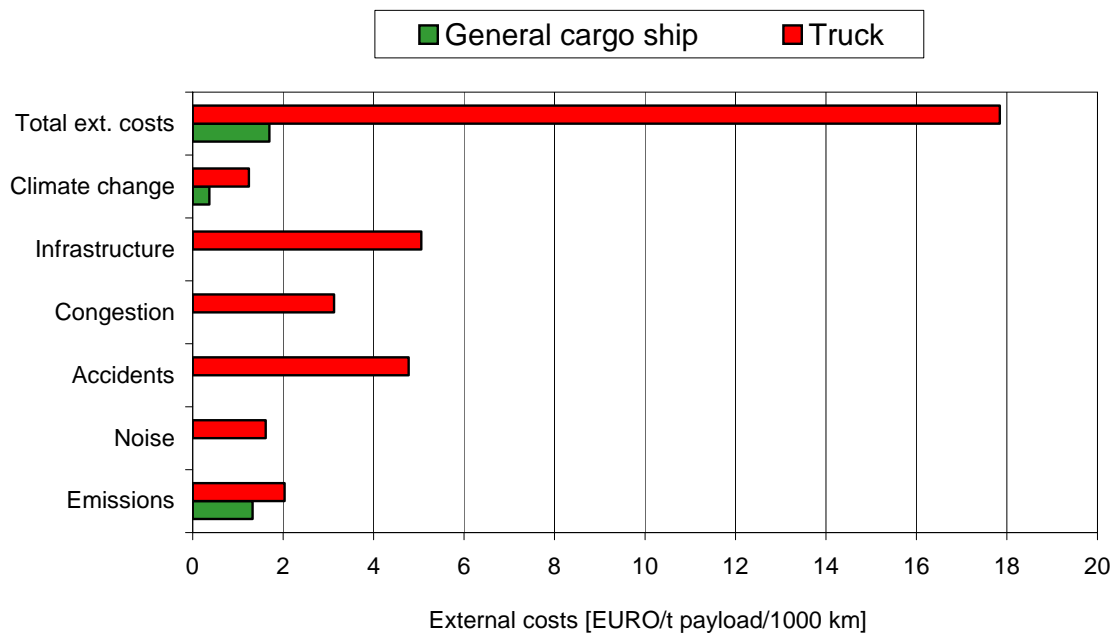
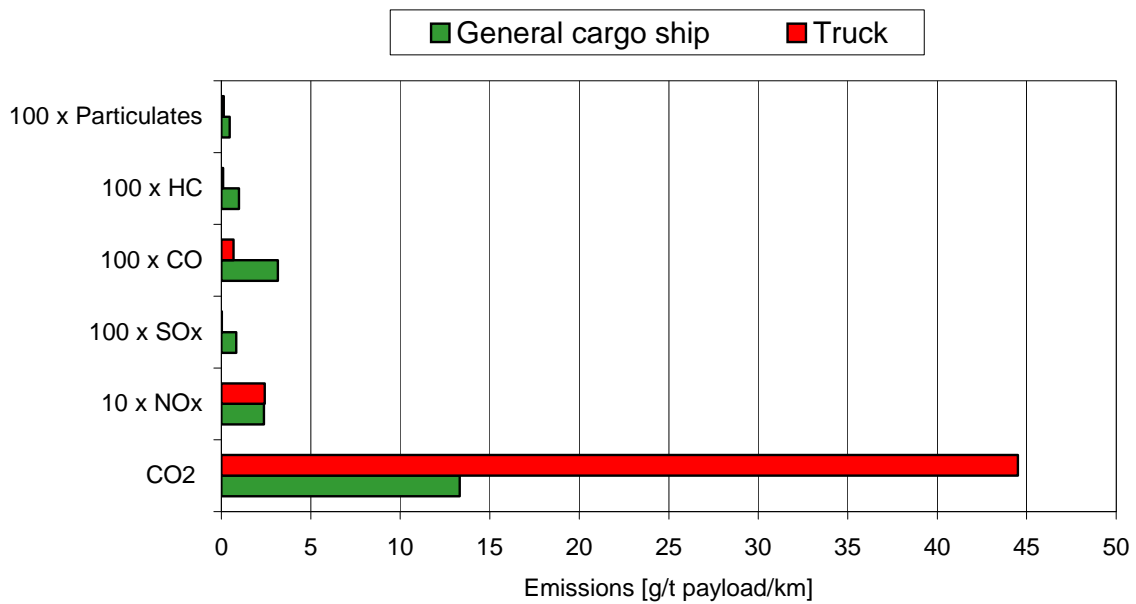
External costs (EURO/t payload/1000 km)

Ship		Truck	
CO ₂	0,40	CO ₂	1,31
NO _x	0,63	NO _x	0,64
SO _x	0,045	SO _x	0,0015
CO	0,00001	CO	0,00000
HC	0,007	HC	0,001
Particulates	0,27	Particulates	0,09
Total	1,35	Total	2,03

