EMSA/OP/10/2013

Impact assessment compilation part 1; Impact assessment in accordance with the EC IA

European Maritime Safety Agency

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Task and objective: Quantitative assessment of the impact of an increase of damage stability requirements.

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Reference to part of this report which may lead to misinterpretation is not permissible.

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3	2015-12-18	Updated according to EMSA comments	Rainer Hamann	Rolf Skjong	Odd Olufsen

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1 PREFACE

This report is a deliverable according to the Framework Service Contract Number EMSA/OP/10/2013. This is the third study commissioned by EMSA related to the damage stability of passenger ships. The previous studies focused on ro-ro passenger ships.

This study aims at further investigating the damage stability in an FSA framework in order to cover the knowledge gaps that have been identified after the finalisation of the previous EMSA studies and the GOALDS project.

The project is separated into 6 studies:

- Identification and evaluation of risk acceptance and cost-benefit criteria and application to risk-based collision damage stability
- Evaluation of risk from watertight doors and risk-based mitigating measures
- Evaluation of raking damages due to groundings and possible amendments to the damage stability framework
- Assessment of cost-effectiveness of previous parts, FSA compilation and recommendations for decision making
- Impact assessment compilation
- Updating of the results obtained from the GOALDS project according to the latest development in IMO.

The project is managed by DNV-GL and is established as a joint project, which includes the following organisations:

Shipyards/designer:

Euro-yards represented by: Meyer Werft, Meyer Turku, STX-France and Fincantieri

Knud E. Hansen AS

Operators:

Royal Caribbean Cruises

Carnival Cruises

Color Line

Stena Line

Universities:

National Technical University of Athens

University of Strathclyde

University of Trieste

Consultants:

Safety at Sea

Software developer:

Napa OY

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4 ABBREVIATIONS

A	Attained index calculated in accordance with SOLAS 2009. Ch.II-1
CBA	Cost Benefit Assessment
CN	Collision
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
EEDI	Energy Efficiency Design Index
EMSA	European Maritime Safety Agency
FSA	Formal Safety Assessment
GR	Grounding
GT	Gross tonnage
GWP	Global Warming Potential
HFO	Heavy fuel oil
HSD	High Speed Diesel
IACS	International Association of Classification Societies
IMO	International Maritime Organization
MDO	Marine diesel oil
MGO	Marine gas oil
MSD	Medium Speed Diesel
NMVOC	Non-methane volatile organic compounds
N_2O	Nitrous oxide
NO_x	Nitrogen oxides
NPV	Net Present Value
PLL	Potential Loss of Life
PM	Particulate matter PM_{10} = particulate matter with a diameter below 10 μm $PM_{2.5}$ = particulate matter with a diameter below 2.5 μm
P&I	Protection and indemnity
R	Required Subdivision Index in accordance with SOLAS 2009. Ch.II-1
RCO	Risk Control Option
SFC	Specific fuel consumption
SO_x	Sulphur oxides
SSD	Slow Speed Diesel
VPF	Value of prevented fatality

5 EXECUTIVE SUMMARY

The main goal of this report is the execution of an impact assessment according to the European Commission's Guidelines on Impact Assessment (SEC(2009) 92) based on the work done in the previous four studies.

Within the limits explained in the following the results of this study reconfirm the cost effectiveness of the RCOs related to collision and groundings examined under the IMO FSA Guidelines.

The impacts arising from risk control options (RCOs) that were developed in the previous tasks of the EMSA III study are evaluated under the European Commission IA Guidelines. The most promising of these RCOs have already been subjected to cost-benefit assessment in Tasks 1 and 3. This cost-benefit assessment was carried out in compliance with IMO FSA guidelines, and mainly considering impacts like changes in fabrication costs and operational costs.

In the present impact assessment, the scope is to enlarge the costs and benefits structure including factors such as air pollution, production of material, business model, infrastructure, impact of an accident on the environment etc., in an attempt also to internalise the so-called external costs. However the available data allows a good quantification of the effects only for air pollution, climate change, including up- and downstream processes, whereas quantification of other impacts would require intensive studies beyond the resources available in this project. Therefore the majority of impacts that are expected to be beneficial, i.e. reducing the NCAF, are not quantifiable based on available information.

The results of the impact assessment show higher cost per unit risk reduction for all RCOs that increase fuel consumption, once air pollution and climate change costs are included, i.e. the RCOs are slightly less cost-effective when evaluated in accordance with EU impact assessment. For the ship designs considered in this investigation, the impact of extra fuel consumption cannot be compensated by the reduced probability of loss of ship and cargo; however the magnitude of the extra fuel consumption may/could be reduced when hull optimisation is carried out for the RCOs. Other beneficial effects on loss of reputation or loss of income may have a large effect; however any estimation would be highly uncertain and therefore these effects are not quantified. Therefore the RCOs could be more cost-effective if all effects of an accident, e.g. loss of reputation, business loss, wreck removal, were quantified.

The results of this study show the cost effectiveness of RCOs related to collision and grounding risk reduction and hence support the results of Task 4 of the EMSA III study.

6 ABSTRACT

This report assesses the potential impacts of increased damage stability requirements for passenger ships. In order to assess all potential impacts, the areas of economy, accidental consequences with respect to safety of life, environment and property are considered, together with indirect effects like Search and Rescue and climate change. Several impacts are identified which were not considered in the cost-benefit assessment carried out in accordance with IMO FSA guidelines, some of which should have been considered also according to the FSA Guidelines (/21/), e.g. additional harbour fee and wreck removal. As far as possible within

this study, all relevant impacts have been quantified. The results are summarised in Section 11.5 of this report, comparing the net present values from this impact assessment with the values previously obtained in the cost-benefit assessment.

7 INTRODUCTION

This report is prepared in accordance with the tender specification and the project proposal and covers subtask 5 “impact assessment”. The investigation focuses on the identification of impacts related to the introduction of new, increased damage stability requirements as suggested in the report of Task 4 of the EMSA III study. The proposal of Task 4 is based on the results of cost-benefit assessments (CBA) carried out in Tasks 1 and 3 for representative novel designs for passenger ships and risk reduction for collision respectively collision and grounding. These cost-benefit assessments are in compliance with the requirement in IMO FSA guidelines and consider the impact of the design changes on operational costs (e.g. fuel, maintenance), newbuilding costs, revenue and avoided loss of ship.

The impact assessment aims at an enhanced investigation and consideration of effects of changes compared to IMO cost-benefit assessment (for more details refer to Report 2015-1024 Impact assessment compilation part 2; Comparison between IMO FSA and the EC IA). For instance, IMO CBA considers only the direct costs of additional fuel consumption whereas an impact assessment also considers the effect of air pollution including the up- and downstream processes. Both methods perform the assessment quantitatively and estimate the effects in terms of US dollar or Euro.

This report summarises the results of investigating the effects of new damage stability requirements for passenger ships. The impact is quantified in terms of Euro, if possible and relevant, for the various novel designs developed in Tasks 1 and 3 of the EMSA III study. An overview of these novel designs in given in Annex A. All impacts are estimated for 30 years' ship lifetime and calculated in terms of NPV using a depreciation rate of 5%. This report is based on the previous studies carried out within this project:

Task 1: Risk Acceptance Criteria and Risk-Based Damage Stability, Final Report, part 2: Formal Safety Assessment (/5/)

Task 2: Evaluation of risk from watertight doors (/6/)

Task 3: Evaluation of risk from raking damages due to grounding (/7/)

Task 4: Assessment of cost-effectiveness of previous parts, FSA compilation and recommendations for decision making (/38/)

8 IDENTIFYING THE PROBLEM

A number of research projects carried out in recent years like EMSA II and GOALDS focused on the damage stability requirements of passenger ships, i.e. cruise vessel, passenger ships, RoPax and RoPax-Rail. As a result of these projects new, increased damage stability requirements were recommended. For instance in the GOALDS project new damage stability requirements were proposed, justified by a cost-benefit assessment in accordance with IMO FSA Guidelines /21/.

The same approach was used for cost-benefit assessment carried out in Task 4 of the EMSA III study in order to assess design solutions for passenger ships (cruise, passenger, RoPax and RoPax-Rail). Thereafter, in the cost-benefit assessments the costs on ship building and operation related to the risk control option were estimated and compared to thresholds related to value of preventing a fatality (VPF). However, this kind of cost-benefit assessment does not consider the external costs caused, for instance, by additional emissions and their impact on people's health.

The problem under consideration is the quantification of the impact of increased damage stability requirements.

9 DEFINE THE OBJECTIVES

This analysis focuses on the identification and quantification of the impact of the risk control options (RCOs) considered in the cost-benefit assessment of Task 4 of this project. The objective is to provide the basis for the justification of new damage stability requirements for passenger ships.

10 DEVELOP MAIN POLICY OPTIONS

In order to develop a proposal for new damage stability requirements for passenger ships, existing ship designs (reference designs) were modified for the purpose of increasing the survivability in case of damage and subsequent flooding. The reference designs are representative of current "state-of-the-art" with respect to damage stability, and several reference designs achieve damage stability values significantly higher than required by current SOLAS 2009 (/22/). The modified designs provide one possible form of increased damage stability and are regarded as risk control options (RCOs). RCOs were evaluated in accordance with the cost-benefit assessment as specified in /21/ considering the collision risk only and the combined risk of collision and grounding; however not all RCOs were evaluated using both accident categories.

RCOs evaluated as cost beneficial in Task 4 of the EMSA III (/38/) project provide the basis for the proposed new damage stability requirement. These RCOs are briefly summarised in Table 10-1.

Even though the RCOs were used for developing the proposed new damage stability requirement they are not considered a policy option as this is defined in the EC IA Guidelines. A policy option would correspond to a new damage stability requirement challenging designers to develop new solutions. The RCOs provide representative examples for possible future designs and therefore allow an estimation of possible impacts of the new requirement, i.e. characterising the space of possible impacts. Thus, this impact assessment will be carried out on basis of the RCOs already developed in previous tasks of the EMSA III study.

Table 10-1 Summary of RCOs evaluated as cost beneficial based on CN and/or CN+GR risk

	Version	Brief description of RCO	A-Index
		Cruise	
Small	**00(Init)**	**Reference version**	0.7202
	06	Increase breadth by 0.5 m	0.8281
	09	Increase breadth by 0.1 m	0.7789
Large	**G2**	**Reference version**	0.8621
	I3	Breadth increased by 1.0 m, Freeboard increased by 0.8 m	0.9288
	K3	Opt. version for collision, changed internal subdivision, freeboard increased by 0.4 m	0.8754
		RoPax	
Baltic	**A (Init)**	**Reference version**	0.8326
	L	Increase breadth by 0.8 m	0.9152
Mediterranean	**V00**	**Reference version**	0.8398
	V14	Optimized for collision: Internal subdivision (bulkheads below bulkhead deck), breadth increased by 0.2 m	0.8718
	V15	Cross flooding devices + watertightness of longitudinal bulkheads	0.8717
	V16	Additional watertight parts of decks	0.8809
Small	**1(Init)**	**Reference version**	0.7947
	2	Raising main deck by 0.3 m	0.8426
Small (De)	**0(Init)**	**Reference version**	0.8412
	1	Raising main deck by 0.3 m	0.8601

11 ANALYSE THE IMPACTS OF THE OPTIONS

11.1 Impacts of risk control options

In this section the impacts of the proposed options, i.e. risk control options, are identified and their relevance discussed. This detailed discussion is included in the subsequent sections including the justification with respect to considering quantitative impact assessment. The characteristics of these RCOs were used to develop a list of potential impacts which was circulated for amendment by the project partners representing the stakeholder yards and owners/operators. For more in depth discussion other stakeholders were contacted, e.g. Maritime Administrations.

The objective of the impact assessment is the quantification of all relevant impacts of these RCOs.

Typically, the impacts of the RCOs can be categorised as:

- Direct: all effects directly linked to the RCO such as increased fuel consumption due to increased lightweight, increased breath, additional costs for material and outfitting or reduced potential loss of life for passengers; and,
- Indirect: effects like additional emissions for production and transport of fuel or steel and related effects on human health and environment.

In general, the risk control options investigated in the EMSA III study led to an increase of new building price caused by considering more costly solutions or requiring additional material and outfitting. Additional material means that lightweight of the vessel increases. A major factor in cost-benefit assessment was the additional fuel consumption caused by changes in ship dimensions requiring additional propulsion power and/or hotel load.

The general benefit of increased damage stability is a reduction in probability of sinking in collision and grounding incidents. A reduced probability of sinking will decrease the risk to people on board, passengers and crew, and additionally reduce the consequences to the environment by reducing the likelihood of ship wrecks having to be removed.

When developing the risk control options the design space was limited by assuming the business model as constant which means that the ship's speed (i.e. schedule) and transport capacity are not parameters that are subject to variation.

In the following an overview is given of the areas analysed with respect to potential impacts and impacts identified:

- Economic
  - o Changes in new building cost regarding additional steel and aluminium but also related costs like outfitting, i.e. CAPEX.
  - o Operational costs
    - ▪ Changes in fuel consumption
    - ▪ Harbour/terminal fees due to increased GT
  - o Changes in turnover/benefit: effect of increased new building costs and operational costs on fares

- Delayed replacement of older ships

- Accident
    - Human life related accident costs
    - Loss of ship
    - Wreck removal
    - Cleaning costs related to accident
    - Loss of cargo
    - Production losses/loss of income
    - Loss of reputation
    - Search and Rescue
    - Accident investigation
    - Legal costs
    - Insurance respectively P&I premium
- Air pollution: all costs related to the effect of air pollution. Typical cost elements are human health, years of human life lost and costs for nature and biosphere.
    - Additional fuel consumption leads to additional air emissions
    - Additional material steel/aluminium and outfitting
- Noise
- Climate change: prevention costs to reduce risk of climate change
    - Additional fuel
    - Additional steel
- Infrastructure, i.e. cost for updating quay or lock

Impacts on human safety, environment and business have to be considered in the analysis and in order to provide a common basis for the evaluation all impacts will be quantified in monetary terms of Euro. Some of the costs were already estimated in terms of Euro for cost-benefit assessment, e.g. CAPEX. Other costs like fuel costs or value of ship are given in terms of US dollar. In the cost-benefit assessment an exchange rate of 1.35 €/US$ was used. This exchange rate is also used for this investigation. For selected RCOs the sensitivity of the evaluation with respect to exchange rate is analysed using the average rate 1.12 €/US$ of 2015.

11.2 What are the costs of the options?

11.2.1 New building costs

The direct costs of the risk control options with respect to additional material were already estimated for the cost-benefit assessment carried out in Tasks 1 and 3 of the EMSA III study. These costs cover additional structural weight and related outfitting, e.g. larger stabiliser, public area, cabin area and technical rooms, as well as additional power for machinery and propulsion. Furthermore, costs for financing, insurance during construction phase etc. were also considered in the CBA. The RCOs and related material costs as well as CAPEX are summarised in Table 11-1 and Table 11-2.

These costs were estimated by the design experts from the yards.

Table 11-1: RCOs and related additional material and mean CAPEX (Part I)

	Version		Brief description of RCO	Change in structure weight	CAPEX (mean)
				t	€
Cruise					
Small	00(Init)		Reference version	--	--
	06	CN/CN++GR	Increase breadth by 0.5 m	69	537,193
	09	CN/CN+GR	Increase breadth by 0.1 m	14	274,479
Large	G2		Reference version	--	
	G3	CN+GR	as G2 with wt. decks	15	259,200
	I3	CN+GR	Breadth increased by 1.0 m, Freeboard increased by 0.8 m	988	12,347,240
	K3	CN+GR	Opt. version for collision, changed internal subdivision, freeboard increased by 0.4 m	480	5,756,754
	K4	CN+GR	Developed for grounding CBA, as K3 with wt. decks	480	6,015,954
	M1	CN+GR	Developed for grounding CBA, double hull increased DB height	901	5,417,304
	M2	CN+GR	Developed for grounding CBA, as M1 with wt. decks	916	5,676,504
	H4	CN	Increased breadth by 1.0 m	480	5,756,754

Table 11-2: RCOs and related additional material and mean CAPEX (Part II)

RoPax					
Large	**A (Init)**		**Reference version**		
	L	CN	Increase breadth by 0.80 m	336	3,337,740
Medium	**V00**		**Reference version**	--	
	V1	CN	V1 - depth +10	8	51840
	V12	CN	V12 - Add bkds below BHD	72	488,484
	V21	CN	V21 - Add bkds on the car deck	45	1,898,856
	V14	CN+GR	Optimized for collision: Internal subdivision (bulkheads below bulkhead deck), breadth increased by 0.2 m	157	1,670,220
	V15	CN+GR	Cross flooding devices + watertightness of longitudinal bulkheads	158.5	1,683,180
	V16	CN+GR	Additional watertight parts of decks	169.4	1,764,612
Small	**1(Init)**		**Reference version**	--	
	2	CN	Raising main deck by 0.3 m	20	129,600
Small (De)	**0(Init)**		**Reference version**	--	
	1	CN	Raising main deck by 0.3 m	10.4	67,392

11.2.2 Operational costs

The proposed RCOs may change operational costs with respect to increased fuel consumption, maintenance and harbour/terminal fees. Typically, all of these costs should be considered in cost-benefit assessment in accordance with IMO FSA guidelines, if relevant.

