Manual for the computer program

SHIP-DESMO Ro-Ro passenger

by

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User manual for the SHIP-DESMO program for Ro-Ro passenger ships

Introduction

This report is a user manual of the generic Ro-Ro ship model program SHIP-DESMO Ro-Ro passenger, primary intended for calculation of the energy demand (fuel consumption) and emissions for Ro-Ro passenger ships. The program is one part of a complete Ro-Ro project, where to separate programs have been developed, one for 1) Ro-Ro cargo ships, named "*SHIP-DESMO Ro-Ro cargo*" and one for 2) Ro-Ro passenger ships, named "*SHIP-DESMO Ro-Ro passenger*". The theoretical background for these two SHIP-DESMO models is described in six separate reports:

1. Report No. 1: *"Prediction of resistance and propulsion power of Ro-Ro ships"* by Hans Otto Kristensen

2. Report No. 2: *"Analysis of technical data of Ro-Ro ships"* by Hans Otto Kristensen

3. Report No. 3: *"Energy demand and exhaust gas emissions of marine engines*" by Hans Otto Kristensen

4. Report No. 4: "*Analysis of propulsion power data of Ro-Ro ships and analysis of the CEN standard 16258 for Ro-Ro ships"* by Hans Otto Kristensen.

5. Report No. 5: "*Energy and emission model for trucks"* by Hans Otto Kristensen.

6. Report No. 6: "*External cost calculator for the SHIP-DESMO model"* by Hans Otto Kristensen.

All six reports have been prepared as deliverables for the project no. 2014-122: Mitigating and reversing the side-effects of environmental legislation on Ro-Ro shipping in Northern Europe. Work Package 2.3 carried out for The Traffic Section of The Technical University of Denmark.

As this report is solely a user manual, the user is highly recommended to become familiar with the background of the SHIP-DESMO program package, as this will ensure the greatest benefit and understanding of using the programs. This will furthermore secure that the input values and the results are as realistic as possible, although the programs include several safeguards against wrong input and also include guidelines for the range of valid input values.

Definitions

L_{wl}	Length of waterline of ship
L_{pp}	Length between perpendiculars
B	Breadth, moulded of ship
T	Draught, moulded amidships (mean draught)
W_L	Lightship weight
D_w	Deadweight of ship
Δ	Displacement mass of ship ($\rho \cdot \nabla = W_L + D_W$)
∇	Displacement volume of ship
S	The wetted surface of immersed hull
A_M	Immersed midship section area
A_{wl}	Area of water plane at a given draught)
D_{prop}	Propeller diameter

V	Speed of ship
g	gravitational constant (9.81 m/s^2)
Fn	Froude number ($Fn = \frac{V}{\sqrt{g \cdot Lpp}}$)
C_B	Block coefficient ($C_B = \frac{\nabla}{Lpp \cdot B \cdot T}$)
C_M	Midship section coefficient ($C_M = \frac{A_M}{B \cdot T}$)
C_p	Prismatic coefficient ($C_P = \frac{C_B}{C_M}$)
C_w	Water plane area coefficient ($C_w = \frac{A_{wl}}{L \cdot B}$)
M	Length displacement ratio or slenderness ratio, $M = \frac{L}{\nabla^{1/3}}$
ρ	Mass density of water

General structure of the SHIP-DESMO program

The SHIP-DESMO program has been developed as Excel 2003 programs, which mean that it can be executed by all Excel versions from 2003 and up to the latest versions from Microsoft.

Folders: INPUT and SHIP DATA

Ship data	
Default ship (0) or ship alternative No. 1 or No. 2	0
Low cargo density (1) or high cargo density (2)	1
Passenger capacity (persons)	1800
Actual number of passengers	200
Total lanemeters (100 %) = LM	**1267**
Total number of cars (100 %)	**435**
Actual payload/deadweight at maximum draught (pct.)	55
Rolling cargo lanemeters in pct. of total LM	20
Bus lanemeters in pct. of total LM	0
Car and caravan lanemeters in pct. of total LM	10
Occupied lanemeters	**380**
Normal speed (knots)	21.9
Actual speed (knots)	21.9
Speed change (pct.)	0
Pass. comfort class (1 = low, 2 = average or 3 = high)	2
Suphur content of oil (%)	0.1
NOx emissions (IMO TIER 1, 2 or 3)	2
Slow speed (1) or medium speed main engine (2)	2
Sailing percentage in harbour conditions	2.0
Remaining draft reserve (m) - shall be positive !	**0.60**

Emission allocation method	
Area (1), mass (2) or average (3)	3

Necessary input has to be specified in the two folders **INPUT** and **SHIP DATA.**

In **INPUT** are specified the more fundamental parameters which are following:

1. The cargo density of the ship. For Ro-Ro passenger ships 2 different cargo densities are avaiable, where cargo density is related to both cargo weight and lanemeters (cargo weight per passenger and lanemeters per passenger).
2. The maximum transport capacity (maximum number of passengers for Ro-Ro passenger ships)
3. The payload in pct. of the maximum deadweight
4. The actual utilization of the lanes in pct. of the maximum lanemeters. Three different types of usage of the lanes have to be specified for Ro-Ro passenger ships: 1) Lanes for pure rolling cargo, 2) Lanes for busses (passenger transport) and 3) Lanes for cars and caravans and mobile homes (passenger transport).
5. The actual number of passengers
6. The ship speed. The normal service speed corresponding to the actual capacity is given and the user can specify the actual speed by a percentage deviation from the proposed default speed
7. The passenger comfort class, which has an influence on the different types of passenger areas (restaurants, cafeterias, cabins, corridors and other public spaces)
8. Emission allocation type, according to the CEN Standard 16258
9. The Sulphur content in the oil fuel
10. The NOx Tier level of the engines (1 – 3)
11. Engine type, i.e. slow speed (2 stroke) or medium speed (4 stroke)
12. The percentage of the total sailing distance which is done in harbor area (city area)

After specification of the primary/main data in INPUT more detailed data can be specified/changed in the folder SHIP DATA in the yellow cells below:

Ship data (Ro-Ro passenger ship)	Units	Default values	Alternative No. 1	Alternative No. 2	Min. allowable value	Max. allowable value
Low cargo density (1) or high cargo density (2)	-	1	1	1	1	2
Ship type (1: Single screw, 2: Conv. twin screw, 3: Twin-skeg)	-	2	2	2	1	3
Passenger capacity	persons	1800	1800	1800	100	3200
Change of length in percent	%	0.0	0.0	0.0	-25	25
Length between pp	m	154.02	154.02	154.02	116	193
Length in waterline incl. bulbous bow	m	159.41	159.41	159.41		
Length over all	m	167.96	167.96	167.96		
Breadth mld.	m	25.37	25.37	25.37	22.87	27.87
Depth to upper continous deck	m	14.64	14.64	14.64	13.18	16.11
Lanemeter	m	1267	1267	1267	300	2154
Lanemeter per passenger	LM/pass.	0.7	0.7	0.7		
Car equivalent	cars	435	435	435		
Design draught	m	5.76	5.76	5.76		
Maximum draught	m	6.07	6.07	6.07	5.07	7.07
Maximum draught - design draught	m	0.32	0.32	0.32		
Design deadweight/Maximum deadweight	%	77	77	77		
Design deadweight	t	3353	3353	3353		
Proposed maximum deadweight per lanemeter	t/m	3.31	3.31	3.31	2.0	5.0
Maximum deadweight correction per lanemeter	t/m	0.0	0.0	0.0	-1.31	1.65
Maximum deadweight correction per lanemeter in pct.	%	0	0	0		
Actual maximum deadweight per lanemeter after corrections	t/m	3.31	3.31	3.31		
Maximum deadweight (based on dw/LM and passengers)	t	4370	4370	4370		

Ro-Ro passenger ships

Proposed payload/deadweight at maximum draught	%	55	55	55		
Actual payload/deadweight at maximum draught	%	55	55	55	40	80
Actual payload per lanemeter at maximum draught	t/m	1.82	1.82	1.82		
Lightweight coefficient	t/m^3	0.176	0.176	0.176		
Lightweight correction	t	0	0	0	-2015	2518
Lightweight	t	10073	10073	10073		
Displacement at design draught	t	13427	13427	13427		
Displacement at maximum draught	t	14443	14443	14443		
Deafault number of berths based on passenger number	-	913	913	913		
Actual number of berths (if default press -1)	-	-1	-1	-1	-1	1826
Gross tonnage	GT	23808	23808	23808		
Gross tonnage (if default press -1)	-	-1	-1	-1		
Block coefficient (based on Lpp) at maximum draught	-	0.594	0.594	0.594	0.5	0.7
Block coefficient (based on Lwl) at maximum draught	-	0.574	0.574	0.574	0.5	0.7
Block coefficient (based on Lwl) at design draught		0.563	0.563	0.563	0.5	0.7
Lpp/Displ.vol.$^{1/3}$ at design draught	-	6.53	6.53	6.53	5	8
Lpp/Displ.vol.$^{1/3}$ at maximum draught	-	6.38	6.38	6.38	5	8
Midship section coefficient at maximum draught	-	0.956	0.956	0.956	0.90	0.99
Midship section coefficient at maximum draught	-	0.958	0.958	0.958	0.90	0.99
Prismatic coefficient at design draught based on Lwl	-	0.589	0.589	0.589	0.50	0.78
Prismatic coefficient at maximum draught based on Lwl	-	0.599	0.599	0.599	0.50	0.78
Waterplane area coefficient based on Lpp	-	0.796	0.796	0.796	0.7	0.9
Wetted surface at design draught	m^2	4198	4198	4198		
Wetted surface at maximum draught	m^2	4351	4351	4351		
Speed change in percent	%	0	0	0	-15	15
Service speed at maximum draught	knots	22.07	22.07	22.07	18.8	25.4
Froude Number at service speed	-	0.287	0.287	0.287		
Scantling trial speed at 100 % deadweight at 75 % MCR	knots	22.0	22.0	22.0		
Froude Number at 'reference speed'	-	0.291	0.291	0.291		
Service allowance on resistance	pct.	15	15	15		
Beaufort No.	-	8	8	8		
Calculated wind speed acc. to Beaufort No.	m/s	19.1	19.1	19.1		
Longitudinal wind resistance coefficient, Cx	-	0.80	0.80	0.80	0.5	1.1
Wind speed to be used for separate wind resistance	m/s	0.0	0	0		
Wind resistance fraction of trial resistance	pct.	0	0	0		
Transmission efficiency	pct.	96	96	96		
General improved propeller efficiency	pct.	0.0	0.0	0.0	0	10
Main engine power (MCR)	kW	20502	20502	20502		
Auxiliary power - calculated acc. to IMO MEPC.212(63)	kW	763	763	763		
Power take off (P_{PTO})	kW	0	0	0		
MIN(P_{PTO}, P_{AE}/0.75)	kW	0	0	0		
MCR - P_{PTO}	kW	20502	20502	20502		
Default propeller diameter	m	4.47	4.47	4.47		
Prop. diameter (if different from default value - otherwise press -1)	m	-1.00	-1.00	-1.00	3.7	5.2
Propeller type (1 = conventional - 2 = ducted)	(-)	1	1	1	1	2
Propeller loading (MCR)	kW/m^2	652	652	652		

In the first column of SHIP DATA the default values, i.e. typical statistically based values, are shown for a Ro-Ro ship given by the general particulars specified in INPUT.

In column 1 and 2 it is possible to specify alternative ship specific values in the yellow cells, other than the default values. However these alternative values have to be within the limits shown in the two columns at the right side of the three columns. These limit values have been obtained from the comprehensive statistical analysis of many hundred Ro-Ro passenger ships which are basis for the SHIP-DESMO model.

Engine technology

ENGINE TYPE & TECHNOLOGY				
Main engine type (slow speed = 1, medium speed = 2)	(-)	2	2	2
Main engine service rating (for non derated engine only)	pct. MCR	90	90	90
Fuel type (HFO = 1, MD/GO = 2, LNG = 3, Dual fuel = 4)	-	2	2	2
SFOC at 75 % MCR in normal ME mode (If default press 1)	g/kW/hour	1	1	190
SFOC for auxiliary engines (If default press 1)	g/kW/hour	1	1	215
If normal tuning press 1 - if low load tuning press 2 (2 stroke)	-	1	1	1
Sulphur content in heavy fuel (HFO)	pct.	1.0	1.0	1.0
Sulphur content in diesel oil or gas oil (DO/GO)	pct.	1.0	1.0	1.0
Derated 2 stroke main engine? (NO = 0, YES = 1)	-	1	1	1
Fuel optimised main engine? (NO = 0, YES = 1)	-	0	0	0
TIER 1, 2 or 3 engine? (1 - 3)	-	2	2	2
Specify NOx reduction technology: EGR (Exhaust Gas Recirculation) =1, SCR (Selective Catalyic Reduction) = 2 or other technology = 3	-	1	1	1
Use of scrubbers if oil is used (NO = 0, YES=1)	-	0	0	0