Appendix D

0.1 % S – IMO Tier I NOx level – 10 % speed reduction

Ship data		Truck data	
Design deaweight (t)	1000	Number of containers per truck	2
Payload/deadweight at design draught (%)	90	Weight per container (t/TEU)	12,5
Capacity utilization (pct.)	100	Length of truck - total (m)	18
Design payload (t)	900	EURO norm (2, 3, 4, 5 or 6)	4
Normal speed (knots)	9,7	Suphur content of oil (%)	0,001
Speed reduction (pct.)	10	Driving distance (km)	400
Actual ship speed (knots)	8,8	Driving percentage in city area	5
Suphur content of oil (%)	0,1	External cost level	
NOx emissions (IMO TIER 1, 2 or 3)	1	1 = Low, 2 = Mean, 3 = High	2
Slow speed (1) or medium speed main engine (2)	2	Ship (EURO/t payload/1000 km)	1,70
Sailing percentage in harbour conditions	2	Truck (EURO/t truck load/1000 km)	17,8



Emissions (g/t payload/km)

Ship		Truck	
CO ₂	13,3	CO ₂	44,5
10 x NO _x	2,37	10 x NO _x	2,43
100 x SO _x	0,83	100 x SO _x	0,03
100 x CO	3,17	100 x CO	0,7
100 x HC	0,99	100 x HC	0,10
100 x Particulates	0,47	100 x Particulates	0,14

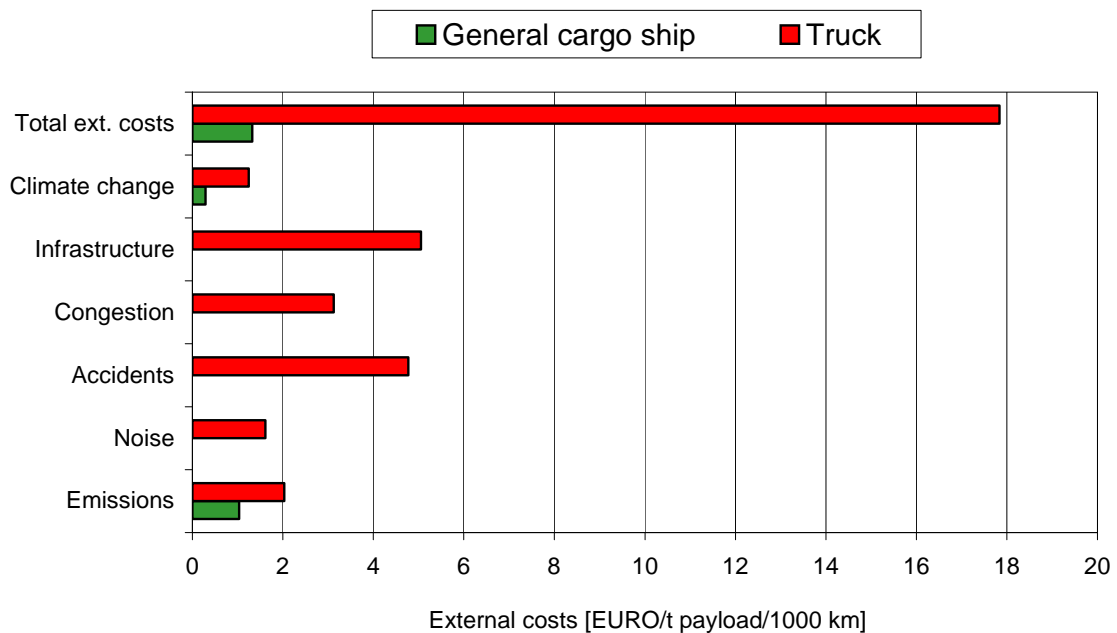
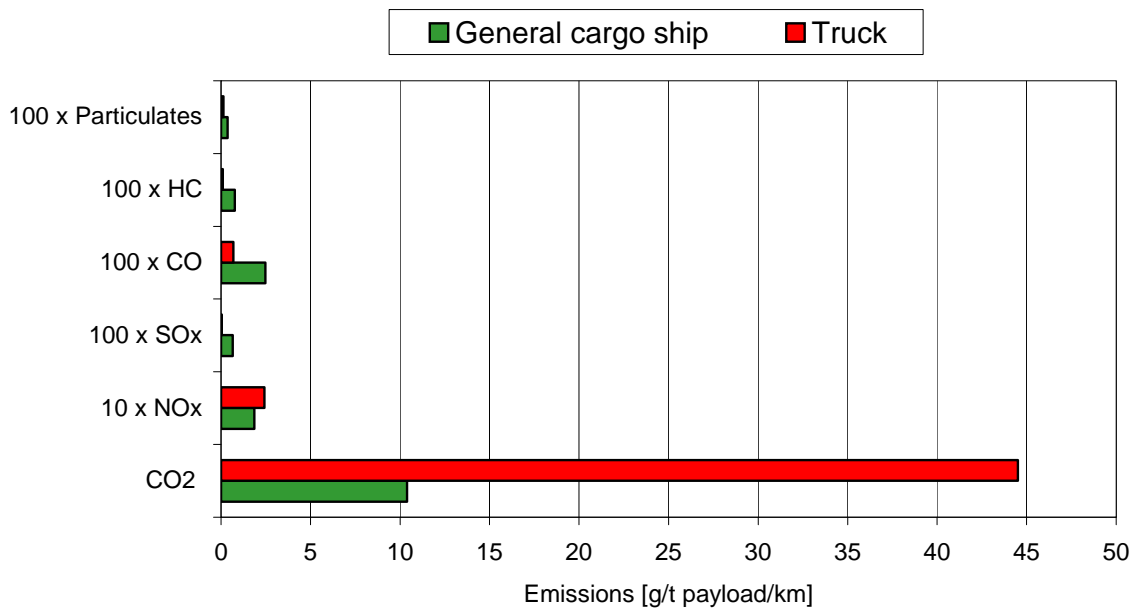
External costs (EURO/t payload/1000 km)