The change in fuel consumption was already estimated for cost-benefit assessment and the values for change in annual fuel consumption are summarised in Table 11-3.

It is mentioned that these changes were estimated on basis of the basic design and do not consider additional optimisation of the hull.

Several RCOs lead to an increase in fuel consumption, and fuel costs were a main contributor to the total costs of an RCO, e.g. for some RCOs up to 50% of total costs. The effect is significant on operational costs, due to the fact that typical service time for cruise and RoPax vessel is 30 years and the fuel prices are relatively high. Hence, the fuel price scenario has a significant impact on the evaluation result (see also Table 11-3). For estimating the fuel costs three price scenarios (low, reference, high) were considered developed based on EIA scenarios of 2013 (/8/). In the EIA scenarios the price development is estimated for crude oil Brent. For the fuel oil price scenarios considered the relative change is applied to the various fuel oil types considered.

The CBA in Tasks 1 and 3 of the EMSA III study was based on the EIA scenario of 2013 /8/. An 2015 update of this EIA scenario is now available. The differences between both scenarios are shown by the example of HFO 380 in Fig. 11.1 and the influence on the results is presented in the analysis. This scenario estimates lower crude oil prices for the next 25 years for low and reference scenario but higher for the high price scenario.

Table 11-3: Change in fuel consumption and related NPV of RCOs for cruise

	Version	Brief description of RCO	Additional fuel	Additional fuel costs for 30 years (NPV) (reference scenario
			t/a	€[1]
		Cruise		
Small	**00(Init)**	**Reference version**	--	
	06	Increase breadth by 0.5 m	73	*762,099*
	09	Increase breadth by 0.1 m	13	*135,716*
Large	**G2**	**Reference version**	--	
	G3	as G2 with wt. decks	0	0
	I3	Breadth increased by 1.0 m, Freeboard increased by 0.8 m	1,198	12,502,179
	K3	Opt. version for collision, changed internal subdivision, freeboard increased by 0.4 m	0	0
	K4	Developed for grounding CBA, as K3 with wt. decks	0	0
	M1	Developed for grounding CBA, double hull increased DB height	532	5,557,057
	M2	Developed for grounding CBA, as M1 with wt. decks	532	5,557,057
	H4		401	4,185,906
		RoPax		
Baltic	**A (Init)**	**Reference version**		
	L	Increase breadth by 0.80 m (LNG Fuelled)	263	3,128,493
Mediterranean	**V00**	**Reference version**	--	
	V1	V1 - depth +10 cm	25	284,422
	V12	V12 - Add bkds below BHD	64	727,562
	V21	V21 - Add bkds on the car deck	4799	54,598,905
	V14	Optimized for collision: Internal subdivision (bulkheads below bulkhead deck), breadth increased by 0.2 m	194	2,207,118
	V15	Cross flooding devices + watertightness of longitudinal bulkheads	196	2,229,872
	V16	Additional watertight parts of decks	204	2,320,887
Small	**0(Init)**	**Reference version**	--	
	2	Raising main deck by 0.3 m	0	0
Small (De)	**0(Init)**	**Reference version**	--	
	1	Raising main deck by 0.3 m	0	0

[1] Exchange rate 1.35 $/€

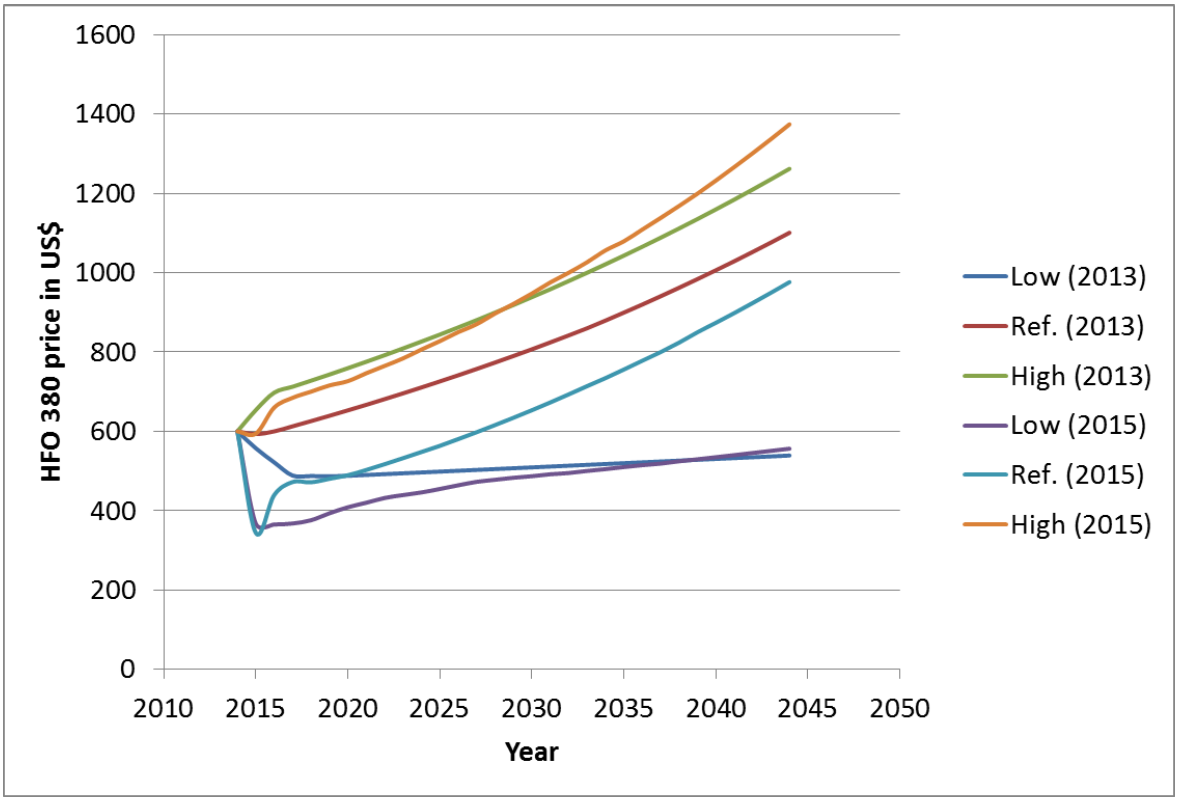

Fig. 11.1: Comparison of oil price scenarios for HFO 380 from 2013 and 2015 (based on /8/, /9/)

For demonstrating the effect of variations in fuel price scenarios, the costs are calculated as NPVs for one tonne and 30 years of operation. This calculation uses the fuel mix from the cost-benefit analysis in Tasks 1 and 3. For the 2013 scenarios and a Mediterranean RoPax (fuel mix: HFO, LSFO, MDO) net present values are US$ 10,500 (low), US$ 15,400 (reference) and US$ 17,700 (high). Based on the updated 2015 scenario accumulated costs for one additional tonne fuel consumption are US$ 9,400 (low), US$ 12,500 (reference) and US$ 17,700 (high). The comparison shows that for the scenarios "low" and "reference" the specific NPV decreased by 10% respectively 19% whereas for the high scenario the NPV is unchanged (lower fuel price in the first 15 years compensated by the higher price in the flowing 15 years). So the uncertainty increased regarding the effect of additional fuel costs.

The fuel costs are considered in the quantitative impact assessment using the values estimated by the CBA in Tasks 1 and 3, i.e. the same 2013 scenarios for oil price development.

The design changes may also increase maintenance costs, e.g. maintenance of coating or renovation of outfitting. These costs were estimated by the yards for the CBA and will be considered in the quantitative IA in the following sections.

Another impact on OPEX is harbour fees due to changes in the parameters used for their determination. Also these costs should be part of an FSA CBA but were not considered in Tasks 1 and 3.

Tariffs differ from port to port as they tend to reflect the services offered. Typically, two categories are distinguished:

- Service to the vessel comprising all activities of entering the harbour including berthing, pilotage, tug assistance etc.

- Service to cargo comprising all services related to loading and unloading, storage etc.

The complexity of harbour fees may be increased by leasing services to private operators. Also the structure differs with the port, e.g. some ports have one general fee whereas others have additional terminal and harbour maintenance fees (e.g. Miami).

The calculation may be based on ship size in terms of gross tonnage. For instance, in Hamburg the harbour fee is 0.2384 €/GT per call plus 0.0325 €/GT per day terminal fee, and in Oslo 0.06 €/GT per call, but offering 62% discount for foreign passenger ships. From the description it is not clear which services are included. Ferry operator specified an average fee of 0.1 €/GT per call and some high price harbours with 0.2 €/GT per call. Additionally or alternatively, some harbours have a passenger related terminal/harbour fee. Due to the fact that the business model is kept constant (constant number of passengers) this is not relevant. Another possibility is the operation of the terminal by the ferry operator (relevant only for RoPax) which may lead to lower harbour fees. However, New York/New Jersey fee is length related, e.g. 11.86 US$/ft (= 28.82 €/m) per day for ships or more than 900 ft (> 274 m) (/31/).

Due to this large spread in basis for harbour fees, the numbers of calls as well as the harbour called have a significant influence on the NPV. In Table 11-4 NPV values for additional harbour fee for the RCOs under consideration are summarised for Hamburg, Oslo and average. For this estimation it is assumed that the ship only calls at this harbour. For cruise, large RoPax and Mediterranean RoPax one call per day is assumed whereas for small RoPax five calls are used. As shown by the comparison to the NPV values estimated for Tasks 1 and 3, harbour fees are relevant for some RCOs, in particular for large cruise and for the small RoPax.

As shown, the Oslo harbour fees provide a lower bound and Hamburg an upper bound. For further analysis Oslo – Average – Hamburg are considered for cruise ships and Oslo - Average – High for RoPax vessel.

Table 11-4: NPV values of additional harbour fee for selected RCOs and NPV of CBA

	Version	NPV of CBA	ΔGT	Additional harbour fees for 30 years (NPV)			
		€		€			
				Hamburg	Oslo	Av	High
Cruise							
Small	**06**	1,566,027	170	267,604	59,270	98,783	197,567
	09	457,696	30	47,224	10,459	17,432	34,865
Large	**G3**	-651,672	0	0	0	0	0
	K3	3,946,311	4727	7,440,970	1,648,055	2,746,759	5,493,518
	K4	4,158,940	1600	2,518,627	557,836	929,726	1,859,452
	M1	8,124,041	1600	2,518,627	557,836	929,726	1,859,452
	M2	8,527,949	2703	4,254,906	942,393	1,570,656	3,141,311
	I3	23,111,227	2703	4,254,906	942,393	1,570,656	3,141,311
	H4	8,712,385	1271	2,000,735	443,131	738,551	1,477,102
RoPax							
Baltic	**L**	6,255,104	1097	1,726,834	382,466	637,443	1,274,887
Mediterranean	**V14**	3,827,199	270	425,018	94,135	156,891	313,782
	V15	-82,361	270	425,018	94,135	156,891	313,782
	V16	-34,369	270	425,018	94,135	156,891	313,782
Small	**2**	114,418	150	236,121	52,297	87,162	174,324
Small (De)	**1**	62,356	143	225,102	49,857	83,094	166,188

11.2.3 Turnover/benefit

In the previous sections direct CAPEX and OPEX costs are discussed. It is rather difficult to estimate how these costs are compensated, i.e. whether they are leading to an increase of ticket fares or negatively influence benefit. An increase in ticket prices is not relevant for impact assessment and CBA of an FSA. An effect that has to be considered is change in revenue which typically is considered in CBA, and in an impact assessment shift in transport capacity to other transport modes.

Ticket pricing is not a transparent process and therefore operators and their associations were asked to describe the effect of the RCOs on ticket prices (see Annex D).

If and to what extent ticket prices can be increased or the estimated increased costs are compensated by other measures depends also on the competition situation, i.e. which alternatives exist. In Europe about 180 non-domestic ferry connections are operated. For 25 of these no alternatives via road or rail exist. For others the onshore alternatives lead to significantly longer connections, e.g. Puttgarden – Rødby, Rostock-Gedser.

One RoPax operator estimated in general an increase of ticket fares by 3% if CAPEX and OPEX would increase by 5% for both normal passenger and trucks. For most of the RCOs investigated for large Baltic and Mediterranean RoPax the increase is estimated to a maximum of 4% (high NPV of RCOs). For small RoPax the NPV of the RCOs is less than 1%. This increase in ticket prices is close to annual inflation rate. How the market will react to such a relatively small increase is difficult to estimate and has not been considered.

From RoPax operators it is mentioned that ship loading capacity will be decreased if the new damage stability requirements reduce the possibility of designing ships having long lower holds and this would increase ticket prices by 10-15%. Current SOLAS 2009 damage stability requirements already limit the dimensions of long lower hold. In the EMSA III study RCOs for RoPax vessel were developed but the feasibility of long lower holds was not investigated in detail. Therefore a firm conclusion regarding feasibility or reduction of dimensions of long lower hold cannot be drawn based on the results from this study.

Generally, the main effect of increased fares will be the reduced transport of trucks. As mentioned in the paragraphs above the reaction in the market will depend on the particular situation, i.e. the potential alternatives and their costs.

The situation for cruise ships is quite different from RoPax. The main purpose of Cruise ship is not transport, and Cruise therefore does not compete with other transport modes. In discussion, cruise ship stakeholders mentioned that the change in newbuilding prices will have no substantial effect on fees and turnover because other factors are much more important.

In general any effect with respect to revenue should already be considered, if relevant, in the cost-benefit assessment in Tasks 1 and 3 of EMSA III.

11.2.4 Fleet renewal

Yards and operators mentioned that increased newbuilding prices and increased operational costs will lead to a delayed replacement of older ships. This resistance of replacing ships is expected to increase with the increase of newbuilding prices, if a direct relation is assumed.

It is mentioned that the delay in fleet renewal will have negative impacts like:

- Longer operation of ships with a lower safety level.
- Longer operation of less environmental friendly ships.
- Less yard capacity utilisation.

Extended life time for passenger ships means operating ships with a lower safety level compared to new ships with increased damage stability as well as continued operation with presumably less fuel efficiency. The difference in safety was already used to justify the new damage stability requirement in cost-benefit assessment from the societal perspective by the value per life saved (4 million US$ / 8 million US$). The effect of delayed replacement is a prolonged time to reaching the new safety level.

Extended life time for current ships means also prolonging the introduction of more environmental friendly ships. This environmental aspect was not considered in the cost-benefit assessment, e.g. operation of ships with higher specific fuel consumption or delayed introduction of new fuels.

A delayed replacement of ships may decrease yard capacity utilisation and may cause a reduction in the number of employees if not compensated by other orders.

Whether this effect of extended life time for passenger ships is likely to occur and how big it is depends not only on the impact of new damage stability requirements but also on the future optimisation potential. In general new ships are more efficient, e.g. by better machinery and fuel systems and can therefore operate at lower costs. The CBA is based on the basic design and therefore does not consider this effect. Additionally, other economic influences exist that may compensate a certain portion of the increase in newbuilding prices. For instance, one may argue that such a decrease in yard capacity utilisation may lead to increased competition between yards leading to decrease of newbuilding prices compensating the effect of the RCOs.

Based on the available information a quantification of this impact is regarded as pure guess and therefore is not further considered in the quantitative IA.

Another aspect mentioned in the context of ship renewal is compliance with EEDI. The relevance of this effect is investigated in detail (see Annex I) demonstrating that the changes in the EEDI for design variations are relatively small. This is an indication that if the vessel in its initial design is in compliance with the required EEDI the RCO will not affect this much and vice versa if the initial design is far from being in compliance.

11.2.5 Air pollution and climate change

As mentioned in the previous sections, a change of design to achieve improved performance in damage stability may lead to an increase in fuel consumption. So far most of the designs developed show an increase in fuel consumption. An increase in (carbon based) fuel consumption leads automatically to an increased release of air polluting substances with impact on human health, years of human life, nature and biosphere. For instance SO_2 affects degradation of infrastructure. Additionally, these emissions are relevant for climate change. These encompass emissions directly linked to the burning of fuel but also the emissions from production and provision, i.e. so called up- and downstream processes.

In the Update of the Handbook on External Costs of Transport /35/ the effect of air pollution is quantified. Details of determining the emissions for the different fuels as well as up- and downstream processes are explained in the Annexes B through G of this report. Air pollution costs were determined considering the location where emissions took place, i.e. the models used for quantification relate to the population and the ecosystem being exposed to the polluting air emissions. The ship types under consideration can operate with four different fuel types, HFO380 (2.51% sulphur), Low Sulphur (0.1% sulphur) Fuel Oil (LSFO), Marine Diesel Oil (MDO) and Liquefied Natural Gas (LNG), each of them with specific air emissions. Relating to the operational area the following is considered:

- Baltic and North Sea: MDO and HFO with a sulphur content of 0.1% and Tier II NO_x emissions according to current regulations
- Black Sea, Mediterranean and remaining North Atlantic: MDO with a sulphur content of 0.14% and HFO with a sulphur content of 2.51% according to IMO averages (/23/) and Tier II NO_x emissions.