When data are specified in INPUT it is indirectly assumed that the ship is driven by diesel-engines. The blue cells in the above mentioned part of the SHIP DATA are transferred directly from INPUT

In the engine type and technology part of SHIP DATA it possible to select four different fuel types:

1. Heavy fuel oil (HFO)
2. Marine diesel oil (MDO)
3. Liquid natural gas in combination with a small amount of diesel oil, i.e. Dual Fuel
4. Purely Liquid Natural gas (LNG)

The normal maximum service engine loading has to be specified, and normally 90 pct. of the maximum engine power (max. continuous rating = MCR) is used except in the case where the main engine is specified as a de-rated engine, which means that the engine in normal service condition can run at 100 pct. of the maximum power (MCR).

More strict demands with respect to NOx emission has entered into force such that all new engines has to fulfill the so-called Tier 2 NOx demands from 2011. From 2016 ships sailing in so-called NOx emission control areas have to fulfill the NOx Tier 3 demands. In 2016 following areas are classified as NOx ECA´s: North America, Canadian coast, US Caribbean including Puerto Rico and the US Virgin Islands.
Different technologies can be used for NOx reduction and following possibilities can be specified in SHIP DATA:

1. EGR (Exhaust Gas Recirculation)
2. SCR (Selective Catalytic Reduction)
3. Other technology

Using a de-rated engine and some of the NOx reducing technologies changes the specific fuel oil consumption (SFOC) of the main engine. The SHIP-DESMO model automatically takes care of these changes such that the SFOC is updated according to the selected engine technology.

If the SFOC for the main engine and auxiliary engines are not known it is possible just to specify 1 as input in the appropriate cells and typical default values will be used corresponding to the engine type and fuel type. However if the actual SFOC is known the SFOC value at 75 % engine load can be specified separately.

Also different, still more stringent SOx demands, have to be fulfilled depending on the sailing area. In the Baltic Sea and the North Sea only 0.1 per cent Sulphur is allowed in the oil. Instead of using oil with a low Sulphur content, the exhaust gas can be cleaned using a scrubber system, which can remove the SOx in the exhaust gas, such that the SOx content in the gas corresponds to using oil with 0.1 per cent Sulphur. In SHIP DATA it is possible to specify whether a scrubber is used for SOx cleaning. The additional power demand needed for a scrubber system (3 %) is indirectly taken care of in the calculation procedures for the oil consumption.

Technically it is possible to introduce a shaft driven electrical generator in the shaft line from the main engine(s), if extra electrical power is needed (typical when bow thrusters are used during harbor manoeuvring), such that this can be generated by the main engine(s). If the SFOC for the main engine is lower than the SFOC for the auxiliary engines, the use and installation of a shaft generator will reduce the so-called Energy Efficiency Design Index (EEDI), which can be beneficial for Ro-Ro ships, which very likely will have problems to fulfill the coming demands to EEDI, especially after 2020.

Information of the technical issues of the different fuel types and engine technologies can be found in Report No. 3: "*Energy demand and exhaust gas emissions of marine engines*" by Hans Otto Kristensen. It is strongly advised to become familiar with the different engine technologies described in this report

Further additional changes can be made in SHIP DATA.

Propeller data

General improved propeller efficiency	pct.	0.0	0.0	0.0	0	10
Main engine power (MCR)	kW	20502	20502	19922		
Auxiliary power - calculated acc. to IMO MEPC.212(63)	kW	763	763	748		
Power take off (P_{PTO})	kW	0	0	0		
MIN(P_{PTO}, P_{AE}/0.75)	kW	0	0	0		
MCR - P_{PTO}	kW	20502	20502	19922		
Default propeller diameter	m	4.47	4.47	5.00		
Prop. diameter (if different from default value - otherwise press -1)	m	-1.00	-1.00	5.00	3.7	5.2
Propeller type (1 = conventional - 2 = ducted)	(-)	1	1	1	1	2

The propeller diameter is automatically calculated on basis of the draught of the ship, which means, that if the draught is changed, the propeller diameter will also be changed. It is also possible to specify an individual propeller diameter completely independently of the draught. In general an increase of the propeller diameter will result in a higher propeller efficiency, such that a 10 pct. larger propeller decreases the propulsion power by 2 – 3 pct.

If a special propeller with a higher efficiency than a normal propeller is assumed, it is possible to specify the added propulsion efficiency in pct. As example the so-called Kappel propeller is reported to increase the efficiency by 4 - 5 pct.

For Ro-Ro ships so called open propellers are normally used, but it is possible to specify a ducted propeller, which is beneficial if the propeller loading is high, which most probably not will be actual for a Ro-Ro ship.

Hull type/hull form

Ship type (1: Single screw, 2: Conv. twin screw, 3: Twin-skeg)	-	2	2	2

Three different hull forms can be specified:

1. A single screw hull form
2. A normal twin screw hull form
3. A twin skeg hull form (with two propellers)

The wetted surface of ship depends on these hull forms, and it is automatically calculated according to the selected hull form. Also different propulsion characteristics are dependent on the hull form and will therefore automatically be calculated by the SHIP-DESMO model.

Length of the ship

The length of the ship can be changed without any change of the basic capacity and the maximum deadweight. The lightweight is automatically updated according to the changed length. A longer hull form will decrease the block coefficient, C_B, and increase the length displacement ratio, $\frac{L}{\nabla^{1/3}}$, which can be beneficial from a resistance point of view. The wetted surface increases when the length is increased, so the change of necessary propulsion power shall be checked before the final change of length is chosen, but normally a power reduction of 2 – 5 pct. can be obtained by 5 pct. length increase.