Ship		Truck	
Emissions	1,33	Emissions	2,03
Noise	0	Noise	1,61
Accidents	0	Accidents	4,78
Congestion	0	Congestion	3,12
Infrastructure	0	Infrastructure	5,05
Climate change	0,37	Climate change	1,24
Total ext. costs	1,70	Total ext. costs	17,8

External costs (EURO/t payload/1000 km)

Ship		Truck	
CO ₂	0,39	CO ₂	1,31
NO _x	0,62	NO _x	0,64
SO _x	0,044	SO _x	0,0015
CO	0,00001	CO	0,00000
HC	0,007	HC	0,001
Particulates	0,26	Particulates	0,09
Total	1,33	Total	2,03

Ship data		Truck data	
Design deaweight (t)	2000	Number of containers per truck	2
Payload/deadweight at design draught (%)	90	Weight per container (t/TEU)	12,5
Capacity utilization (pct.)	100	Length of truck - total (m)	18
Design payload (t)	1800	EURO norm (2, 3, 4, 5 or 6)	4
Normal speed (knots)	10,3	Suphur content of oil (%)	0,001
Speed reduction (pct.)	10	Driving distance (km)	400
Actual ship speed (knots)	9,2	Driving percentage in city area	5
Suphur content of oil (%)	0,1	External cost level	
NOx emissions (IMO TIER 1, 2 or 3)	1	1 = Low, 2 = Mean, 3 = High	2
Slow speed (1) or medium speed main engine (2)	2	Ship (EURO/t payload/1000 km)	1,32
Sailing percentage in harbour conditions	2	Truck (EURO/t truck load/1000 km)	17,8



Emissions (g/t payload/km)

Ship		Truck	
CO ₂	10,4	CO ₂	44,5
10 x NO _x	1,85	10 x NO _x	2,43
100 x SO _x	0,65	100 x SO _x	0,03
100 x CO	2,47	100 x CO	0,7
100 x HC	0,77	100 x HC	0,10
100 x Particulates	0,37	100 x Particulates	0,14