For calculating the impact of additional fuel consumption it is assumed that medium speed diesel engines are used, which is typically the engine type used for cruise and RoPax. The introduction of any future exhaust gas treatment was not considered. The specific costs for the fuel types and sea regions are summarised in Table 11-5 and Table 11-6.

Table 11-5: Specific air pollution costs for different fuels in € per tonne of fuel (Part I)

	Baltic			**Black Sea**				**Mediterranean**	
	€/t_{fuel}			€/t_{fuel}				€/t_{fuel}	
	MDO	HFO	LNG	MDO	HFO	LSFO	LNG	MDO	HFO
Sulphur cont.	0.1%	0.1%	-	0.14%	2.51%	0.1%	-	0.14%	2.51%
SO_2	10.0	10.3	0.1	21.0	390.2	15.6	0.2	17.7	328.8
NOx Tier II MSD	230.1	244.8	36.8	205.6	218.8	218.8	32.9	90.6	96.4
NMVOC	3.4	3.4	3.3	1.5	1.5	1.5	1.5	2.3	2.3
PM2.5Tier II MSD	17.9	46.9	0.0	29.3	76.7	29.3	0.0	24.1	62.9
SUM	261.4	305.4	40.2	257.5	687.2	265.2	34.6	134.6	490.4

Table 11-6: Specific air pollution costs for different fuels in € per tonne of fuel (Part II)

	Mediterranean		**North Sea**			**Rem. North-East Atlantic**			
	€/t_{fuel}		€/t_{fuel}			€/t_{fuel}			
	LSFO	LNG	MDO	HFO	LNG	MDO	HFO	LSFO	LNG
Sulphur cont.	0.1%		0.1%	0.1%		0.14%	2.51%	0.1%	
SO_2	13.1	0.1	14.4	14.9	0.2	7.7	142.3	5.7	0.1
NOx Tier II MSD	96.4	14.5	291.3	309.9	46.6	110.2	117.2	117.2	17.6
NMVOC	2.3	2.3	6.5	6.5	6.3	2.2	2.2	2.2	2.1
PM2.5Tier II MSD	24.1	0.0	33.5	87.7	0.0	7.2	18.9	7.2	0.0
SUM	135.9	16.9	345.8	419.0	53.1	127.2	280.6	132.3	19.8

Another aspect to be considered is the cost of climate change. In /12/ climate change costs are given as 90 €/t_{CO2e}. Typically, climate change costs consider the emissions CO_2, CH_4 and N_2O. Based on the characteristic values for the fuel types under consideration, climate change cost are calculated (Table 11-7). Climate change costs are independent of sea regions. The climate change costs of LNG are higher than for the traditional fuels because of considered related methane releases of (methane slip) and the CO_{2e} of 25. This value of methane slip is given in the IMO Greenhouse Gas Study (/23/) which is within the range of 0.02 to 0.06 kg_{CO2e}/kg_{LNG} determined by Hartman et al. (/14/).

Table 11-7: Climate change costs per unit fuel for ship fuel types

			CO_2	CH_4	N_2O	SUM
Fuel type	MDO	kg/kg_{fuel}	3.206	6E-05	0.0002	
	HFO	kg/kg_{fuel}	3.114	6E-05	0.0002	
	LNG		2.75	0.0512	0.0001	
Greenhouse gas potential in terms of CO_2	GWP		1	25	298	
CO_2 eqv.	MDO	kg/kg_{fuel}	3.206	0.0015	0.0447	3.25
	HFO	kg/kg_{fuel}	3.114	0.0015	0.0477	3.16
	LNG	kg/kg_{fuel}	2.75	1.28	0.03278	4.06
Climate change costs	MDO	€/t_{fuel}	288.54	0.14	4.02	292.7
	HFO	€/t_{fuel}	280.26	0.14	4.29	284.69
	LNG	€/t_{fuel}	247.5	115.2	2.95	365.65

Emissions for up- and downstream processes given in /35/ do not distinguish between air pollution and climate change, and therefore a combined value is used. As explained in the Annex the external costs of air pollution and climate change of up- and downstream process for oil based fuel are 85 €/t_{fuel} with lower and upper bounds of 60 €/t_{fuel} and 110 €/t_{fuel}. For LNG, influence of upstream processes is considered via the GHG emissions considering gas production, purification, liquefaction and transport (Annex C.b).These emissions sum up to 0.49 kg_{CO2e}/kg_{LNG} or 44 €/t_{LNG}.

In total the costs for air pollution and climate change for burning fuel oil including up- and downstream process are in the same magnitude as the fuel oil price and therefore considered in quantitative IA.

For quantitative IA the fuel mix from the CBA is used.

Another aspect with relation to air pollution and climate change is material production which is investigated for steel as an example. In the Annex 0 the emissions for steel production and related upstream processes, i.e. iron ore and coal mining, are collected and external costs are estimated. External costs consider climate change costs for steel production based on the typical European fabrication process (/19/) using mainly "new" material with average CO_2 emissions of 1.8 t_{CO2}/t_{Steel} (162 €/t_{Steel}). Additional air pollution costs (NVOC and PM) are estimated to 10 €/t_{Steel} based on /11/ and /35/. Also the upstream process consisting of mining of iron ore and coal is estimated covering the main particulars, i.e. typical climate change and air polluting emissions. For mining of iron ore the average external costs are about 97 €/t_{Steel} and for coal on average 20 €/t_{Steel}.

Total steel climate change costs and air pollution costs are estimated to be 290 €/t_{Steel} which is equivalent to about 5% of the costs for integrating 1 t of steel in a ship structure. This is not a significant contribution but can easily be considered in quantitative IA.

11.2.6 Noise

Scientific investigation showed that underwater noise negatively influences marine mammals and fish /1/. One of the important sources of underwater noise is commercial shipping as the dominant source of noise below 300 Hz, mainly caused by the engine and the propeller. Underwater noise influences the behaviour with direct energetic impact (escape, flight response) and long-term effects on foraging, navigation, and reproduction activities.

The influence of the design changes on noise were discussed with experts. A linear correlation between underwater noise and installed/required power exists. The slope of this correlation can be reduced by optimisation. In /35/ only air noise was considered and emission sources car, motorcycle, bus, light and heavy commercial vehicles as well as trains but no ships and no underwater noise. Studies regarding underwater noise were carried out within IMO and EU but so far no requirements exist.

Generally, diesel-electric power systems offer the best acoustic design opportunities, e.g. isolation mounts for generator sets, optimised location in the vessel and quiet motors. Additionally, podded system provides the benefit of better inflow reducing the noise and vibration of the propeller. In /34/ the costs of retrofitting to minimise cavitation noise for a 180 m passenger ferry were estimated between 400,000 US$ and 2,300,000 US$ considering new design, construction of new propeller, PBCF/Propeller Cap Turbine and installation. It was mentioned that this design should lead to fuel saving between 5-10%. However, the costs of noise reduction for a new design were not provided and it remains unclear which costs are relevant for a new design.

The information found indicates that additional optimisation potential exists, i.e. additional measures for compensating the noise increase by increased installed power are available. The impact in terms of costs is expected to be small but it is not possible to estimate and therefore could not be considered in quantitative impact assessment.

11.2.7 Infrastructure costs

An aspect mentioned by operator representatives is that changes in ship dimensions can lead to infrastructure impacts, e.g. requiring extension of quay or lock. In principle these costs should be considered in the CBA of an FSA.

In EMSA III the ship operator and designer explained that passenger ships are designed for a particular operation, i.e. considering constraints set by the port. The designs investigated for RoPax achieved an increase in damage stability without changing ship length (L_{OA}) and draught. For cruise ships only the RCOs M1 and M2 grew in length by 3 metres and draught changes in the magnitude of some centimetres. In contrast most of the RCOs show an increase in beam up to one metre. If the reference ship is already designed to the limit, an increase of beam is no feasible solution. In such cases the design space needs to be enlarged towards the business model, i.e. transport capacity. This case was excluded from EMSA III and hence no information was given regarding CAPEX, OPEX etc.

Due to the high uncertainty regarding quantification of infrastructure costs, the relevance of this impact is questionable and cannot be estimated and is not considered in quantitative analysis.

11.3 What are the benefits of the options?

11.3.1 Human life related accident costs

The objective of increasing the damage stability requirement for passenger ships is the reduced probability of sinking/capsize after accidents leading to water ingress, i.e. collision or grounding. The direct benefits with respect to human safety were estimated in terms of potential loss of life in the EMSA III investigation and will be summarised when evaluating the different RCOs.

The costs of loss of human life are already considered via the Value Preventing a Fatality (VPF).

11.3.2 Loss of ship / ship damage / loss of cargo

Increased damage stability will not influence the probability of having a collision or grounding. So the effect will result from the differences in damage extent / costs between ships that would stay afloat (new requirement) instead of sinking (old requirement). In the cost-benefit assessment the benefit of avoiding sinking was already considered via the actual value of the ship (estimated in relation to newbuilding price). This estimation was based on the assumption that the ship is a wreck, i.e. is not repaired. Typically, the cost benefit assessment should also consider the costs related to loss of cargo.

The costs avoided (benefits) regarding loss of ship by increased damage stability were already considered in the cost-benefit assessment and will be considered quantitatively.

Loss of cargo is only relevant for RoPax ships that carry trucks. If sinking can be avoided, less cargo will be damaged. Trucks transport goods of different value, e.g. simple goods like beer or expensive goods like luxury cars. For estimating the value of cargo the figure used in FSA on containerships may be used, which is about 18,000 €[2] per TEU (20 foot Container). The length of a trailer with a 40 foot container is about 16.50 m. The large Baltic RoPax has about 1,200 m trailer lane metres providing space for about 70 trailers which is equivalent to a cargo value about 2.5 million Euros. The value of the trailers is estimated to 2.5 to 5 million Euros. Additionally, large RoPax provide space for about 270 cars (1,350 lane metres, 5 m per car, average value of € 20,000 per car) which is equivalent to about 5.4 million Euros. Hence in total the value of cargo is about 10 to 13 million Euros or 5% of the ship new building price.

Even if relatively small this impact is considered for the investigation of RoPax with 3% of ship new building price assuming the same loading conditions as for the risk analysis.

An aspect related to damage to cargo is the release of substances harmful to the environment. Linked to the probability of ship sinking the probability for the release of harmful substances will decrease. The effect is not quantifiable because no criterion for the quantification is available.

[2] Calculated with an exchange rate of 1.12 $/€; 15,000 € and for 1.35 $/€

Another effect related to sinking is on ship traffic, e.g. if the ship sinks/capsizes in restricted waters or harbour. For example, daily revenue for Kiel Canal is about 300,000 to 500,000 €. A blockage of the canal for two weeks would cause a loss of revenue between 4.2 and 7 million Euros plus additional costs for the ships travelling around Denmark (time and fuel). Estimating potential losses for a harbour is difficult because not only the loss in revenue for the operator of the harbour has to be considered but also the delay in cargo transport. Harbour operators mostly operate terminals in several harbours allowing no estimation of the revenue for a single harbour. The largest operator in Hamburg is HHLA with annual revenue of 1.2 bn Euros (~ 3.3 million Euros/day), or 46.2 million Euros for two weeks of blocking all HHLA terminals. This estimation shows that the costs for longer blockage of a large harbour are considerable. However, the accident frequency per ship year in such a location is smaller than the average annual frequency and so is the benefit of risk reduction. Due to the high uncertainty in any estimation regarding the possible costs as well as in the risk reduction this impact is not further considered.

11.3.3 Wreck removal / cleaning costs

Increased damage stability will reduce the probability of sinking and hence costs related to loss of ship and salvage. The costs of salvage and related cleaning are typical cost parameters for an FSA cost-benefit assessment but are not considered in Tasks 1 and 3.

Costs depend on whether the wreck is removed or remains on the seabed. However, in the latter case the removal of oil from the wreck will be necessary to prevent later oil pollution. Cleaning costs for oil pollution due to tank damage in collision are not relevant because RCOs neither affect accident probability nor the probability of fuel oil tank damage.

Costs for wreck removal depend on the accident location, in particular water depth, and requirements by the coastal state regarding wreck removal. For instance, the costs are higher for removing the entire wreck instead of cutting it into pieces. Publically available information on wreck removal costs is rare. In the single case known, wreck removal costs were about three times the newbuilding price of the ship. However, probability of sinking is low (in the range of 1 E-05 to 6 E-05 per ship year) and thereafter the effect of increased damage stability relatively small.

It is mentioned that wreck removal costs and cleaning costs are covered by insurance.

For the impact assessment, wreck removal costs are estimated with a lower bound equal to the newbuilding price of the vessel and a higher bound equal to three times newbuilding price. This also covers the costs of oil removal from the wreck.

11.3.4 Production losses / loss of income

Typically, serious accidents like collision and in particular collision leading to ship sinking will cause public attention and negatively influence occupation rates either because customers postpone their journey or chose other transport modes. It can be expected that operators try to minimise the impact for instance by lowering ticket fares. Anyway, revenues will decrease and subsequently benefit and hence also tax paid. For instance in the RCCL annual report of 2013 it was stated “The decrease in consumer cruise spending as a result of the Costa Concordia incident and the economic uncertainty in Europe had an adverse impact on our cash flows from operations in 2012” and further “If any such incident occurs during a time of high seasonal demand, the effect could disproportionately impact our results of operations for the year”.

The annual revenue of Carnival in 2014 was about 15 bn. US$ and about 8 bn. US$ for Royal Caribbean Cruise Line (RCCL) and therefore, even small relative changes are quite large values. The change in sinking frequency for RCOs for large cruise and RoPax ships is in the range of 1 E-05 to 6 E-05 per ship year. For a fleet of 200 ships the annual frequency is estimated to 2 E-03 to 1.2 E-02. This means that if a 10% decrease in revenue for one year can be avoided the effect would be in the range of 2 to 20 million dollars per year. Relating this effect to the increase in newbuilding cost (cost-benefit assessment) means that it is distributed over 200 ships which is equivalent to an effect of several ten thousands of dollars. The NPV for 30 years is estimated to 160, 000 to 1.6 million dollars. So the effect on the evaluation can be only important with respect to the upper value.

Whether such an effect will occur in reality and in case how long it will be notable is uncertain. Already in 2012 RCCL was of the opinion that “We continue to believe the impact of the Costa Concordia incident will not have a significant long term impact on our business” (/49/) and in the 2013 annual report no reference was made regarding this incident. This is also supported by the RCCL figures for passenger ticket revenues (Fig. 11.1) which showed a decrease between 2008 and 2009 but afterwards grow continuously until 2014. For Carnival the revenues showed the same until 2011 but in 2012 the revenues drop by 4% and were nearly constant in 2013. This may be put in correlation with the Costa Concordia accident; however the comparison with RCCL data shows that this effect is limited to Carnival. In 2014 Carnival’s passenger ticket revenues grew in the same range as for RCCL.

For Costa Concordia accident 32 fatalities were reported and it is likely that the effect of for instance 3,200 fatalities is expected to be much higher. But any quantification in this respect is only pure guess.

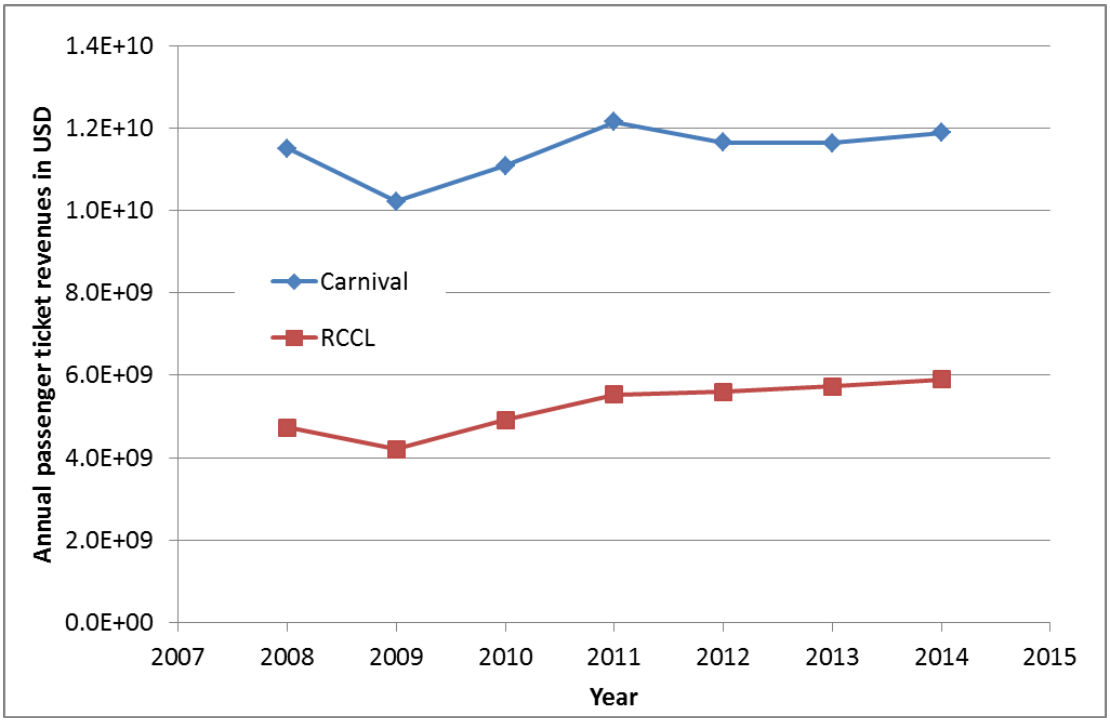

Figure 11-1: Annual passenger ticket revenues of cruise operators Carnival and RCCL between 2008 and 2014 (/45/, /46/, /47/, /48/, /49/ and /50/)

Based on this investigation the impact is not quantitatively considered.