Change of breadth, draught and depth

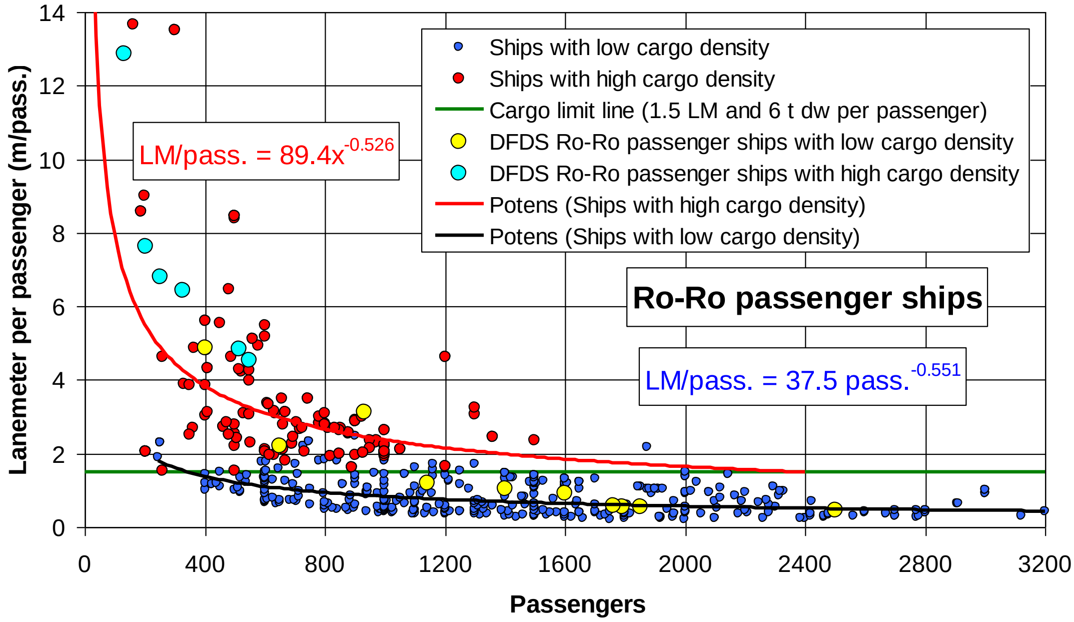
Breadth mld.	m	25.37	25.37	25.37
Depth to upper continous deck	m	14.64	14.64	14.64
Lanemeter	m	1267	1267	1267
Lanemeter per passenger	LM/pass.	0.7	0.7	0.7
Car equivalent	cars	435	435	435
Design draught	m	5.76	5.76	5.76
Maximum draught	m	6.07	6.07	6.07

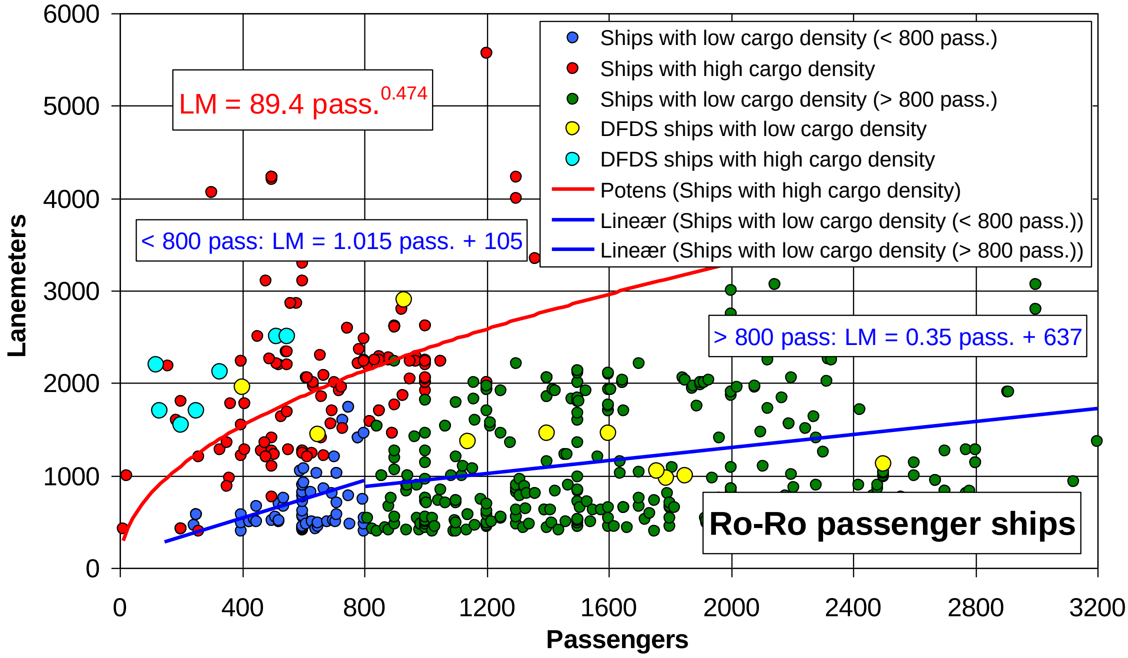
It is also possible to change the maximum draught, the breadth and the depth of the ship, without changing the capacity, i.e. lanes, max. number of passengers and deadweight. The lightweight is automatically changed due to the changed dimensions, using an empirical lightweight formula.