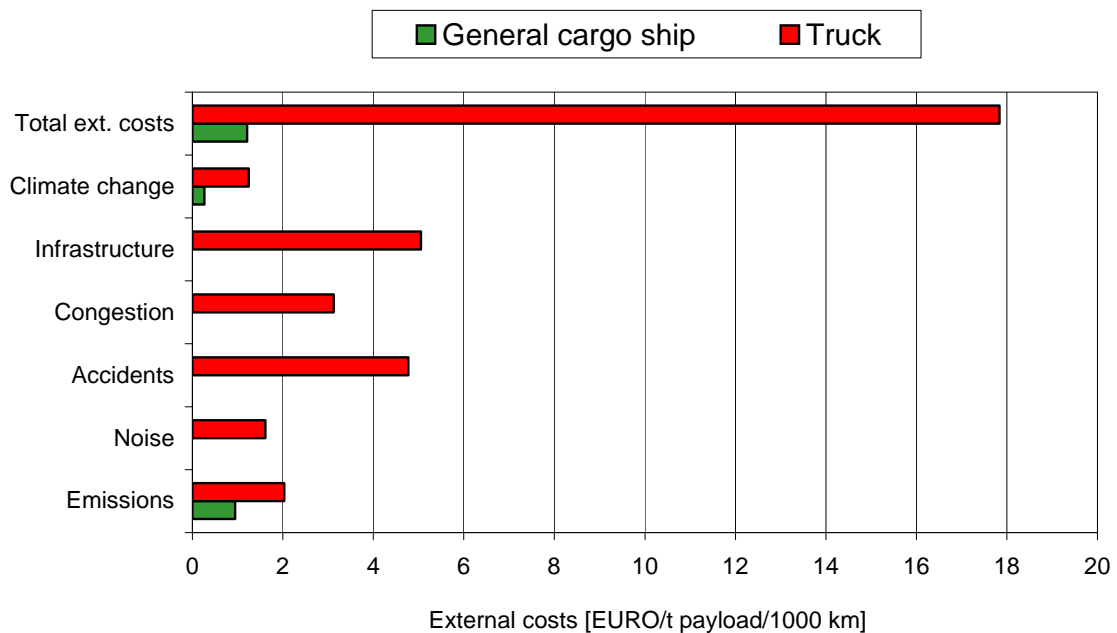
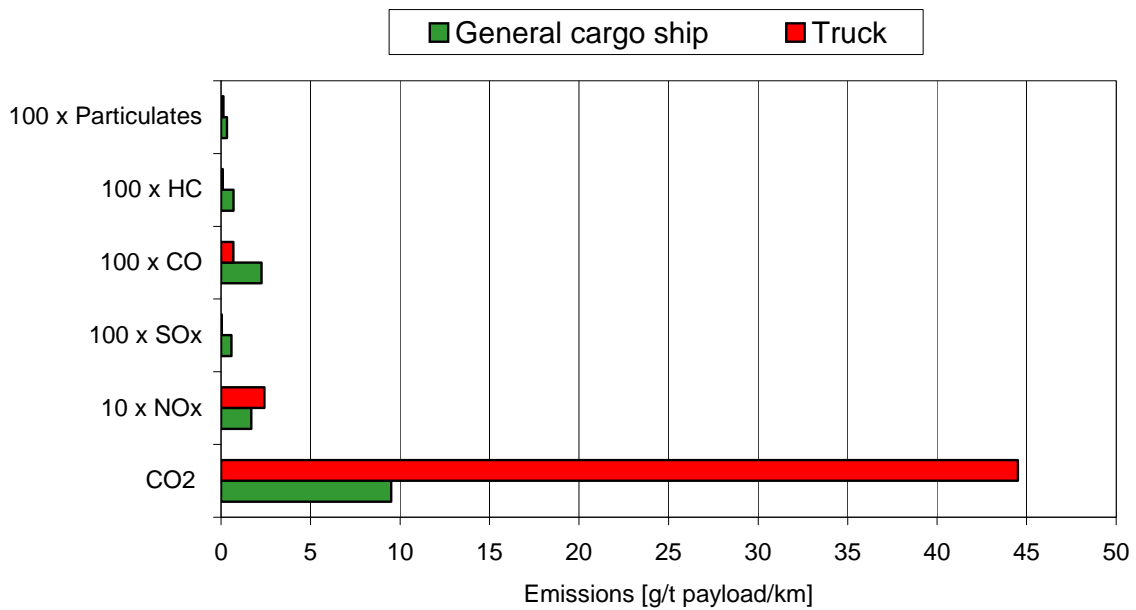
External costs (EURO/t payload/1000 km)

Ship		Truck	
Emissions	1,03	Emissions	2,03
Noise	0	Noise	1,61
Accidents	0	Accidents	4,78
Congestion	0	Congestion	3,12
Infrastructure	0	Infrastructure	5,05
Climate change	0,29	Climate change	1,24
Total ext. costs	1,32	Total ext. costs	17,8

External costs (EURO/t payload/1000 km)

Ship		Truck	
CO ₂	0,31	CO ₂	1,31
NO _x	0,49	NO _x	0,64
SO _x	0,035	SO _x	0,0015
CO	0,00001	CO	0,00000
HC	0,005	HC	0,001
Particulates	0,20	Particulates	0,09
Total	1,03	Total	2,03

Ship data		Truck data	
Design deaweight (t)	4000	Number of containers per truck	2
Payload/deadweight at design draught (%)	90	Weight per container (t/TEU)	12,5
Capacity utilization (pct.)	100	Length of truck - total (m)	18
Design payload (t)	3600	EURO norm (2, 3, 4, 5 or 6)	4
Normal speed (knots)	11,7	Suphur content of oil (%)	0,001
Speed reduction (pct.)	10	Driving distance (km)	400
Actual ship speed (knots)	10,5	Driving percentage in city area	5
Suphur content of oil (%)	0,1	External cost level	
NOx emissions (IMO TIER 1, 2 or 3)	1	1 = Low, 2 = Mean, 3 = High	2
Slow speed (1) or medium speed main engine (2)	2	Ship (EURO/t payload/1000 km)	1,21
Sailing percentage in harbour conditions	2	Truck (EURO/t truck load/1000 km)	17,8



Emissions (g/t payload/km)

Ship		Truck	
CO ₂	9,5	CO ₂	44,5
10 x NO _x	1,69	10 x NO _x	2,43
100 x SO _x	0,59	100 x SO _x	0,03
100 x CO	2,26	100 x CO	0,7
100 x HC	0,71	100 x HC	0,10
100 x Particulates	0,33	100 x Particulates	0,14