11.3.5 Loss of reputation

Loss of reputation is an effect of accidents likely to be mentioned but hard to quantify and, therefore, typically not considered in an FSA cost-benefit assessment even if a relevant factor. Loss of reputation influences the success of business and is therefore closely linked to the section above “loss of income”, e.g. slowed down business development or financing problems negatively influencing revenues. Catastrophic events have shown significant effects of “loss of reputation”, for instance the Piper Alpha accident (Gas platform operated by Occidental Petroleum in North Sea, accident in 1988) that resulted in a withdrawal of the company from the North Sea. Another example is the Herald of Free Enterprise incident (1987) leading to severe impact on the operator Townsend Thoresen which needed two years to recover from it. Eventually the entire fleet was re-painted and company rebranded to the new branding P&O European Ferries. Unfortunately, no information on the costs of this rebranding could be found.

11.3.6 Search and Rescue

It is quite obvious that direct effort for search and rescue depends on the scenario, i.e. how long, what equipment and how many persons involved. Investigations carried out (see Annex) delivered a relatively high independency of costs and number of missions. An example from US Coast Guard: a patrol boat 1,150 US$/hr and a search plane ~7,600 US$/hr. However, the US Coast Guard and many other governments do not charge for at sea search and rescue missions. Furthermore, there are more important factors on annual budget than the number of missions.

Therefore, no effect on search and rescue costs is expected and this impact is not further considered.

11.3.7 Accident investigation

Following SOLAS regulation I/21 and MARPOL 73/78 articles 8 and 12, each Administration undertakes to conduct an investigation into any casualty occurring to ships under its flag. These investigations are carried out by Administration in order to identify accident causes and evaluate the need for maintaining regulations. Most Maritime Administration will not charge any costs which mean that costs are covered by the annual budget of the Administration. Therefore, similar to search and rescue no direct relation between accident and costs can be established.

Due to the fact that the risk control option will not reduce the accident frequency there is no effect expected.

11.3.8 Legal costs

Legal costs significantly depend on the country of settlement. For instance in Germany cost relates to the size of claim in other countries per hour. Also the size of claim may depend on the country, e.g. compensation for injuries differs between Germany and USA (it also differs between States of the US). As mentioned above, accident frequency will not be affected by increased damage stability requirements but the severity will be influenced, i.e. not the number of lawsuits but the size of claims. Due to the small change in the frequency of sinking, the effect per ship is regarded to be small and therefore not further considered for quantitative assessment.

11.3.9 Insurance and P&I premium

Marine insurance and Protection and Indemnity (P&I) take over the costs of ship accidents, such as costs of wreck removal, cleaning of pollution, compensation for injuries and fatalities and legal costs. Due to the fact that typically an insurance contract defines a franchise below which a shipowner has to pay claims, insurance and P&I cover only the claims above this threshold. Generally, for any cost-benefit assessment only accident related costs or insurance/P&I premiums should be considered to avoid double counting. The different cost elements of a claim relevant for the EMSA III study are discussed in the previous sections. More information regarding the coverage of claims and the development of premiums is summarised in Annexes D and G of this report. Depending on the accident, claims may reach very high values, e.g. the costs for Costa Concordia accident are estimated to €1.5 bn. (/16/) covering all costs like wreck removal and compensation for passengers.

Insurance and P&I compensate accident costs and hence the impact of the new requirements with respect to avoided damage costs may alternatively be estimated via the premiums instead of quantifying the costs of single parameters, e.g., for loss of ship, wreck removal and loss of cargo. Realising this approach is problematic because the premiums reflect all damages (above the franchise) and not only the effect of accidents relevant for this study. Furthermore, the model used by insurances for fixing the premium considers also parameters that have no direct relation to a particular damage. For instance, parameters like the historical development and the introduction of risk mitigating measures. This evaluation for fixing the premium is carried out individually for each customer. Accordingly, a standard premium does not exist.

According to /17/ premiums for passenger ships were raised by 170% or 2.3799 USD per Gross Tonne and year between 2012 and 2015. Accordingly the annual premium for a large cruise ship (150,000 GT) increased by approximately $ 350,000. This increase considers all damages and any estimation of the effect of collision and grounding accidents is impossible without detailed information on the model used by insurance and P&I. Therefore, also a rough estimation of the changes in premium with respect to avoided ship sinking in collision accident is impossible.

The model for setting the insurance and P&I premium is unknown and therefore any cost estimation of the effect due to new damage stability requirements is less reliable than the estimation of single cost parameters carried out in previous sections. Therefore, the single cost parameters are considered as far as quantifiable.

11.4 Qualitative comparison of impacts

This section provides an overview of the impacts discussed above and a classification into the categories of positive impact ("pros"), i.e. supporting the introduction of increased damage stability requirements, and negative, i.e. against introduction.

Impact	Pros	Cons
Newbuilding costs		Higher newbuilding costs due to increase in material consumption, outfitting and related (CAPEX)
Fuel consumption		Increase in fuel consumption leads to increased operational costs. None of RCOs showed decrease in fuel consumption. However it may be worth keeping in mind that hull optimisation could bring the increase in fuel consumption down.
Air pollution		Directly linked to fuel consumption and amplifies the effect of increased fuel consumption
Climate change		Directly linked to consumption of fuel and material. Amplifies the effect of both
Harbour fee		Mostly fees are calculated on basis of GT. Even if ship dimensions are kept constant GT may change. None of RCOs led to decrease in GT. Higher effect on ships with frequent calls.
Turnover/benefit		Higher newbuilding prices and increased operational costs can lead to increased ticket prices or reduced benefit. Increased ticket prices can lead to a shift to other transport modes for RoPax. Effect depends on local situation.
Fleet renewal		One follow-up of increased cost in areas listed above. Extend depends on many other factors like competition or increase in efficiency that can compensate negative effects. If fleet renewal is delayed, negative effects on environment (e.g. increased air pollution) are possible.
Noise		Related to installed power. Negative impact of RCOs that require additional power to

		compensate additional resistance.
Infrastructure		Changes in ship dimensions may require modification of infrastructure.
Human life related accident costs	Reduced number of fatalities and hence costs for society	
Loss of ship	Reduced number of ship losses Additional positive effect if blockage of harbour is considered	
Ship damage	Repairing damage to ship that stays afloat is less extensive than for refloated ship.	
Loss of cargo	Loss/damage to cargo smaller when ship stays afloat Reduced environmental pollution by cargo harmful to environment	
Wreck removal	Reduced number of wreck removals	
Production losses / loss of income	Avoid negative effect on revenues	
Loss of reputation	Avoided negative effect on business development and revenues.	
Search and rescue	--	--
Accident investigation	--	--
Legal costs	Reduced severity of collision accidents	
Insurance /P&I	Long-term premium for insurance and P&I should reflect spending for wreck removal, cleaning etc. Less serious damages should reduce premium.	

11.5 Quantification of impacts

In this section the results of the quantification of the impacts are summarised for the ship types cruise and RoPax. The quantification is performed for the different risk control options investigated and used for justifying the proposed damage stability requirement for passenger ships, i.e. cruise and RoPax. Details of the calculation/estimation are given in the respective section below.

The following impacts could be estimated:

- Additional fuel consumption
- Air pollution and climate change costs related to additional fuel and material
- Harbour fees
- Additional operational costs
- Avoided salvage costs

As mentioned in the previous sections, the impacts of harbour fees, additional operational costs and avoided salvage cost, are elements typically considered in FSA cost-benefit assessment.

All costs were calculated in terms of net present values (NPV) for an operation time of 30 years and using a depreciation rate of 5% which was already used in Tasks 1 and 3 of the EMSA III study. Fuel costs are calculated using the EIA oil price scenarios 2013 (/8/) and 2015 (/9/). The different cost parameters are superimposed to one value "NPV IA" which considers all quantifiable impacts of the RCOs, i.e. CAPEX, OPEX, FUELEX, air pollution, climate change, upstream etc. For some of them it is possible to make low, mean and high estimations which are considered. The low, mean and high values for air pollution are determined as follows:

- Low: minimum of air pollution costs for all operational areas
- Mean: RoPax: average of "low" and "high"; Cruise: costs for mix of operational areas (20% Baltic, 20% Black Sea, 35% Mediterranean, 15% North Sea and remaining 10% North Atlantic)
- High: maximum of air pollution costs for all operational areas.

Air pollution costs are calculated based on the fuel distribution specified by the yards for the RCOs. For Baltic and North Sea area air pollution costs are based on 0.1% sulphur content for MDO, HFO and LSFO. For Black Sea, Mediterranean and remaining North Atlantic the sulphur content is 0.14% for MDO, 2.51% for HFO and 0.1% for LSFO. The increased usage of fuels with lower sulphur content is considered via the fuel distribution.

The following sections provide for each RCO investigated in Tasks 1 and 3 the results of the impact quantification. The results are summarised in tables considering RCO characteristics, NPV-FSA, NPV-IA and related NCAF values. The NPV-FSA considers all costs estimated in the context of the cost-benefit assessment, i.e. CAPEX, OPEX, FUELEX, Loss of ship and Revenues, i.e. all costs that were already considered in the cost-benefit assessments in Tasks 1 and 3. The NPV-IA considers NPV-FSA plus all other quantifiable effects, i.e. costs related to air emissions, upstream processes, climate change, harbour fees, salvage and loss of cargo. For each of the NPVs the NCAF is provided as well. NCAF is calculated by dividing additional costs and economic benefits by change in risk. Additionally, the tables provide the characteristics of the RCOs with respect to Attained Index, increase in A-Index compared to the reference design and the estimated risk reduction:

The NCAF values are compared to the threshold used in CBA of Tasks 1 and 3 of 8 million US dollar (≈5.9 million Euros) and values below are printed in "**bold**".

Additionally, figures provide an overview of the cost parameters for fuel, air pollution, climate change and upstream for fuel and steel, as well as for comparing the two NPV values. In these figures error bands highlight the variation between low and high cost estimation.

More details regarding the different impacts can be found in the Annex J.

11.5.1 Small Cruise

The results for the RCOs 01 to 09 of small cruise are summarised in Table 11-8 (Part I) and Table 11-9 (Part II). The NCAF values for the RCOs 06 and 09 are calculated for risk reduction with respect to collision as well as for collision and grounding in combination, ref. (06 (CN+GR); 09 (CN+GR) in Table 11-9. NPV-IA is calculated without consideration of salvage because ship value was not provided.

The external costs for air pollution and climate change are calculated for all RCOs investigated using the fuel mix model of the cost-benefit assessment in Tasks 1 and 3, i.e. 100% MDO. Fig. 11.3 shows the comparison between NCAF (FSA) and NCAF (IA).

Table 11-8: Quantified impacts of RCOs for small cruise in terms of NPV and NCAF (Part I)

			RCO				
			01	**02**	**03**	**04**	**05**
A-Index			0.7263	0.7307	0.7442	0.7544	0.7944
ΔA			0.0061	0.0105	0.024	0.0342	0.0742
ΔPLL (30 yrs)	CN	fat	0.006	0.011	0.024	0.034	0.075
NPV-FSA	Low	€	-1.73E+03	5.35E+04	1.62E+05	2.00E+05	5.37E+05
	Mean	€	-6.90E+02	6.94E+04	2.15E+05	2.65E+05	7.35E+05
	High	€	3.53E+02	8.53E+04	2.60E+05	3.22E+05	8.79E+05
NCAF (FSA)	Low	€/Fat	**-2.8E+05**	**5.1E+06**	6.7E+06	**5.8E+06**	7.2E+06
	Mean	€/Fat	**-1.1E+05**	6.6E+06	8.9E+06	7.7E+06	9.9E+06
	High	€/Fat	**5.8E+04**	8.1E+06	1.1E+07	9.4E+06	1.2E+07
NPV-IA	Low	€	-1.73E+03	5.36E+04	2.00E+05	2.38E+05	9.00E+05
	Mean	€	-6.90E+02	6.95E+04	2.39E+05	2.89E+05	9.54E+05
	High	€	3.53E+02	8.54E+04	2.73E+05	3.36E+05	1.13E+06
NCAF (IA)	Low	€/Fat	**-2.8E+05**	**5.1E+06**	8.3E+06	6.9E+06	1.2E+07
	Mean	€/Fat	**-1.1E+05**	6.6E+06	9.9E+06	8.4E+06	1.3E+07
	High	€/Fat	**5.8E+04**	8.1E+06	1.1E+07	9.8E+06	1.5E+07

Table 11-9: Quantified impacts of RCOs for small cruise in terms of NPV and NCAF (Part I)

			RCO					
			06	**07**	**08**	**09**	**06 (CN+GR)**	**09 (CN+GR)**
A-Index			0.8281	0.81874	0.8752	0.7789		
ΔA			0.1079	0.09854	0.155	0.0587		
ΔPLL (30 yrs)	CN	fat	0.108	0.099	0.156	0.059	0.569	0.305
NPV-FSA	Low	€	1.13E+06	2.29E+06	3.25E+06	3.37E+05	1.13E+06	3.37E+05
	Mean	€	1.57E+06	3.11E+06	4.44E+06	4.58E+05	1.57E+06	4.58E+05
	High	€	1.85E+06	3.67E+06	5.23E+06	5.52E+05	1.85E+06	5.52E+05
NCAF (FSA)	Low	€/Fat	1.0E+07	2.3E+07	2.1E+07	**5.7E+06**	**2.0E+06**	**1.1E+06**
	Mean	€/Fat	1.4E+07	3.1E+07	2.8E+07	7.8E+06	**2.8E+06**	**1.5E+06**
	High	€/Fat	1.7E+07	3.7E+07	3.4E+07	9.4E+06	**3.3E+06**	**1.8E+06**
NPV-IA	Low	€	1.90E+06	3.65E+06	5.43E+06	4.75E+05	1.90E+06	4.75E+05
	Mean	€	2.12E+06	4.05E+06	6.04E+06	5.57E+05	2.12E+06	5.57E+05
	High	€	2.39E+06	4.44E+06	6.86E+06	6.48E+05	2.39E+06	6.48E+05
NCAF (IA)	Low	€/Fat	1.8E+07	3.8E+07	3.5E+07	8.0E+06	**3.3E+06**	**1.6E+06**
	Mean	€/Fat	2.0E+07	4.2E+07	3.9E+07	9.4E+06	**3.7E+06**	**1.8E+06**
	High	€/Fat	2.2E+07	4.8E+07	4.4E+07	1.1E+07	**4.2E+06**	**2.1E+06**

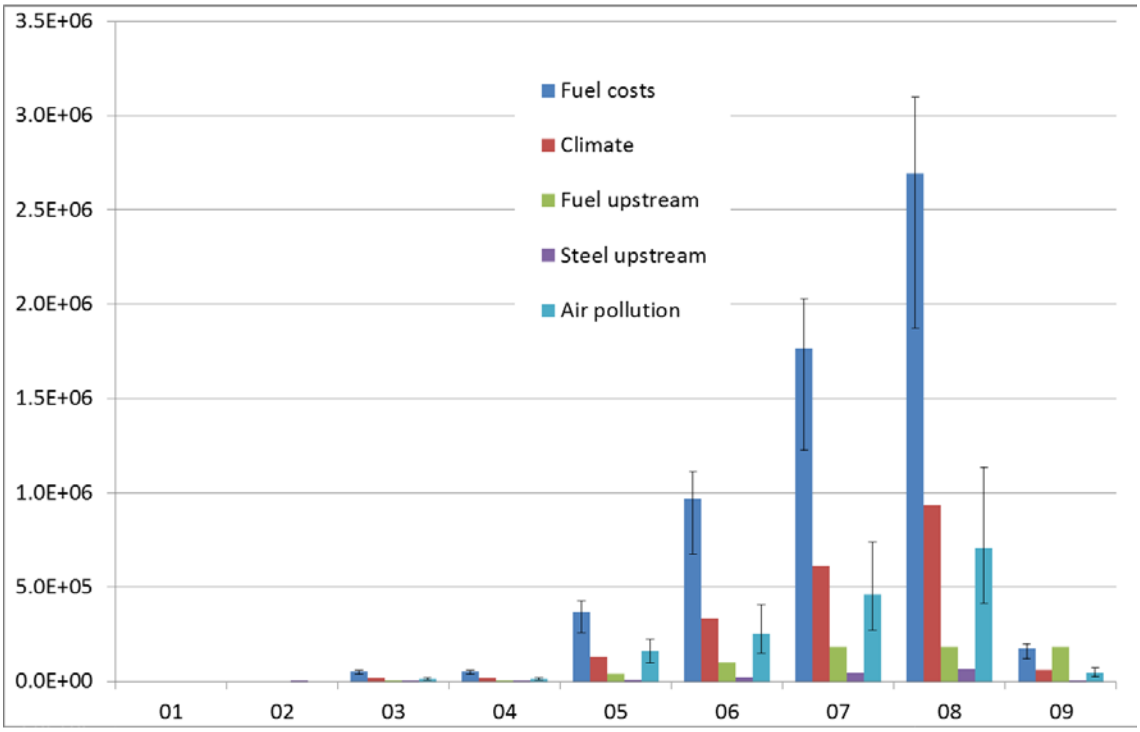

Fig. 11.2: Overview of single impact costs for the different RCOs of small cruise.