Lanemeters and berths

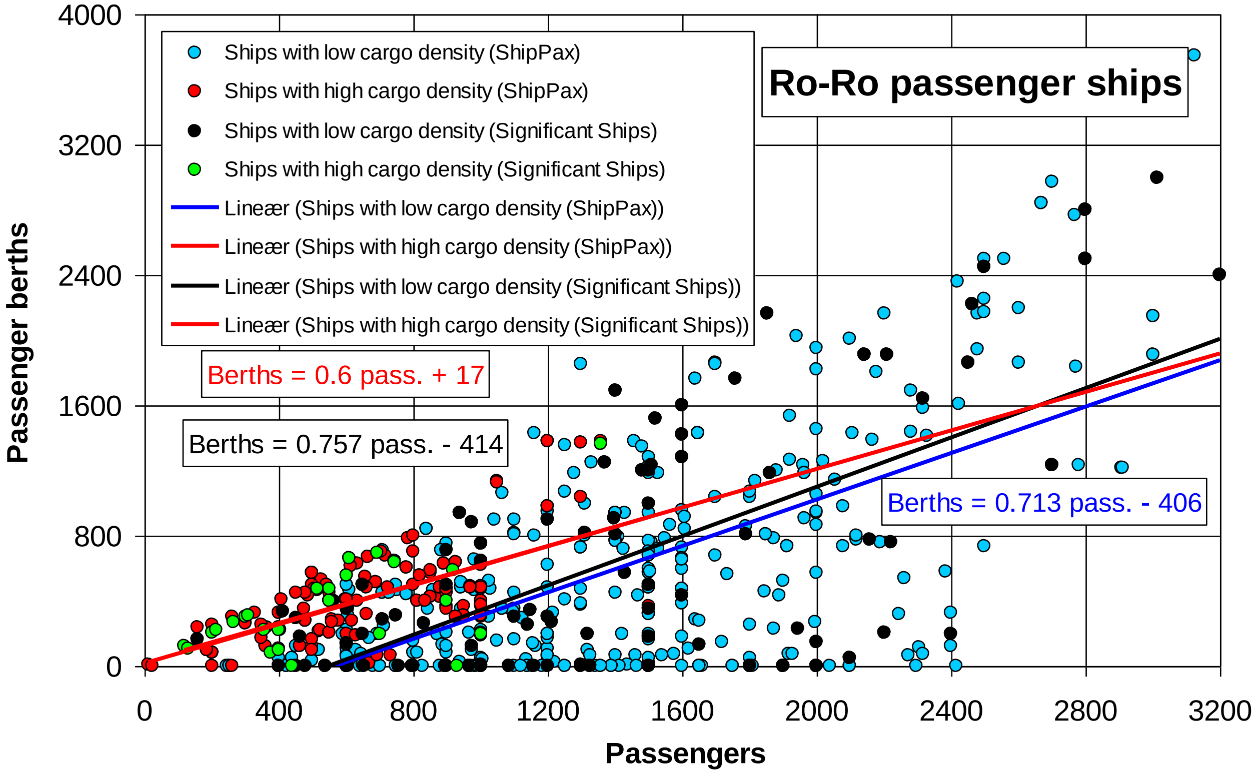
For Ro-Ro passenger ships the lanemeters and the berths are calculated as default values. It is possible to change these values individually with the limits shown in the program. Change of number of berths results in a changed lightweight and the program automatically calculates the corrected lightweight according to the changed number of berths.

The lanemeters as function of passenger capacity are shown on the following figures:





The number of berths as function of the passenger capacity are shown in the following figure:



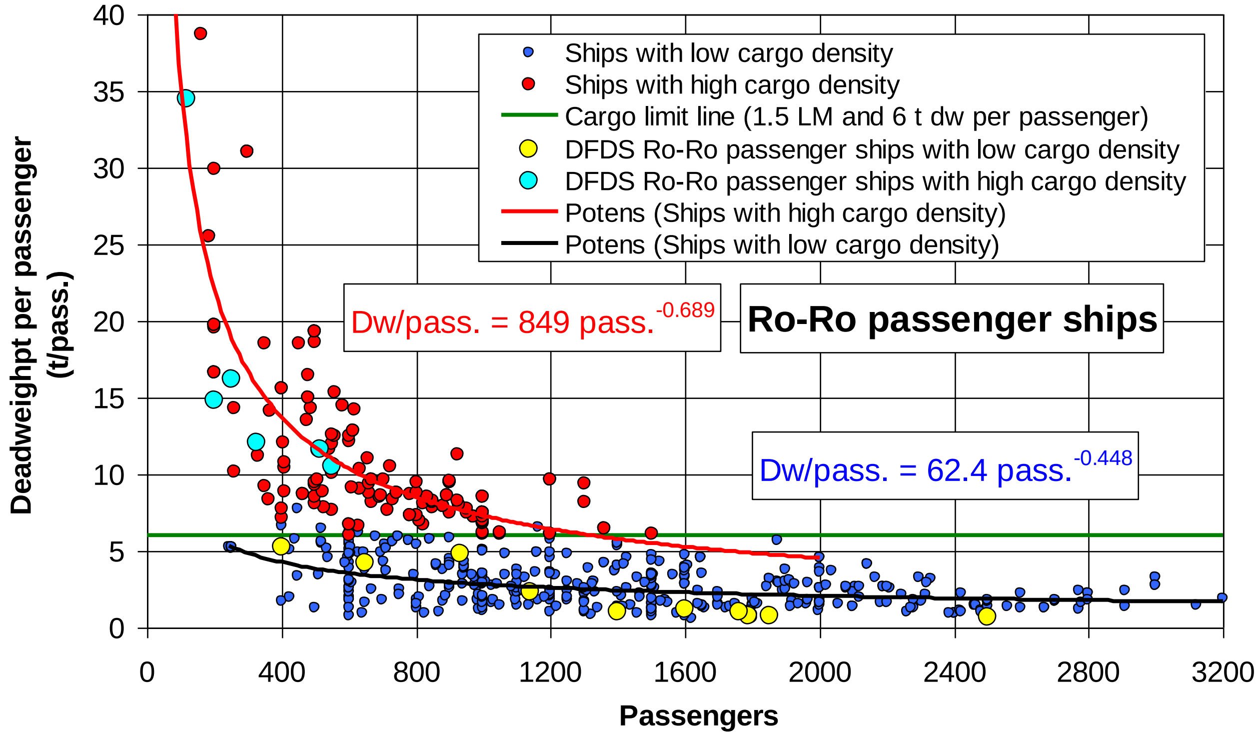
Change of deadweight

Proposed maximum deadweight per lanemeter	t/m	3.31	3.31	3.31
Maximum deadweight correction per lanemeter	t/m	0.0	0.0	0.0
Maximum deadweight correction per lanemeter in pct.	%	0	0	0
Actual maximum deadweight per lanemeter after corrections	t/m	3.31	3.31	3.31
Maximum deadweight (based on dw/LM and passengers)	t	4370	4370	4370