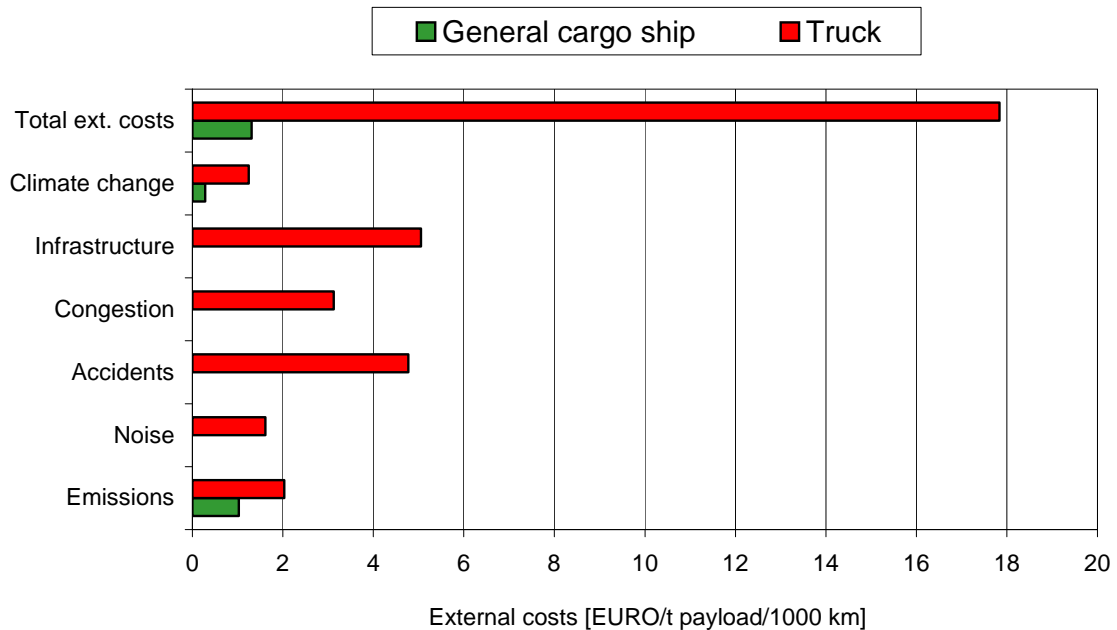
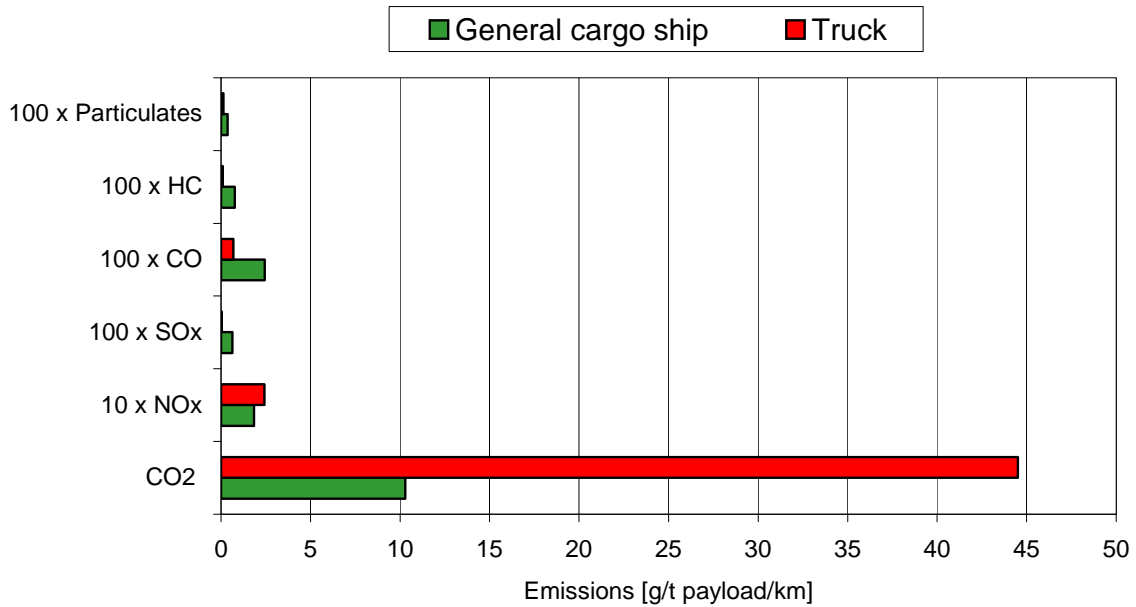
External costs (EURO/t payload/1000 km)

Ship		Truck	
Emissions	0,95	Emissions	2,03
Noise	0	Noise	1,61
Accidents	0	Accidents	4,78
Congestion	0	Congestion	3,12
Infrastructure	0	Infrastructure	5,05
Climate change	0,27	Climate change	1,24
Total ext. costs	1,21	Total ext. costs	17,8

External costs (EURO/t payload/1000 km)

Ship		Truck	
CO ₂	0,28	CO ₂	1,31
NO _x	0,44	NO _x	0,64
SO _x	0,032	SO _x	0,0015
CO	0,00001	CO	0,00000
HC	0,005	HC	0,001
Particulates	0,19	Particulates	0,09
Total	0,95	Total	2,03