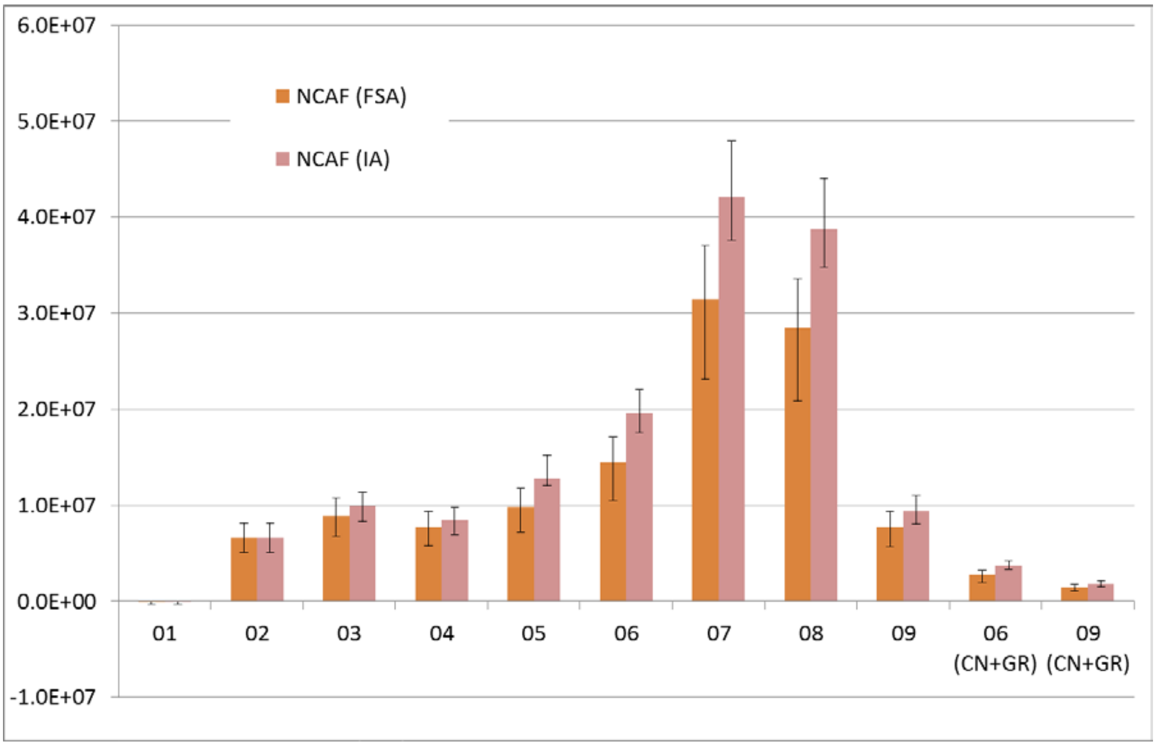

Fig. 11.3: Comparison of NCAF (FSA) and NCAF (IA) for small cruise ship RCOs. For RCOs 6th and 9th NCAF values for CN as well as CN+GR are plotted.

11.5.2 Large Cruise

For large cruise ships RCOs were investigated in two steps, first with respect to collision and secondly with respect to collision and grounding in combination. All RCOs investigated are considered in the quantification of impact and results are summarised in

- Table 11-10, Fig. 11.4 and Fig. 11.5 for RCOs focusing on collision
- Table 11-13, Fig. 11.6 and Fig. 11.7 for RCOs focusing on collision and grounding

For most of the RCOs and collision risk only the consideration of the quantifiable impacts led to an increase in NPV-IA compared to NPV-FSA and subsequently to higher NCAF values. In case of RCOs H4 and I3 this is simply caused by the increase of fuel consumption which for both is close to 50% of the total NPV-FSA. Following the operation model, cruise ships use exclusively heavy fuel oil and MDO. The external costs for these fuels are about 30% to 50% of the initial fuel prices and therefore boost the negative effect.

For the RCOs K1 and K2 the NCAF (IA) is lower than NCAF (FSA) because these RCOs cause no additional impact compared to CBA except avoided salvage costs.

The sensitivity of NCAF values with respect to fuel price scenario and exchange rate is investigated by either changing the fuel price scenario from 2013 to 2015 or changing the exchange rate from 1.35 US$/€ to 1.12 US$/€. The reference is 2013 fuel price scenario and 1.35 US$/€ as shown in Table 11-10 and Table 11-13. The results are summarised in Table 11-11 and Table 11-12 for designs evaluated for collision risk reduction and with respect to the threshold of 5.9 million Euros no sensitivity is observed. A similar influence is observed for the evaluation for collision and grounding risk together (Table 11-14 and Table 11-15).

Table 11-10: Impact of RCOs for large cruise and collision risk

			RCO						
			H4	I3	J1	K1	K2	K3	L1
A-Index			0.90872	0.92877	0.90039	0.87191	0.8777	0.87469	0.8774
ΔA			0.04651	0.06656	0.03818	0.0097	0.01549	0.01248	0.01519
ΔPLL (30 yrs)	CN	fat	0.654	0.937	0.538	0.138	0.219	0.187	0.215
NPV-FSA	Low	€	7.31E+06	1.83E+07	7.14E+06	3.81E+05	4.60E+06	8.87E+05	2.81E+06
	Mean	€	9.77E+06	2.46E+07	9.64E+06	4.94E+05	5.78E+06	1.13E+06	3.80E+06
	High	€	1.16E+07	2.90E+07	1.14E+07	6.07E+05	6.96E+06	1.38E+06	4.49E+06
NCAF (FSA)	Low	€/Fat	1.1E+07	1.9E+07	1.3E+07	**2.8E+06**	2.1E+07	**4.7E+06**	1.3E+07
	Mean	€/Fat	1.5E+07	2.6E+07	1.8E+07	**3.6E+06**	2.6E+07	6.1E+06	1.8E+07
	High	€/Fat	1.8E+07	3.1E+07	2.1E+07	**4.4E+06**	3.2E+07	7.4E+06	2.1E+07
NPV-IA	Low	€	1.12E+07	3.10E+07	1.20E+07	2.91E+05	4.46E+06	1.35E+06	4.67E+06
	Mean	€	1.51E+07	4.15E+07	1.62E+07	4.39E+05	5.69E+06	2.01E+06	6.24E+06
	High	€	1.93E+07	5.37E+07	2.10E+07	5.87E+05	6.92E+06	3.89E+06	7.79E+06
NCAF (IA)	Low	€/Fat	1.7E+07	3.3E+07	2.2E+07	**2.1E+06**	2.0E+07	7.2E+06	2.2E+07
	Mean	€/Fat	2.3E+07	4.4E+07	3.0E+07	**3.2E+06**	2.6E+07	1.1E+07	2.9E+07
	High	€/Fat	3.0E+07	5.7E+07	3.9E+07	**4.3E+06**	3.2E+07	2.1E+07	3.6E+07

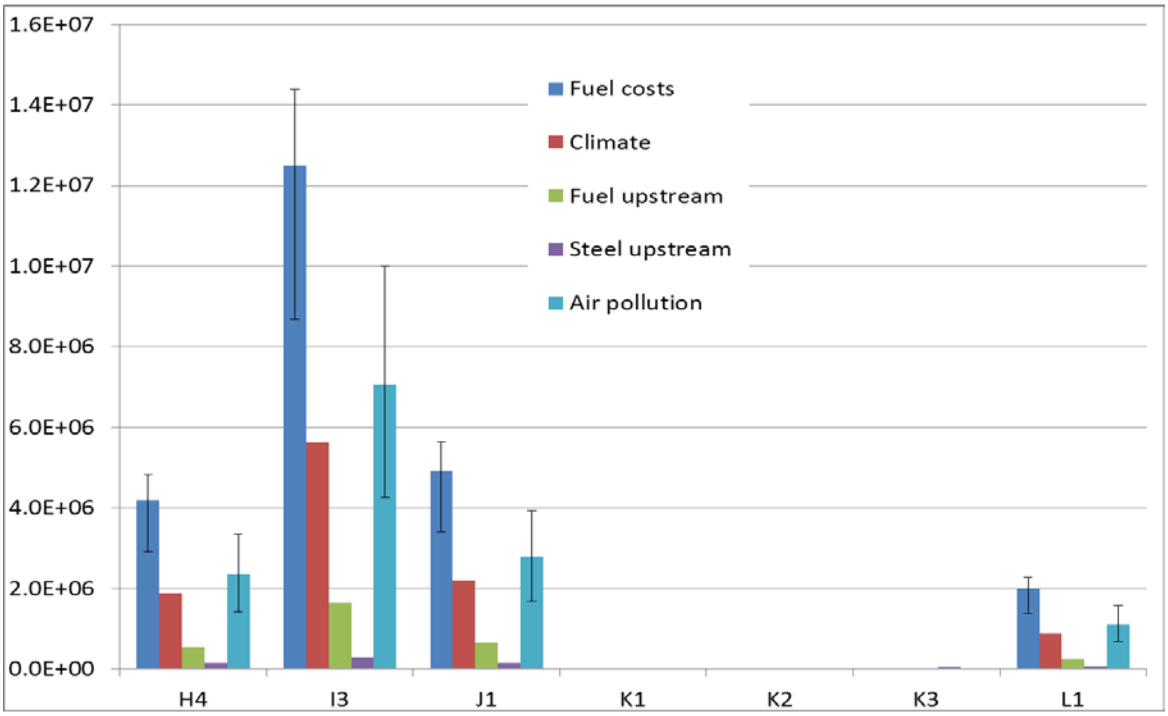

Fig. 11.4: Overview of single impact costs for large cruise ship RCOs

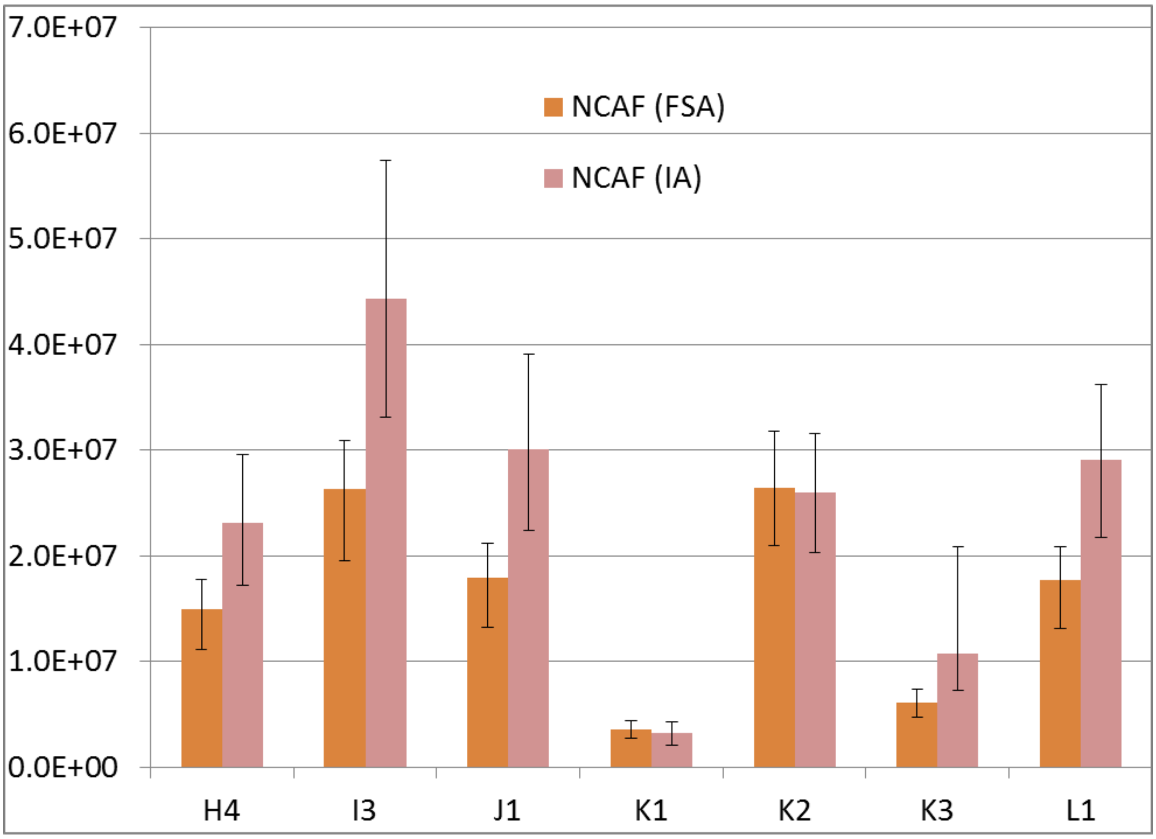

Fig. 11.5: Comparison of NCAF (FSA) and NCAF (IA) for large cruise ship RCOs

Table 11-11: Sensitivity of NCAF values with respect to fuel price scenario and exchange rate (large cruise CN)

				RCO			
				H4	**I3**	**J1**	**K1**
A-Index				0.90872	0.92877	0.90039	0.87191
Fuel scenario 2014; 1.35 US$/€	NCAF (FSA)	Low	€/Fat	1.1E+07	1.9E+07	1.3E+07	**2.8E+06**
		Mean	€/Fat	1.5E+07	2.6E+07	1.8E+07	**3.6E+06**
		High	€/Fat	1.8E+07	3.1E+07	2.1E+07	**4.4E+06**
	NCAF (IA)	Low	€/Fat	1.7E+07	3.3E+07	2.2E+07	**2.1E+06**
		Mean	€/Fat	2.3E+07	4.4E+07	3.0E+07	**3.2E+06**
		High	€/Fat	3.0E+07	5.7E+07	3.9E+07	**4.3E+06**
Fuel scenario 2015; 1.35 US$/€	NCAF (FSA)	Low	€/Fat	1.1E+07	1.8E+07	1.3E+07	**2.8E+06**
		Mean	€/Fat	1.4E+07	2.4E+07	1.6E+07	**3.6E+06**
		High	€/Fat	1.8E+07	3.1E+07	2.1E+07	**4.4E+06**
	NCAF (IA)	Low	€/Fat	1.7E+07	3.2E+07	2.2E+07	**2.1E+06**
		Mean	€/Fat	2.2E+07	4.2E+07	2.8E+07	**3.2E+06**
		High	€/Fat	3.0E+07	5.7E+07	3.9E+07	**4.3E+06**
Exchange rate 1.12; Fuel scenario 2014	NCAF (FSA)	Low	€/Fat	1.2E+07	2.1E+07	1.5E+07	**2.7E+06**
		Mean	€/Fat	1.6E+07	2.9E+07	2.0E+07	**3.5E+06**
		High	€/Fat	1.9E+07	3.4E+07	2.3E+07	**4.4E+06**
	NCAF (IA)	Low	€/Fat	1.8E+07	3.5E+07	2.3E+07	**1.9E+06**
		Mean	€/Fat	2.4E+07	4.7E+07	3.2E+07	**3.0E+06**
		High	€/Fat	3.1E+07	6.0E+07	4.1E+07	**4.2E+06**

Table 11-12: Sensitivity of NCAF values with respect to fuel price scenario and exchange rate (large cruise CN)