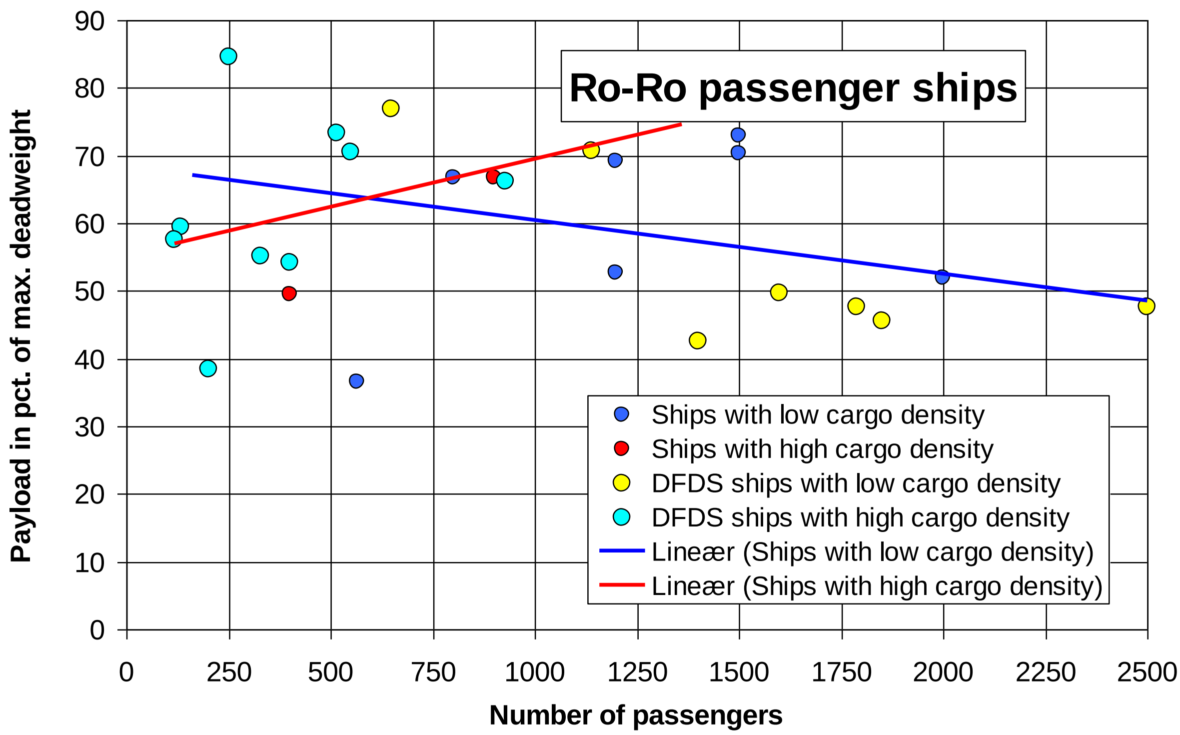
The deadweight depends on the actual cargo density of the ship type as follows:

1. Low cargo density (low number of lanes and deadweight per passenger)
2. High cargo density (high number of lanes and deadweight per passenger)

The deadweight per passenger for two cargo density classes are shown in the following figure by the black and red curves:



In addition to the cargo density class it is possible to change the maximum deadweight per lanemeter either in direct values or in percentage. Especially when the high cargo density type is choosen or when the dw/lanemeter is increased, it will be natural to change the ratio of payload in pct. of the deadweight from a default value of 55 – 60 pct. to 65 – 80 pct. as shown on the following figure.



In relation to cargo weight, the user shall have in mind that the difference between the actual draught and the maximum draught shall be positive. A negative value means that the ship is loaded to a draught exceeding the maximum allowable draught. This draught indication is shown in the folder INPUT.

Emission calculations

Transport services carried out by Ro-Ro passenger ships fulfils two separate transport needs, namely 1) passenger related transport of passengers and personal cars, campers etc. and 2) pure freight transport of trucks and other rolling cargo such as unaccompanied vehicles/mafi trailers.

The CEN Standard 16258 describes two different allocation methods for allocation of the total ship emissions on passenger and freight transport. The two methods are the so-called 1) mass method and the 2) area method.

The results of the emission calculations are found in three different folders:

1. Emission area allocation according to CEN 16258
2. Emission mass allocation according to CEN 16258
3. Emission AVERAGE allocation which is based on an average of the area and the mass allocation method

All types of emissions (as defined and documented in the folder Emission factors) are presented in the emission folders, where the emissions are related to different parameters such as 1) per nautical mile, 2) per hour, 3) per passenger per nautical mile and finally 4) per lanemeter per nautical mile.

In the three emission folders are also included the external cost calculations, which are calculated according to the cost values defined and documented in the folder External cost factors.

Comparison with other transport modes

In the folder INPUT it is possible to specify the transport modes:

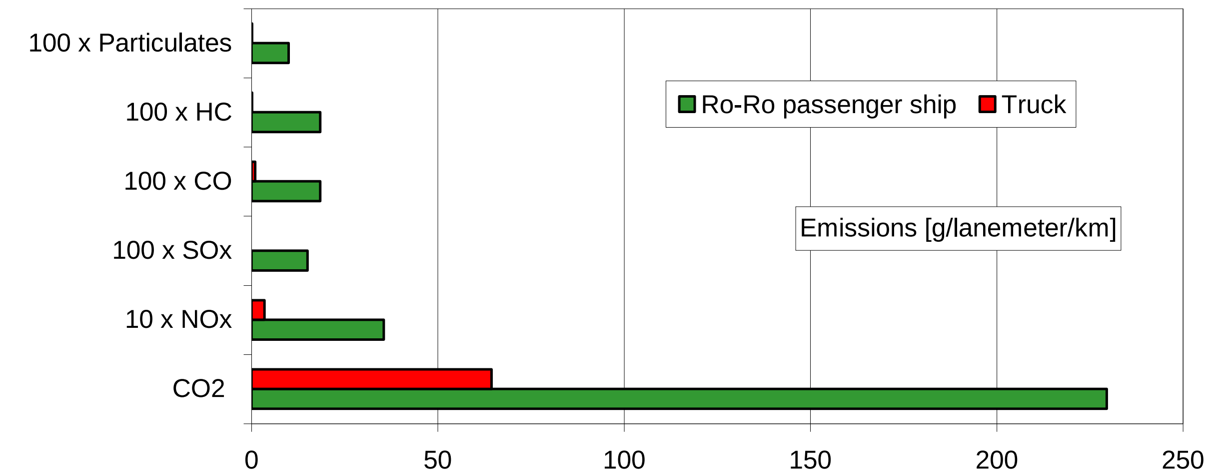
1. Transportation of cargo by truck
2. Transportation of passenger by bus
3. Transportation of passengers by car