Ship data		Truck data	
Design deaweight (t)	6000	Number of containers per truck	2
Payload/deadweight at design draught (%)	90	Weight per container (t/TEU)	12,5
Capacity utilization (pct.)	100	Length of truck - total (m)	18
Design payload (t)	5400	EURO norm (2, 3, 4, 5 or 6)	4
Normal speed (knots)	13,6	Suphur content of oil (%)	0,001
Speed reduction (pct.)	10	Driving distance (km)	400
Actual ship speed (knots)	12,2	Driving percentage in city area	5
Suphur content of oil (%)	0,1	External cost level	
NOx emissions (IMO TIER 1, 2 or 3)	1	1 = Low, 2 = Mean, 3 = High	2
Slow speed (1) or medium speed main engine (2)	2	Ship (EURO/t payload/1000 km)	1,31
Sailing percentage in harbour conditions	2	Truck (EURO/t truck load/1000 km)	17,8



Emissions (g/t payload/km)

Ship		Truck	
CO ₂	10,3	CO ₂	44,5
10 x NO _x	1,84	10 x NO _x	2,43
100 x SO _x	0,64	100 x SO _x	0,03
100 x CO	2,45	100 x CO	0,7
100 x HC	0,76	100 x HC	0,10
100 x Particulates	0,36	100 x Particulates	0,14

External costs (EURO/t payload/1000 km)

Ship		Truck	
Emissions	1,02	Emissions	2,03
Noise	0	Noise	1,61
Accidents	0	Accidents	4,78
Congestion	0	Congestion	3,12
Infrastructure	0	Infrastructure	5,05
Climate change	0,29	Climate change	1,24
Total ext. costs	1,31	Total ext. costs	17,8

External costs (EURO/t payload/1000 km)

Ship		Truck	
CO ₂	0,30	CO ₂	1,31
NO _x	0,48	NO _x	0,64
SO _x	0,034	SO _x	0,0015
CO	0,00001	CO	0,00000
HC	0,005	HC	0,001
Particulates	0,20	Particulates	0,09
Total	1,02	Total	2,03

Appendix E

Ship particulars from computer program

Ship data	Units	Default values
Container capacity (type 1: <4900 TEU type 2: >4900 TEU)	TEU	77
Panamax (1) or Postpanamax type (2)	(-)	1
Length between pp	m	67,49
Length in waterline incl. bulbous bow (= 1,01 Lpp)	m	68,17
Length over all	m	73,51
Breadth mld.	m	12,95
Depth	m	5,96
Design draught	m	3,52
Scantling draught	m	3,59
Scantling draught - design draught	m	0,07
Design deadweight/Scantling deadweight	%	94,6
Design deadweight	tons	1000
Scantling deadweight	tons	1055
Scantling deadweight/TEU	tons/TEU	13,78
Lightweight coefficient	t/m ³	0,180
Lightweight	tons	940
Displacement at design draught	tons	1940
Displacement at scantling draught	tons	1995
Block coefficient (based on Lpp) at design draught	-	0,615
Block coefficient (based on Lpp) at scantling draught	-	0,620
Lpp/Displ.vol. ^{2/3} at design draught	-	5,46
Lpp/Displ.vol. ^{2/3} at scantling draught	-	5,41
Midship section coefficient	-	0,98
Prismatic coefficient at design draught	-	0,627
Prismatic coefficient at scantling draught	-	0,632
Waterplane area coefficient	-	0,867
Wetted surface at design draught	m ²	988
Wetted surface at scantling draught	m ²	1002
Service speed at design draught	knots	9,7
Froude Number at service speed	-	0,194
Scantling trial speed at 75 % MCR ('reference speed')	knots	9,7
Froude Number at 'reference speed'	-	0,192
Service allowance on resistance	pct.	10
Transmission efficiency	pct.	96
Normal main engine service rating	pct. MCR	85
Main engine power (MCR)	kW	427
Main engine type (slow speed = 1, medium speed = 2)	-	2
Auxiliary power at sea at design draught	kW	21
Propeller diameter	m	2,47
Propeller loading (MCR)	kW/m ²	89

Ship data	Units	Default values
Container capacity (type 1: <4900 TEU type 2: >4900 TEU)	TEU	154
Panamax (1) or Postpanamax type (2)	(-)	1
Length between pp	m	74,46
Length in waterline incl. bulbous bow (= 1,01 Lpp)	m	75,21
Length over all	m	80,92
Breadth mld.	m	14,09
Depth	m	6,55
Design draught	m	4,15
Scantling draught	m	4,28
Scantling draught - design draught	m	0,13
Design deadweight/Scantling deadweight	%	94,3
Design deadweight	tons	2000
Scantling deadweight	tons	2121
Scantling deadweight/TEU	tons/TEU	13,77
Lightweight coefficient	t/m ³	0,173
Lightweight	tons	1190
Displacement at design draught	tons	3190
Displacement at scantling draught	tons	3311
Block coefficient (based on Lpp) at design draught	-	0,714
Block coefficient (based on Lpp) at scantling draught	-	0,719
Lpp/Displ.vol. ^{2/3} at design draught	-	5,10
Lpp/Displ.vol. ^{2/3} at scantling draught	-	5,04
Midship section coefficient	-	0,98
Prismatic coefficient at design draught	-	0,729
Prismatic coefficient at scantling draught	-	0,733
Waterplane area coefficient	-	0,865
Wetted surface at design draught	m ²	1342
Wetted surface at scantling draught	m ²	1370
Service speed at design draught	knots	10,3
Froude Number at service speed	-	0,194
Scantling trial speed at 75 % MCR ('reference speed')	knots	10,2
Froude Number at 'reference speed'	-	0,193
Service allowance on resistance	pct.	10
Transmission efficiency	pct.	96
Normal main engine service rating	pct. MCR	85
Main engine power (MCR)	kW	726
Main engine type (slow speed = 1, medium speed = 2)	-	2
Auxiliary power at sea at design draught	kW	36
Propeller diameter	m	2,91
Propeller loading (MCR)	kW/m ²	109