				RCO		
				K2	**K3**	**L1**
A-Index				0.8777	0.87469	0.8774
Fuel scenario 2014; 1.35 US$/€	NCAF (FSA)	Low	€/Fat	2.1E+07	**4.7E+06**	1.3E+07
		Mean	€/Fat	2.6E+07	**6.1E+06**	1.8E+07
		High	€/Fat	3.2E+07	7.4E+06	2.1E+07
	NCAF (IA)	Low	€/Fat	2.0E+07	7.2E+06	2.2E+07
		Mean	€/Fat	2.6E+07	1.1E+07	2.9E+07
		High	€/Fat	3.2E+07	2.1E+07	3.6E+07
Fuel scenario 2015; 1.35 US$/€	NCAF (FSA)	Low	€/Fat	2.1E+07	**4.7E+06**	1.2E+07
		Mean	€/Fat	2.6E+07	**6.1E+06**	1.6E+07
		High	€/Fat	3.2E+07	7.4E+06	2.1E+07
	NCAF (IA)	Low	€/Fat	2.0E+07	7.2E+06	2.1E+07
		Mean	€/Fat	2.6E+07	1.1E+07	2.7E+07
		High	€/Fat	3.2E+07	2.1E+07	3.6E+07
Exchange rate 1.12; Fuel scenario 2014	NCAF (FSA)	Low	€/Fat	2.1E+07	**4.7E+06**	1.4E+07
		Mean	€/Fat	2.6E+07	**6.0E+06**	2.0E+07
		High	€/Fat	3.2E+07	7.3E+06	2.3E+07
	NCAF (IA)	Low	€/Fat	2.0E+07	**7.0E+06**	2.3E+07
		Mean	€/Fat	2.6E+07	1.1E+07	3.1E+07
		High	€/Fat	3.2E+07	2.1E+07	3.8E+07

Table 11-13: Impact of RCOs for large cruise and collision+grounding risk

			RCO						
			G3	**K3**[3]	**K4**	**M1**	**M2**	**I3**	**H4**
A-Index	side		0.9264	0.962468	0.962122	0.940626	0.94162	0.9483	0.943666
	bottom		0.935358	0.952206	0.953448	0.981842	0.978016	0.952	0.940546
ΔPLL (30 yrs)	CN+GR	fat	2.308	4.856	5.013	6.849	6.818	5.270	4.333
NPV-FSA	Low	€	-8.86E+05	2.43E+06	2.58E+06	4.77E+06	5.15E+06	1.65E+07	6.04E+06
	Mean	€	-6.52E+05	3.95E+06	4.16E+06	8.12E+06	8.53E+06	2.31E+07	8.71E+06
	High	€	-4.18E+05	5.46E+06	5.73E+06	1.06E+07	1.10E+07	2.78E+07	1.07E+07
NCAF (FSA)	Low	€/Fat	**-3.8E+05**	**5.0E+05**	**5.2E+05**	**7.0E+05**	**7.6E+05**	**3.1E+06**	**1.4E+06**
	Mean	€/Fat	**-2.8E+05**	**8.1E+05**	**8.3E+05**	**1.2E+06**	**1.3E+06**	**4.4E+06**	**2.0E+06**
	High	€/Fat	**-1.8E+05**	**1.1E+06**	**1.1E+06**	**1.5E+06**	**1.6E+06**	**5.3E+06**	**2.5E+06**
NPV-IA	Low	€	-3.61E+06	-2.30E+06	-2.28E+06	2.56E+06	3.37E+06	2.47E+07	6.79E+06
	Mean	€	-2.47E+06	1.40E+06	1.52E+06	1.06E+07	1.13E+07	3.70E+07	1.19E+07
	High	€	-1.32E+06	6.31E+06	6.54E+06	1.57E+07	1.63E+07	5.11E+07	1.74E+07
NCAF (IA)	Low	€/Fat	**-1.6E+06**	**-4.7E+05**	**-4.6E+05**	**3.7E+05**	**4.9E+05**	**4.7E+06**	**1.6E+06**
	Mean	€/Fat	**-1.1E+06**	**2.9E+05**	**3.0E+05**	**1.6E+06**	**1.7E+06**	7.0E+06	**2.8E+06**
	High	€/Fat	**-5.7E+05**	**1.3E+06**	**1.3E+06**	**2.3E+06**	**2.4E+06**	9.7E+06	**4.0E+06**

[3] This design was further optimised and has different NPV-FSA than the "K3"design of CN

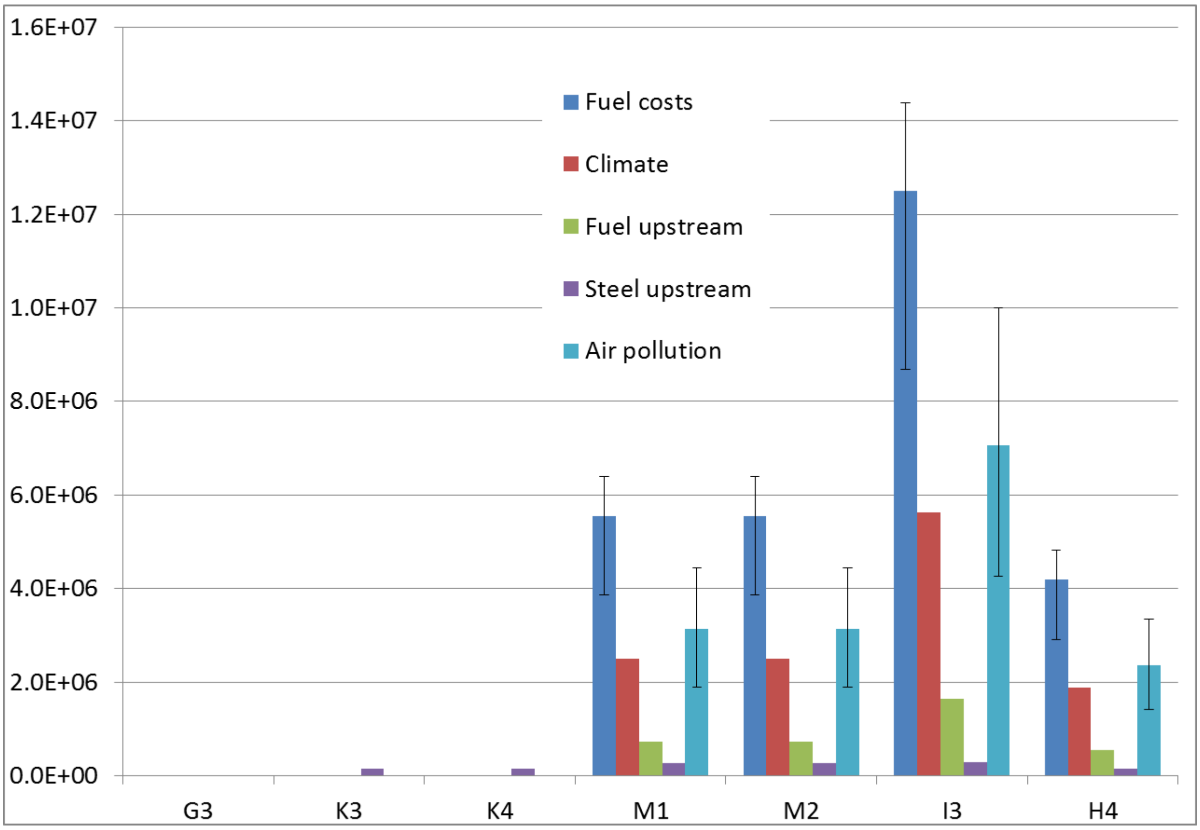

Fig. 11.6: Overview of single impact costs for large cruise ship RCOs

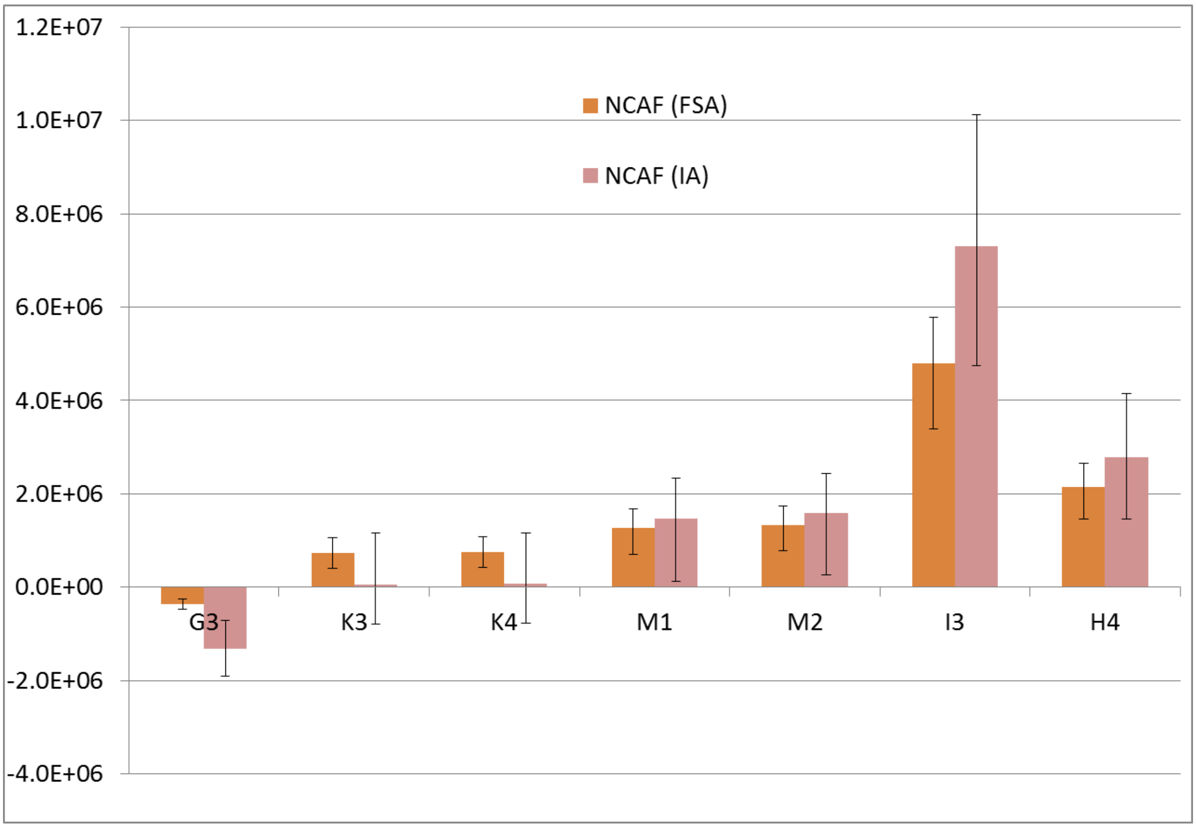

Fig. 11.7: Comparison of NCAF (FSA) and NCAF (IA) for large cruise ship RCOs

Table 11-14: Sensitivity of NCAF values with respect to fuel price scenario and exchange rate (large cruise CN+GR)

				RCO			
				G3	**K3**	**K4**	**M1**
A-Index	side			0.9264	0.962468	0.962122	0.940626
	bottom			0.935358	0.952206	0.953448	0.981842
Fuel scenario 2014; 1.35 US$/€	NCAF (FSA)	Low	€/Fat	**-3.8E+05**	**5.0E+05**	**5.2E+05**	**7.0E+05**
		Mean	€/Fat	**-2.8E+05**	**8.1E+05**	**8.3E+05**	**1.2E+06**
		High	€/Fat	**-1.8E+05**	**1.1E+06**	**1.1E+06**	**1.5E+06**
	NCAF (IA)	Low	€/Fat	**-1.6E+06**	**-4.7E+05**	**-4.6E+05**	**3.7E+05**
		Mean	€/Fat	**-1.1E+06**	**2.9E+05**	**3.0E+05**	**1.6E+06**
		High	€/Fat	**-5.7E+05**	**1.3E+06**	**1.3E+06**	**2.3E+06**
Fuel scenario 2015; 1.35 US$/€	NCAF (FSA)	Low	€/Fat	**-3.8E+05**	**5.0E+05**	**5.2E+05**	**6.3E+05**
		Mean	€/Fat	**-2.8E+05**	**8.1E+05**	**8.3E+05**	**1.0E+06**
		High	€/Fat	**-1.8E+05**	**1.1E+06**	**1.1E+06**	**1.5E+06**
	NCAF (IA)	Low	€/Fat	**-1.6E+06**	**-4.7E+05**	**-4.6E+05**	**3.1E+05**
		Mean	€/Fat	**-1.1E+06**	**2.9E+05**	**3.0E+05**	**1.4E+06**
		High	€/Fat	**-5.7E+05**	**1.3E+06**	**1.3E+06**	**2.3E+06**
Exchange rate 1.12; Fuel scenario 2014	NCAF (FSA)	Low	€/Fat	**-4.8E+05**	**4.1E+05**	**4.2E+05**	**7.1E+05**
		Mean	€/Fat	**-3.6E+05**	**7.4E+05**	**7.5E+05**	**1.3E+06**
		High	€/Fat	**-2.5E+05**	**1.1E+06**	**1.1E+06**	**1.7E+06**
	NCAF (IA)	Low	€/Fat	**-1.9E+06**	**-7.9E+05**	**-7.8E+05**	**1.3E+05**
		Mean	€/Fat	**-1.3E+06**	**5.8E+04**	**7.5E+04**	**1.5E+06**
		High	€/Fat	**-7.2E+05**	**1.2E+06**	**1.2E+06**	**2.3E+06**

Table 11-15: Sensitivity of NCAF values with respect to fuel price scenario and exchange rate (large cruise CN+GR)

				RCO		
				M2	**I3**	**H4**
A-Index	side			0.94162	0.9483	0.943666
	bottom			0.978016	0.952	0.940546
Fuel scenario 2014; 1.35 US$/€	NCAF (FSA)	Low	€/Fat	**7.6E+05**	**3.1E+06**	**1.4E+06**
		Mean	€/Fat	**1.3E+06**	**4.4E+06**	**2.0E+06**
		High	€/Fat	**1.6E+06**	**5.3E+06**	**2.5E+06**
	NCAF (IA)	Low	€/Fat	**4.9E+05**	**4.7E+06**	**1.6E+06**
		Mean	€/Fat	**1.7E+06**	**7.0E+06**	**2.8E+06**
		High	€/Fat	**2.4E+06**	9.7E+06	**4.0E+06**
Fuel scenario 2015; 1.35 US$/€	NCAF (FSA)	Low	€/Fat	**6.9E+05**	**2.9E+06**	**1.3E+06**
		Mean	€/Fat	**1.1E+06**	**3.9E+06**	**1.8E+06**
		High	€/Fat	**1.6E+06**	**5.3E+06**	**2.5E+06**
	NCAF (IA)	Low	€/Fat	**4.3E+05**	**4.5E+06**	**1.5E+06**
		Mean	€/Fat	**1.5E+06**	**6.6E+06**	**2.6E+06**
		High	€/Fat	**2.4E+06**	9.7E+06	**4.0E+06**
Exchange rate 1.12; Fuel scenario 2014	NCAF (FSA)	Low	€/Fat	**7.7E+05**	**3.4E+06**	**1.5E+06**
		Mean	€/Fat	**1.3E+06**	**4.8E+06**	**2.2E+06**
		High	€/Fat	**1.7E+06**	**5.8E+06**	**2.7E+06**
	NCAF (IA)	Low	€/Fat	**2.7E+05**	**4.7E+06**	**1.5E+06**
		Mean	€/Fat	**1.6E+06**	7.3E+06	**2.8E+06**
		High	€/Fat	**2.4E+06**	1.0E+07	**4.1E+06**

11.5.3 Baltic RoPax

The results for Baltic RoPax RCOs are summarised in Table 11-16 and Table 11-17. For RoPax the NPV-IA considers also the small amount of avoided cargo loss. More details regarding the different impacts are summarised in Fig. 11.8. The comparison of both NPVs is shown in Fig. 11.9.

As shown by the results the RCOs B, C, D, F, K2 and L are below or slightly above the threshold used in Tasks 1 and 3 with respect to their NCAF (FSA) value (mean and/or low, only for K2 all values are below threshold). After consideration of additional impacts the low values for B, F and L are below the threshold and for K2 also the mean value.

Likewise to large cruise, close to 50% of NCAF (FSA) values is caused by additional fuel consumption. However, in this case the effect of air pollution is lower because 95% of the fuel in LNG. Although LNG is used the climate change costs are not negligible.

Table 11-16: Impact of RCOs for Baltic RoPax and collision risk – Part I

			RCO				
			B	**C**	**D**	**E**	**F**
A-Index			0.87025	0.867044	0.882378	0.87862	0.899677
ΔA			0.03765	0.034444	0.049778	0.04602	0.067077
ΔPLL (30 yrs)	CN	fat	0.596	0.544	0.788	0.728	1.062
NPV-FSA	Low	€	2.37E+06	2.47E+06	3.68E+06	4.68E+06	3.88E+06
	Mean	€	3.23E+06	3.38E+06	4.98E+06	6.27E+06	5.24E+06
	High	€	3.81E+06	3.98E+06	5.86E+06	7.39E+06	6.17E+06
NCAF (FSA)	Low	€/Fat	**4.0E+06**	**4.5E+06**	**4.7E+06**	6.4E+06	**3.7E+06**
	Mean	€/Fat	**5.4E+06**	6.2E+06	6.3E+06	8.6E+06	**4.9E+06**
	High	€/Fat	6.4E+06	7.3E+06	7.4E+06	1.0E+07	**5.8E+06**
NPV-IA	Low	€	3.35E+06	3.71E+06	5.39E+06	6.77E+06	5.62E+06
	Mean	€	4.38E+06	4.89E+06	7.02E+06	8.80E+06	7.30E+06
	High	€	5.24E+06	5.98E+06	8.53E+06	1.08E+07	8.86E+06
NCAF (IA)	Low	€/Fat	**5.6E+06**	6.8E+06	6.8E+06	9.3E+06	**5.3E+06**
	Mean	€/Fat	7.3E+06	9.0E+06	8.9E+06	1.2E+07	6.9E+06
	High	€/Fat	8.8E+06	1.1E+07	1.1E+07	1.5E+07	8.3E+06

The sensitivity of NCAF values with respect to fuel price scenario and exchange rate is investigated and the results are summarised in Table 11-18 and Table 11-19 for designs evaluated for collision risk reduction, respectively CN+GR and with respect to the threshold of 5.9 million Euros. For the evaluation with respect to CN risk a sensitivity in relation to exchange rate is observed, i.e. with an exchange rate of 1.12 USD/€ some of the RCOs are over the threshold. However, with respect to CN+GR the evaluation result is not affected.