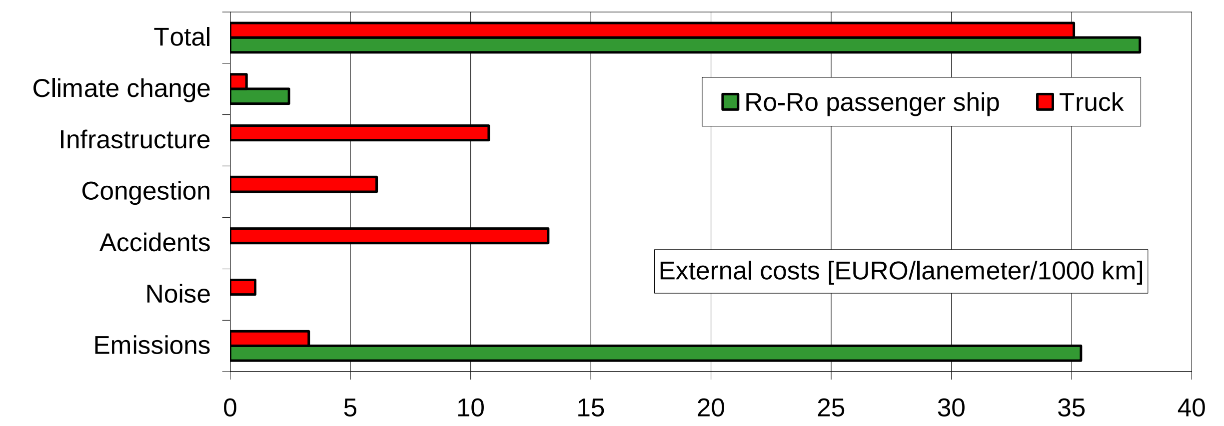
The technical details of these transport forms are documented in the folder Truck, car and bus data, where the energy and emission calculation procedures are given.

In the INPUT folder are presented emission and external cost values for the three different land transport modes, such that it is possible to compare the emission performance and the external cost performance between all these land based transport forms with the equivalent transport by the actual Ro-Ro passenger ship under the specified condition and with the specified technical main particulars.

Ship data	
Default ship (0) or ship alternative No. 1 or No. 2	0
Low cargo density (1) or high cargo density (2)	1
Passenger capacity (persons)	1800
Actual number of passengers	1500
Total lanemeters (100 %) = LM	**1267**
Total number of cars (100 %)	**435**
Actual payload/deadweight at maximum draught (pct.)	55
Rolling cargo lanemeters in pct. of total LM	20
Bus lanemeters in pct. of total LM	20
Car and caravan lanemeters in pct. of total LM	60
Occupied lanemeters	**1267**
Normal speed (knots)	22.1
Actual speed (knots)	22.1
Speed change (pct.)	0
Pass. comfort class (1 = low, 2 = average or 3 = high)	2
Suphur content of oil (%)	0.1
NOx emissions (IMO TIER 1, 2 or 3)	2
Slow speed (1) or medium speed main engine (2)	2
Sailing percentage in harbour conditions	2.0
Remaining draft reserve (m) - shall be positive !	**0.33**

Truck data	
Total weight of truck cargo (t)	18.0
Truck weight (empty)	10.0
Truck weight (loaded)	28.0
Length of truck - total (m)	14.0
EURO norm (2, 3, 4, 5 or 6)	4
Driving distance (km)	400
Driving percentage in city area	5
Car data (Euro Norm 6)	
Diesel (1) or petrol driven (2) car	2
Normal (1) or hybrid (2)	1
Engine volume (0.8 - 2.2 litres)	1.8
Number of passengers (max. 4)	2
Bus data	
EURO norm (3 - 6)	4
Number of passengers (max. 45)	40
External cost level	
1 = Low, 2 = Mean, 3 = High	2
EURO/DKK exchange rate	7.50
Emission allocation method	
Area (1), mass (2) or average (3)	3





Emissions (g/cargo lanemeter/km)

Ship		Truck	
CO_2	229.5	CO_2	64.4
10 x NOx	35.5	10 x NOx	3.52
100 x SOx	15.0	100 x SOx	0.04
100 x CO	18.5	100 x CO	1.00
100 x HC	18.5	100 x HC	0.15
100 x Particulates	9.9	100 x Particulates	0.20

External costs (EURO/lanemeter/1000 km)

Ship		Truck	
Emissions	35.40	Emissions	3.27
Noise	0.00	Noise	1.05
Accidents	0.00	Accidents	13.24
Congestion	0.00	Congestion	6.10
Infrastructure	0.00	Infrastructure	10.76
Climate change	2.45	Climate change	0.69
Total	**37.8**	**Total**	**35.1**

External costs (EURO/lanemeter/1000 km)

Ship		Truck	
CO_2	2.45	CO_2	0.69
NOx	25.06	NOx	2.48
SOx	4.20	SOx	0.01
CO	0.00	CO	0.00
HC	0.05	HC	0.00
Particulates	3.63	Particulates	0.09
Total	**35.40**	**Total**	**3.27**

Service allowance on ship power (%)	10

It is possible to scale the influence some of the external costs as follows:

Externality	Scaling (pct)
Noise	100
Accidents	100
Congestion	100
Infrastructure	100
Climate change	100

100 pct. means full implementation according to the quidelines by DTU/COWI (2016)

Emissions (g/passenger/km)

Ship		Bus	
CO_2	133.2	CO_2	17.9
10 x NOx	20.1	10 x NOx	1.1
100 x SOx	8.7	100 x SOx	0.1
100 x CO	10.7	100 x CO	2.0
100 x HC	10.7	100 x HC	0.1
100 x Particulates	5.8	100 x Particulates	0.1

External costs (EURO/passenger/1000 km)