Ship data	Units	Default values
Container capacity (type 1: <4900 TEU type 2: >4900 TEU)	TEU	311
Panamax (1) or Postpanamax type (2)	(-)	1
Length between pp	m	88,60
Length in waterline incl. bulbous bow (= 1,01 Lpp)	m	89,49
Length over all	m	95,90
Breadth mld.	m	16,33
Depth	m	7,72
Design draught	m	5,29
Scantling draught	m	5,50
Scantling draught - design draught	m	0,21
Design deadweight/Scantling deadweight	%	93,6
Design deadweight	tons	4000
Scantling deadweight	tons	4274
Scantling deadweight/TEU	tons/TEU	13,74
Lightweight coefficient	t/m ³	0,161
Lightweight	tons	1801
Displacement at design draught	tons	5801
Displacement at scantling draught	tons	6075
Block coefficient (based on Lpp) at design draught	-	0,740
Block coefficient (based on Lpp) at scantling draught	-	0,745
Lpp/Displ.vol. ^{2/3} at design draught	-	4,97
Lpp/Displ.vol. ^{2/3} at scantling draught	-	4,90
Midship section coefficient	-	0,98
Prismatic coefficient at design draught	-	0,755
Prismatic coefficient at scantling draught	-	0,760
Waterplane area coefficient	-	0,862
Wetted surface at design draught	m ²	1970
Wetted surface at scantling draught	m ²	2024
Service speed at design draught	knots	11,7
Froude Number at service speed	-	0,203
Scantling trial speed at 75 % MCR ('reference speed')	knots	11,6
Froude Number at 'reference speed'	-	0,201
Service allowance on resistance	pct.	10
Transmission efficiency	pct.	96
Normal main engine service rating	pct. MCR	85
Main engine power (MCR)	kW	1591
Main engine type (slow speed = 1, medium speed = 2)	-	2
Auxiliary power at sea at design draught	kW	80
Propeller diameter	m	3,70
Propeller loading (MCR)	kW/m ²	148

Ship data	Units	Default values
Container capacity (type 1: <4900 TEU type 2: >4900 TEU)	TEU	471
Panamax (1) or Postpanamax type (2)	(-)	1
Length between pp	m	102,86
Length in waterline incl. bulbous bow (= 1,01 Lpp)	m	103,89
Length over all	m	110,96
Breadth mld.	m	18,50
Depth	m	8,89
Design draught	m	6,27
Scantling draught	m	6,54
Scantling draught - design draught	m	0,27
Design deadweight/Scantling deadweight	%	92,9
Design deadweight	tons	6000
Scantling deadweight	tons	6453
Scantling deadweight/TEU	tons/TEU	13,70
Lightweight coefficient	t/m ³	0,152
Lightweight	tons	2566
Displacement at design draught	tons	8566
Displacement at scantling draught	tons	9019
Block coefficient (based on Lpp) at design draught	-	0,700
Block coefficient (based on Lpp) at scantling draught	-	0,707
Lpp/Displ.vol. ^{2/3} at design draught	-	5,07
Lpp/Displ.vol. ^{2/3} at scantling draught	-	4,98
Midship section coefficient	-	0,98
Prismatic coefficient at design draught	-	0,714
Prismatic coefficient at scantling draught	-	0,721
Waterplane area coefficient	-	0,859
Wetted surface at design draught	m ²	2565
Wetted surface at scantling draught	m ²	2645
Service speed at design draught	knots	13,6
Froude Number at service speed	-	0,219
Scantling trial speed at 75 % MCR ('reference speed')	knots	13,4
Froude Number at 'reference speed'	-	0,216
Service allowance on resistance	pct.	10
Transmission efficiency	pct.	96
Normal main engine service rating	pct. MCR	85
Main engine power (MCR)	kW	3034
Main engine type (slow speed = 1, medium speed = 2)	-	2
Auxiliary power at sea at design draught	kW	152
Propeller diameter	m	4,39
Propeller loading (MCR)	kW/m ²	200