Table 11-17: Impact of RCOs for Baltic RoPax and collision risk and CN+GR together for RCO L – Part II

			RCO				
			I	**J1**	**K2**	**L**	**L (CN+GR)**
A-Index			0.8494	0.9183769	0.904213	0.915184	0.9697 0.9737
ΔA			0.0168	0.0857769	0.071613	0.082584	
ΔPLL (30 yrs)	CN	fat	0.266	1.358	1.133	1.307	4.268
NPV-FSA	Low	€	4.47E+06	2.50E+07	3.78E+06	4.65E+06	4.65E+06
	Mean	€	5.90E+06	3.43E+07	4.96E+06	6.26E+06	6.26E+06
	High	€	6.99E+06	4.00E+07	5.89E+06	7.37E+06	7.37E+06
NCAF (FSA)	Low	€/Fat	1.7E+07	1.8E+07	**3.3E+06**	**3.6E+06**	**1.1E+06**
	Mean	€/Fat	2.2E+07	2.5E+07	**4.4E+06**	**4.8E+06**	**1.5E+06**
	High	€/Fat	2.6E+07	2.9E+07	**5.2E+06**	**5.6E+06**	**1.7E+06**
NPV-IA	Low	€	5.94E+06	3.78E+07	4.91E+06	6.72E+06	6.72E+06
	Mean	€	7.66E+06	4.80E+07	6.39E+06	8.72E+06	8.72E+06
	High	€	9.30E+06	5.49E+07	7.91E+06	1.06E+07	1.06E+07
NCAF (IA)	Low	€/Fat	2.2E+07	2.8E+07	**4.3E+06**	**5.1E+06**	**1.6E+06**
	Mean	€/Fat	2.9E+07	3.5E+07	**5.6E+06**	6.7E+06	**2.0E+06**
	High	€/Fat	3.5E+07	4.0E+07	7.0E+06	8.1E+06	**2.5E+06**

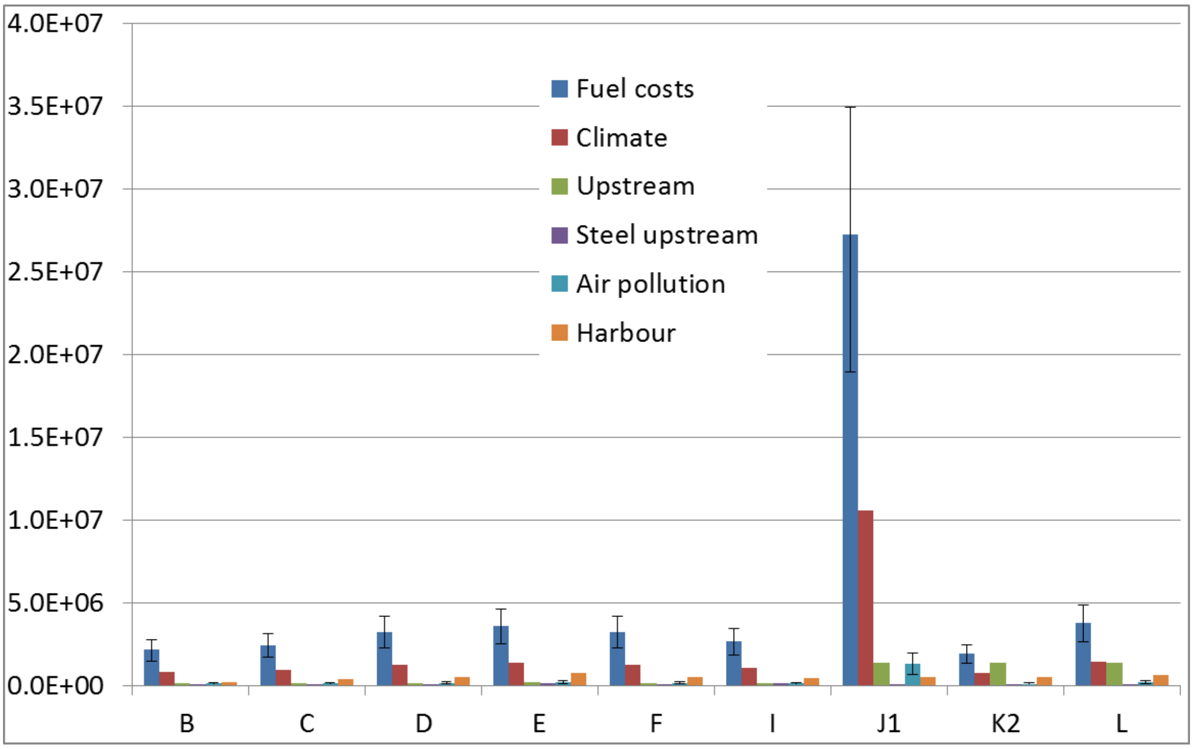

Fig. 11.8: Overview of single impact costs for Baltic RoPax ship RCOs

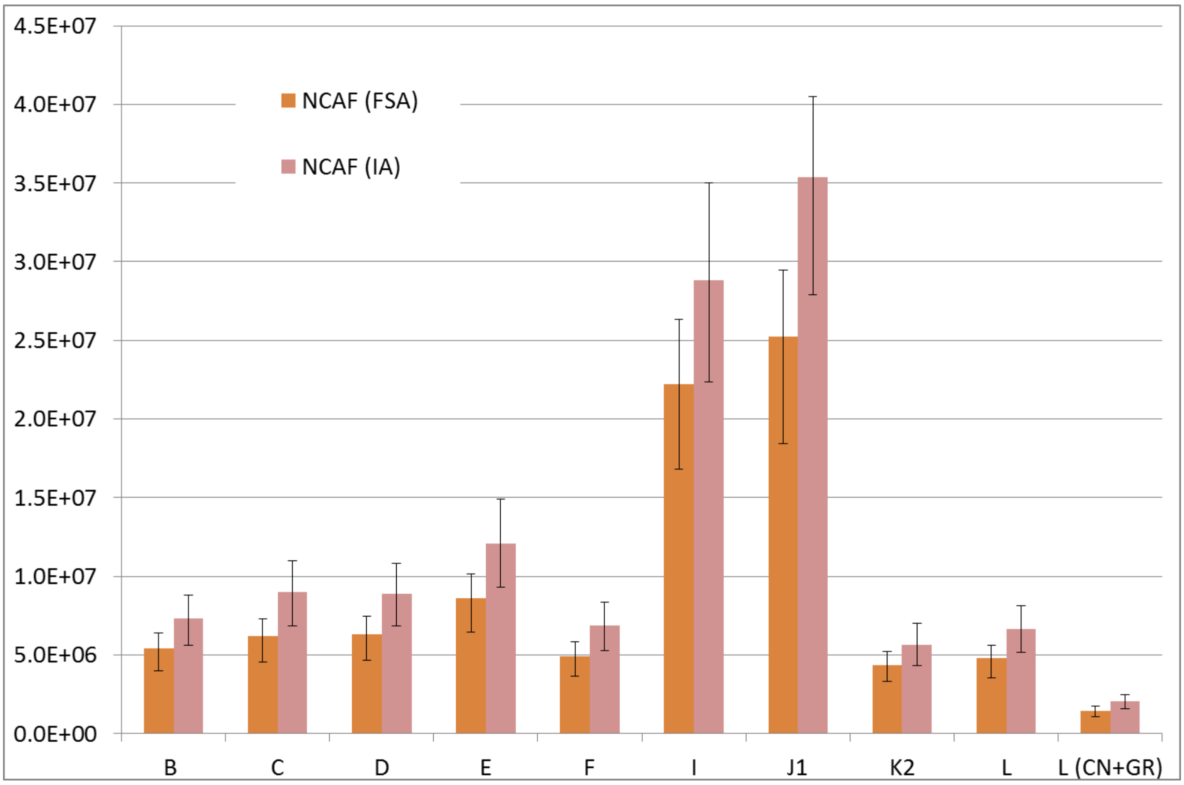

Fig. 11.9: Comparison of NCAF (FSA) and NCAF (IA) for Baltic RoPax ship RCOs

Table 11-18: Sensitivity of NCAF values with respect to fuel price scenario and exchange rate (Baltic RoPax CN / CN+GR)

				RCO				
				B	**C**	**D**	**E**	**F**
A				0.87025	0.867044	0.882378	0.87862	0.899677
Fuel scenario 2014; 1.35 US$/€	NCAF (FSA)	Low	€/Fat	**4.0E+06**	**4.5E+06**	**4.7E+06**	6.4E+06	**3.7E+06**
		Mean	€/Fat	**5.4E+06**	6.2E+06	6.3E+06	8.6E+06	**4.9E+06**
		High	€/Fat	6.4E+06	7.3E+06	7.4E+06	1.0E+07	**5.8E+06**
	NCAF (IA)	Low	€/Fat	**5.6E+06**	6.8E+06	6.8E+06	9.3E+06	**5.3E+06**
		Mean	€/Fat	7.3E+06	9.0E+06	8.9E+06	1.2E+07	6.9E+06
		High	€/Fat	8.8E+06	1.1E+07	1.1E+07	1.5E+07	8.3E+06
Fuel scenario 2015; 1.35 US$/€	NCAF (FSA)	Low	€/Fat	**3.7E+06**	**4.2E+06**	**4.4E+06**	6.1E+06	**3.5E+06**
		Mean	€/Fat	**4.8E+06**	**5.5E+06**	**5.6E+06**	7.8E+06	**4.4E+06**
		High	€/Fat	6.4E+06	7.3E+06	7.4E+06	1.0E+07	**5.8E+06**
	NCAF (IA)	Low	€/Fat	**5.4E+06**	6.5E+06	6.6E+06	9.0E+06	**5.1E+06**
		Mean	€/Fat	6.7E+06	8.2E+06	8.2E+06	1.1E+07	6.4E+06
		High	€/Fat	8.8E+06	1.1E+07	1.1E+07	1.5E+07	8.3E+06
Exchange rate 1.12; Fuel scenario 2014	NCAF (FSA)	Low	€/Fat	**4.4E+06**	**5.0E+06**	**5.1E+06**	**7.0E+06**	**4.0E+06**
		Mean	€/Fat	**6.0E+06**	**7.0E+06**	**7.0E+06**	9.4E+06	**5.4E+06**
		High	€/Fat	**7.1E+06**	8.2E+06	8.2E+06	1.1E+07	**6.4E+06**
	NCAF (IA	Low	€/Fat	**6.0E+06**	7.3E+06	7.3E+06	9.8E+06	**5.6E+06**
		Mean	€/Fat	7.9E+06	9.7E+06	9.6E+06	1.3E+07	7.4E+06
		High	€/Fat	9.5E+06	1.2E+07	1.2E+07	1.6E+07	8.9E+06

Table 11-19: Sensitivity of NCAF values with respect to fuel price scenario and exchange rate (Baltic RoPax CN / CN+GR)

				RCO				
				I	**J1**	**K2**	**L**	**L (CN+GR)**
A				0.8494	0.9183769	0.904213	0.915184	0.9697 0.9737
Fuel scenario 2014; 1.35 US$/€	NCAF (FSA)	Low	€/Fat	1.8E+07	**3.3E+06**	**3.6E+06**	**1.1E+06**	**1.1E+06**
		Mean	€/Fat	2.5E+07	**4.4E+06**	**4.8E+06**	**1.5E+06**	**1.5E+06**
		High	€/Fat	2.6E+07	2.9E+07	**5.2E+06**	**5.6E+06**	**1.7E+06**
	NCAF (IA)	Low	€/Fat	2.8E+07	**4.3E+06**	**5.1E+06**	**1.6E+06**	**1.6E+06**
		Mean	€/Fat	3.5E+07	**5.6E+06**	6.7E+06	**2.0E+06**	**2.0E+06**
		High	€/Fat	3.5E+07	4.0E+07	7.0E+06	8.1E+06	**2.5E+06**
Fuel scenario 2015; 1.35 US$/€	NCAF (FSA)	Low	€/Fat	1.6E+07	1.7E+07	**3.2E+06**	**3.4E+06**	**1.0E+06**
		Mean	€/Fat	2.1E+07	2.2E+07	**4.1E+06**	**4.3E+06**	**1.3E+06**
		High	€/Fat	2.6E+07	2.9E+07	**5.2E+06**	**5.6E+06**	**1.7E+06**
	NCAF (IA)	Low	€/Fat	2.2E+07	2.7E+07	**4.2E+06**	**5.0E+06**	**1.5E+06**
		Mean	€/Fat	2.7E+07	3.2E+07	**5.4E+06**	6.2E+06	**1.9E+06**
		High	€/Fat	3.5E+07	4.0E+07	7.0E+06	8.1E+06	**2.5E+06**
Exchange rate 1.12; Fuel scenario 2014	NCAF (FSA)	Low	€/Fat	1.8E+07	2.1E+07	**3.5E+06**	**3.9E+06**	**1.2E+06**
		Mean	€/Fat	2.4E+07	2.9E+07	**4.7E+06**	**5.3E+06**	**1.6E+06**
		High	€/Fat	2.8E+07	3.3E+07	**5.5E+06**	**6.2E+06**	**1.9E+06**
	NCAF (IA)	Low	€/Fat	2.3E+07	3.0E+07	**4.5E+06**	**5.4E+06**	**1.7E+06**
		Mean	€/Fat	3.0E+07	3.9E+07	**5.9E+06**	**7.1E+06**	**2.2E+06**
		High	€/Fat	3.7E+07	4.4E+07	7.3E+06	8.7E+06	**2.7E+06**

11.5.4 Mediterranean RoPax

The results for Mediterranean RoPax RCOs are summarised in Table 11-20 for collision and Table 11-21 for collision and grounding. For RoPax the NPV-IA considers also the small amount of avoided cargo loss. More details regarding the different impacts for collision are summarised in Fig. 11.10 and collision and grounding in Fig. 11.12. The comparison of both NPVs is shown in Fig. 11.11 (collision)[4] and Fig. 11.13 (collision and grounding).

It is mentioned that RCOs V15 and V16 are cost beneficial for NCAF (FSA) and NCAF (IA) as well as considering only the effect on collision risk.

For Mediterranean RoPax sensitivity of NCAF is investigated for CN+GR risk (Table 11-22). The evaluation with respect to the threshold of 5.9 million Euros shows no sensitivity regarding fuel price scenario and exchange rate.