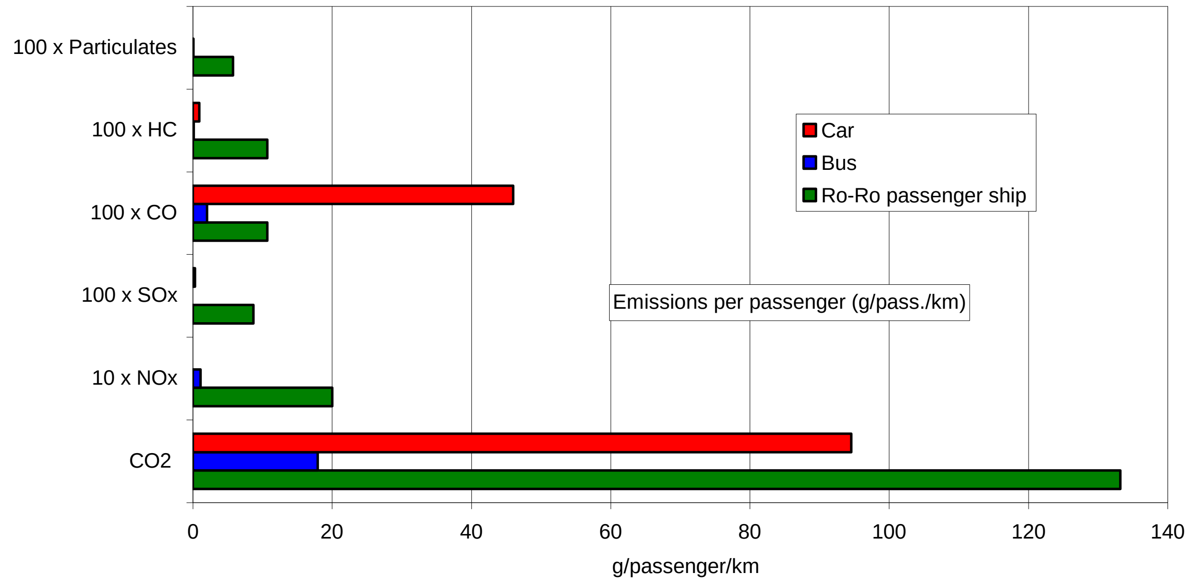
Ship		Bus	
Emissions	20.54	Emissions	1.06
Noise	0.00	Noise	0.80
Accidents	0.00	Accidents	1.73
Congestion	0.00	Congestion	2.33
Infrastructure	0.00	Infrastructure	2.07
Climate change	1.42	Climate change	0.19
Total	**22.0**	**Total**	**8.2**

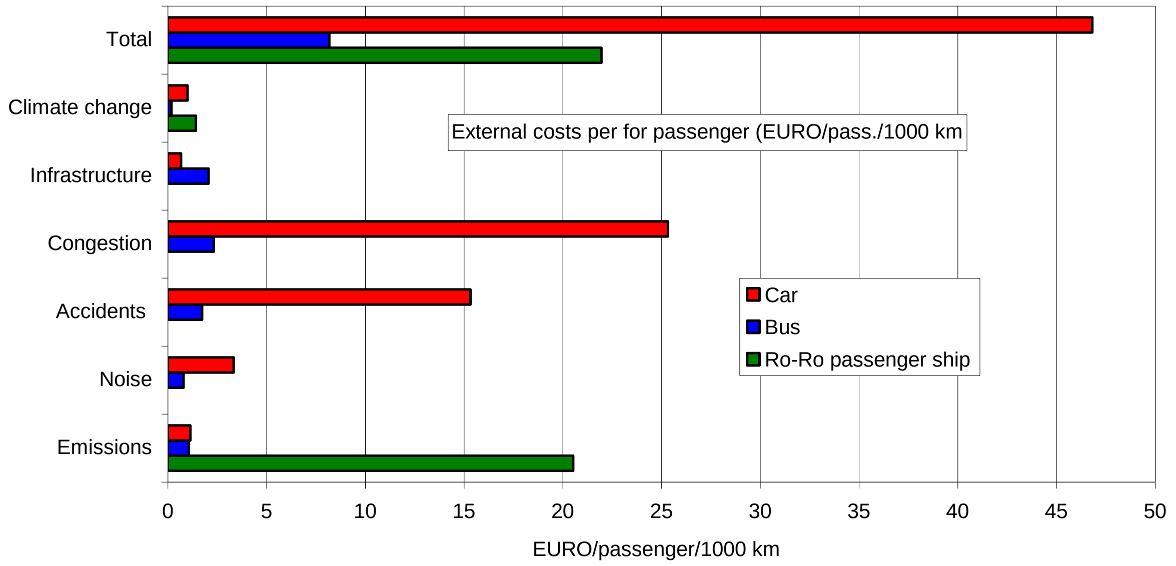
Emissions (g/passenger/km)

Ship		Car	
CO_2	133.2	CO_2	94.6
10 x NOx	20.1	10 x NOx	0.032
100 x SOx	8.7	100 x SOx	0.312
100 x CO	10.7	100 x CO	46.0
100 x HC	10.7	100 x HC	0.93
100 x Particulates	5.8	100 x Particulates	0.036

External costs (EURO/passenger/1000 km)

Ship		Car	
Emissions	20.54	Emissions	1.14
Noise	0.00	Noise	3.33
Accidents	0.00	Accidents	15.33
Congestion	0.00	Congestion	25.3
Infrastructure	0.00	Infrastructure	0.67
Climate change	1.42	Climate change	1.01
Total	**22.0**	**Total**	**46.8**





Total external costs for all transported items for a Ro-Ro passenger ship versus road (EURO/km)

By sea		By road (trucks and cars only)	
Area allocation method	EURO/km		EURO/km
Cargo	3.39	Cargo	8.89
Passengers	39.14	Passengers by car	70.22
Total	**42.53**	**Total**	**79.11**
Mass allocation method		**By road (trucks and busses only)**	
Cargo	15.79	Cargo	8.89
Passengers	26.74	Passengers by busses	12.28
Total	**42.53**	**Total**	**21.17**
Average allocation method			
Cargo	9.59		
Passengers	32.94		
Total	**42.53**		

Power prediction folders

Following folders are essential for the different types of power predictions needed to obtain the necessary propulsion power under different assumptions as follows:

PS1: Power prediction for service condition (i.e. including the prescribed service allowance, normally 15 pct.) at maximum draught according to default main dimensions

PT1: Power prediction for trial condition at maximum draught where the EEDI reference speed is calculated, i.e. the speed obtained at 75% MCR at maximum draught with NO service allowance. Valid for default main dimensions.

PAS1: Power prediction for actual service condition as specified in INPUT for default main dimensions

PS2: Power prediction for service condition (i.e. including the prescribed service allowance, normally 15 pct.) at maximum draught according to main dimensions for Alternative 1

PT2: Power prediction for trial condition at maximum draught where the EEDI reference speed is calculated, i.e. the speed obtained at 75% MCR at maximum draught with NO service allowance. Valid for Alternative 1.

PAS2: Power prediction for actual service condition as specified in INPUT for main dimensions for Alternative 1

PS3: Power prediction for service condition (i.e. including the prescribed service allowance, normally 15 pct.) at maximum draught according to main dimensions for Alternative 2

PT3: Power prediction for trial condition at maximum draught, where the EEDI reference speed is calculated, i.e. the speed obtained at 75% MCR at maximum draught with NO service allowance. Valid for alternative 2.

PAS3: Power prediction for actual service condition as specified in INPUT for main dimensions for Alternative 2.

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