Appendix F

Truck engine data	EU 1996	EU 2001	EU 2006	EU 2011	EU 2015
Version: 16th November 2009	EURO 2	EURO 3	EURO 4	EURO 5	EURO 6
Specific oil consumption (kg/kWh)	0,20	0,20	0,20	0,20	0,20
NOx emission (g/kWh)	7,0	5,0	3,5	2,0	0,4
CO emission (g/kWh)	1,20	1,20	0,10	0,10	0,10
HC emission (g/kWh)	0,30	0,25	0,015	0,015	0,004
Particulate emission (g/kWh)	0,15	0,10	0,02	0,02	0,01
Sulphur content in oil (pct.)	0,001	0,001	0,001	0,001	0,001
SO ₂ emission (g/kWh)	0,004	0,00	0,00	0,00	0,00
CO ₂ emission (g/kg)	3206	3206	3206	3206	3206
NOx emission (g/kg)	35,0	25,0	17,5	10,0	2,0
CO emission (g/kg)	6,0	6,0	0,5	0,5	0,5
HC emission (g/kg)	1,50	1,25	0,075	0,075	0,02
Particulate emission (g/kg)	0,75	0,50	0,10	0,10	0,05
SO ₂ emission (g/kg)	0,02	0,02	0,02	0,02	0,02
NOx emission (g/MJ)	0,82	0,58	0,41	0,23	0,05
CO emission (g/MJ)	0,14	0,14	0,01	0,01	0,01
HC emission (g/MJ)	0,035	0,029	0,00175	0,00175	0,0005
Particulate emission (g/MJ)	0,018	0,012	0,002	0,002	0,001
SO ₂ emission (g/MJ)	0,0005	0,0005	0,0005	0,0005	0,0005
Calorific value for diesel oil (MJ/kg)	42,8				
EURO NORM				4	
TEU per truck		TEU/truck		2	
Average weight of a container (TEU)		t/TEU		12,5	
Length of truck - total		m		18,0	
Driving distance		km		400	
Weight of truck load		t/truck		25,0	
Fuel consumption ratio - driving distance		(-)		1,000	
Energy consumption per TEU per km		MJ/TEU/km		7,4	
Energy consumption per lanemeter per km		MJ/lm/km		0,83	
Energy consumption per ton load per km		MJ/t/km		0,59	
Oil consumption per TEU per km		g/TEU/km		174	
Oil consumption per lanemeter per km		g/lm/km		19,3	
Oil consumption per ton load per km		g/t/km		13,9	
CO ₂ emissions per TEU per km		g/TEU/km		556	
CO ₂ emissions per lanemeter per km		g/lm/km		61,8	
CO ₂ emissions per ton load per km		g/t/km		44,5	
NOx emissions per TEU per km		g/TEU/km		3,04	
NOx emissions per lanemeter per km		g/lm/km		0,34	
NOx emissions per ton load per km		g/t/km		0,24	
HC emissions per TEU per km		g/TEU/km		0,01	
HC emissions per lanemeter per km		g/lm/km		0,001	
HC emissions per ton load per km		g/t/km		0,001	
CO emissions per TEU per km		g/TEU/km		0,09	
CO emissions per lanemeter per km		g/lm/km		0,010	
CO emissions per ton load per km		g/t/km		0,007	
SOx emissions per TEU per km		g/TEU/km		0,003	
SOx emissions per lanemeter per km		g/lm/km		0,0004	
SOx emissions per ton load per km		g/t/km		0,0003	
Particulate emissions per TEU per km		g/TEU/km		0,017	
Particulate emissions per lanemeter per km		g/lm/km		0,0019	
Particulate emissions per ton load per km		g/t/km		0,0014	

Appendix G

External costs 2009 (DTU)

CITY	DKK/kg		
	Low	Mean	High
CO ₂	0,15	0,22	0,44
Particulates	567	1.827	9.941
NOx	9	18	71
SOx	41	72	220
CO	0	0,017	0,034
HC	4	5	8

	EURO/kg		
	Low	Mean	High
	0,0196	0,029	0,059
	76	244	1325
	1,22	2,45	9,44
	5,422	9,620	29,384
	0	0,00227	0,00455
	0,525	0,700	1,049

NON CITY	DKK/kg		
	Low	Mean	High
CO ₂	0,15	0,22	0,44
Particulates	140	388	1.898
NOx	10	20	80
SOx	16	39	177
CO	0	0,003	0,005
HC	4	5	8

	EURO/kg		
	Low	Mean	High
	0,0196	0,029	0,059
	19	52	253
	1,40	2,62	10,67
	2,10	5,25	23,61
	0	0,00035	0,00070
	0,525	0,700	1,049

City traffic percentage of total traffic for ship
 City traffic percentage of total traffic for truck

2
5

Sensitivity analysis (1 = Low cost values, 2 = Mean cost values, 3 = High cost values)

2

	Averaged values EURO/kg	Averaged values EURO/kg
CO ₂	0,0294	0,0294
Particulates	56	61
NOx	2,62	2,61
SOx	5,33	5,47
CO	0,0004	0,0004
HC	0,700	0,700

Climate change	Low	Mean	High	EURO/t	Low	Mean	High
DKK/t CO ₂	140	209	419		18,6	27,9	55,8

16 t truck

	DKK/km		
	Low	Mean	High
Noise	0,16	0,30	0,62
Accidents	0,19	0,90	1,17
Congestion	0,15	0,59	1,61
Infrastructure	0,23	0,95	1,41

	EURO/km		
	Low	Mean	High
	0,0210	0,0403	0,0824
	0,0252	0,119	0,156
	0,0195	0,078	0,215
	0,0308	0,126	0,188

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