Table 11-20: Impact of RCOs for Mediterranean RoPax and collision risk

			RCO		
			V1	**V12**	**V14**
A-Index			0.84036	0.84956	0.87176
ΔA			0.00054	0.00974	0.032
ΔPLL (30 yrs)	CN	fat	0.005	0.080	0.261
NPV-FSA	Low	€	2.35E+05	8.76E+05	2.80E+06
	Mean	€	3.36E+05	1.20E+06	3.83E+06
	High	€	3.85E+05	1.42E+06	4.52E+06
NCAF (FSA)	Low	€/Fat	5.0E+07	1.1E+07	1.1E+07
	Mean	€/Fat	7.1E+07	1.5E+07	1.5E+07
	High	€/Fat	8.2E+07	1.8E+07	1.7E+07
NPV-IA	Low	€	5.38E+05	1.57E+06	4.82E+06
	Mean	€	6.98E+05	2.02E+06	6.20E+06
	High	€	8.52E+05	2.39E+06	7.32E+06
NCAF (IA)	Low	€/Fat	1.1E+08	2.0E+07	1.8E+07
	Mean	€/Fat	1.5E+08	2.5E+07	2.4E+07
	High	€/Fat	1.8E+08	3.0E+07	2.8E+07

[4] It should be noted that ths Mediterranean RoPax in its initial design had an ample marging wrt level of requireed index R

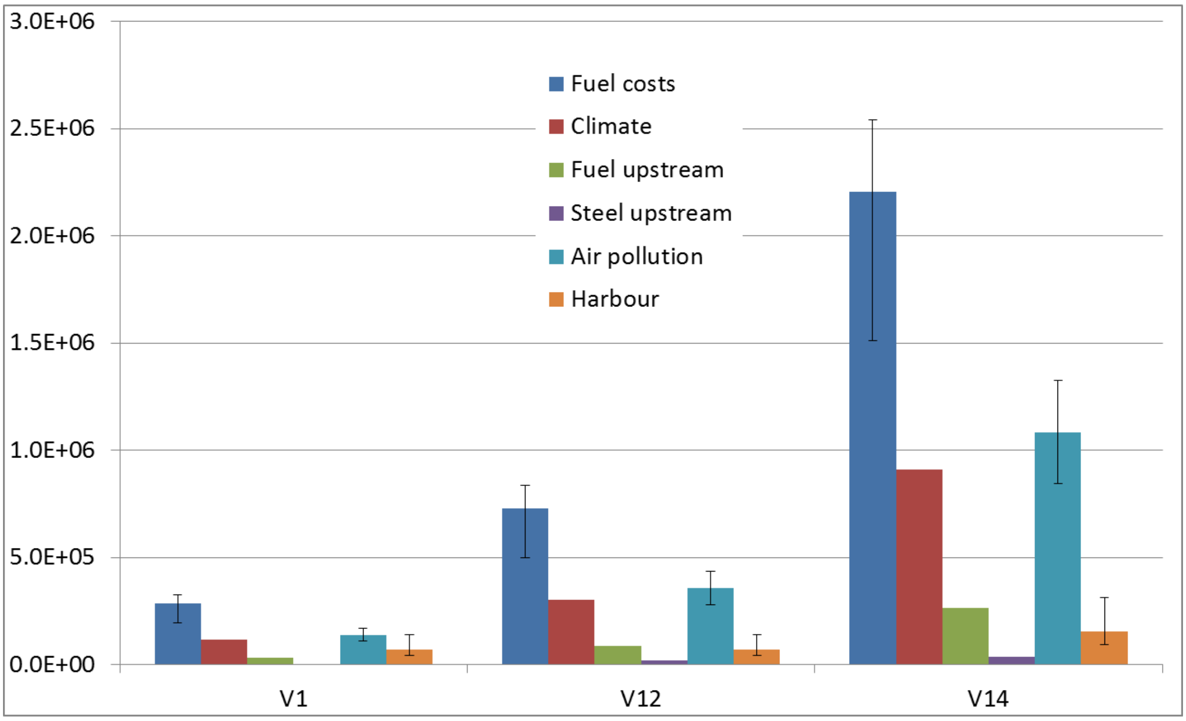

Fig. 11.10: Overview of single impact costs for Mediterranean RoPax ship RCOs

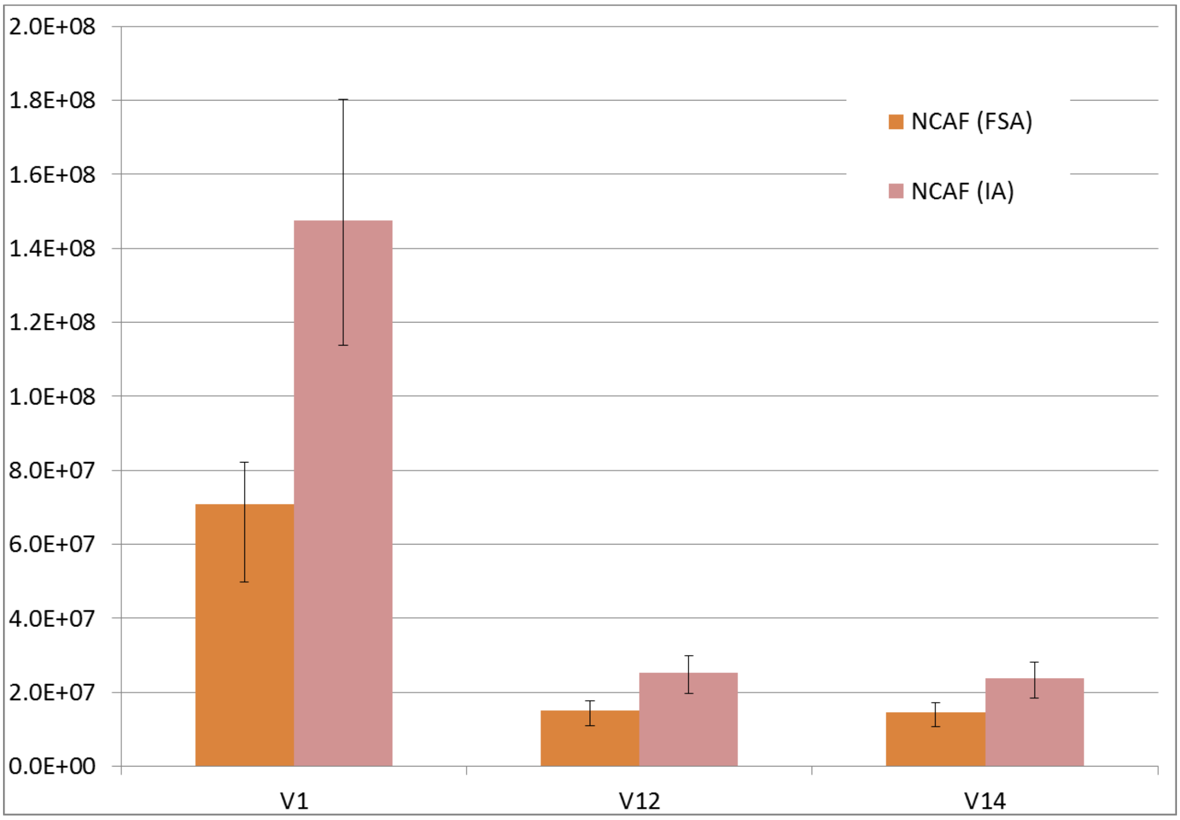

Fig. 11.11: Comparison of NCAF (FSA) and NCAF (IA) for Mediterranean RoPax ship RCOs

Table 11-21: Impact of RCOs for Mediterranean RoPax- collision and grounding risk

			RCO		
			V14	**V15**	**V16**
ΔA-Index	Bottom		0.0018	0.001214	0.01368
	side		0.0044	0.010854	0.020474
ΔPLL (30 yrs)	CN+GR	fat	0.472	0.744	1.379
NPV-FSA	Low	€	2.79E+06	2.73E+06	2.71E+06
	Mean	€	3.83E+06	3.79E+06	3.84E+06
	High	€	4.50E+06	4.49E+06	4.60E+06
NCAF (FSA)	Low	€/Fat	**5.9E+06**	**3.7E+06**	**2.0E+06**
	Mean	€/Fat	8.1E+06	**5.1E+06**	**2.8E+06**
	High	€/Fat	9.5E+06	6.0E+06	**3.3E+06**
NPV-IA	Low	€	4.78E+06	4.54E+06	4.23E+06
	Mean	€	6.18E+06	6.03E+06	5.92E+06
	High	€	7.30E+06	7.24E+06	7.33E+06
NCAF (IA)	Low	€/Fat	1.0E+07	6.1E+06	**3.1E+06**
	Mean	€/Fat	1.3E+07	8.1E+06	**4.3E+06**
	High	€/Fat	1.5E+07	9.7E+06	**5.3E+06**

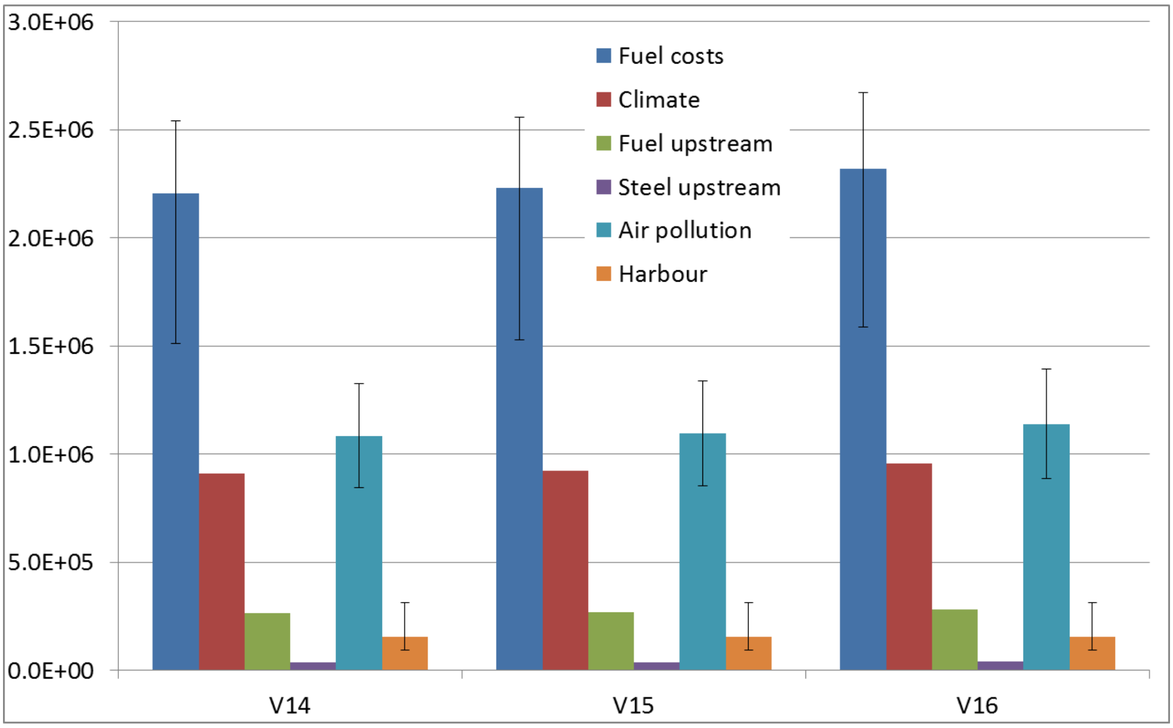

Fig. 11.12: Overview of single impact costs for Mediterranean RoPax ship RCOs (CN+GR)

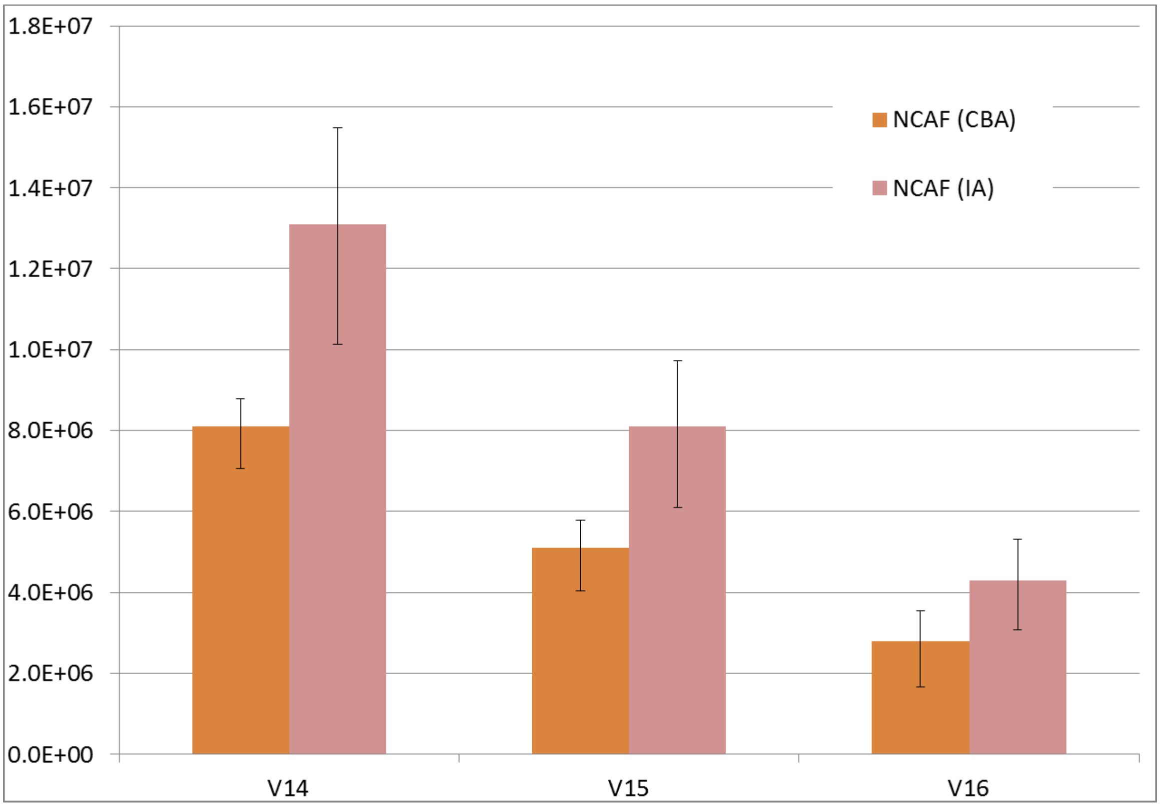

Fig. 11.13: Comparison of NCAF (FSA) and NCAF (IA) for Mediterranean RoPax ship RCOs (CN+GR)

Table 11-22: Sensitivity of NCAF values with respect to fuel price scenario and exchange rate (Mediterranean RoPax CN / CN+GR)

				RCO		
				V14	**V15**	**V16**
A	side			0.9519	0.9584	0.9680
	bottom			0.9829	0.9823	0.9948
Fuel scenario 2014; 1.35 US$/€	NCAF (FSA)	Low	€/Fat	**5.9E+06**	**3.7E+06**	**2.0E+06**
		Mean	€/Fat	8.1E+06	**5.1E+06**	**2.8E+06**
		High	€/Fat	9.5E+06	6.0E+06	**3.3E+06**
	NCAF (IA)	Low	€/Fat	1.0E+07	6.1E+06	**3.1E+06**
		Mean	€/Fat	1.3E+07	8.1E+06	**4.3E+06**
		High	€/Fat	1.5E+07	9.7E+06	**5.3E+06**
Fuel scenario 2015; 1.35 US$/€	NCAF (FSA)	Low	€/Fat	**5.6E+06**	**3.5E+06**	**1.8E+06**
		Mean	€/Fat	7.2E+06	**4.5E+06**	**2.5E+06**
		High	€/Fat	9.5E+06	6.0E+06	**3.3E+06**
	NCAF (IA)	Low	€/Fat	9.8E+06	**5.9E+06**	**2.9E+06**
		Mean	€/Fat	1.2E+07	7.5E+06	**4.0E+06**
		High	€/Fat	1.5E+07	9.7E+06	**5.3E+06**
Exchange rate 1.12; Fuel scenario 2014	NCAF (FSA)	Low	€/Fat	**6.5E+06**	**4.1E+06**	**2.2E+06**
		Mean	€/Fat	9.0E+06	**5.7E+06**	**3.1E+06**
		High	€/Fat	1.1E+07	**6.7E+06**	**3.7E+06**
	NCAF (IA)	Low	€/Fat	1.1E+07	**6.4E+06**	**3.2E+06**
		Mean	€/Fat	1.4E+07	8.6E+06	**4.5E+06**
		High	€/Fat	1.7E+07	1.0E+07	**5.6E+06**

11.5.5 Small RoPax

The results for both sip types, i.e. double ended (DE) and single ended ferry, are summarised in the following. The GCAF values in Table 11-23 show that RCO1 is well below the threshold for both NCAF (FSA) and NCAF (IA). For the DE RoPax only RCO1 (DE) is below the threshold for NPV-FSA. The details are summarised in Fig. 11.14 and Fig. 11.15 showing the effect of the impacts additional to those considered in the CBA. For RCO 2 (DE) the increase in fuel consumption is the major cost contributor.

For both small RoPax types under consideration a significant increase in damage stability is possible without any effect on the fuel consumption and therefore no additional impact on air pollution and climate change exist.

Table 11-23: Impact of RCOs for small / DE RoPax and collision risk

			RCO		
			1 (DE)	**2 (DE)**	**1**
A-Index			0.8601	0.8782	0.84257
ΔA			0.0189	0.037	0.04787
ΔPLL (30 yrs)	CN	fat	0.054	0.106	0.142
NPV-FSA	Low	€	4.79E+04	3.12E+06	8.55E+04
	Mean	€	6.24E+04	4.42E+06	1.14E+05
	High	€	7.68E+04	5.11E+06	1.43E+05
NCAF (FSA)	Low	€/Fat	**8.9E+05**	3.0E+07	**6.0E+05**
	Mean	€/Fat	**1.2E+06**	4.2E+07	**8.0E+05**
	High	€/Fat	**1.4E+06**	4.8E+07	**1.0E+06**
NPV-IA	Low	€	2.85E+05	5.78E+06	3.07E+05
	Mean	€	4.71E+05	7.76E+06	5.26E+05
	High	€	9.06E+05	9.38E+06	1.01E+06
NCAF (IA)	Low	€/Fat	**5.3E+06**	5.5E+07	**2.2E+06**
	Mean	€/Fat	8.7E+06	7.3E+07	**3.7E+06**
	High	€/Fat	1.7E+07	8.9E+07	7.1E+06

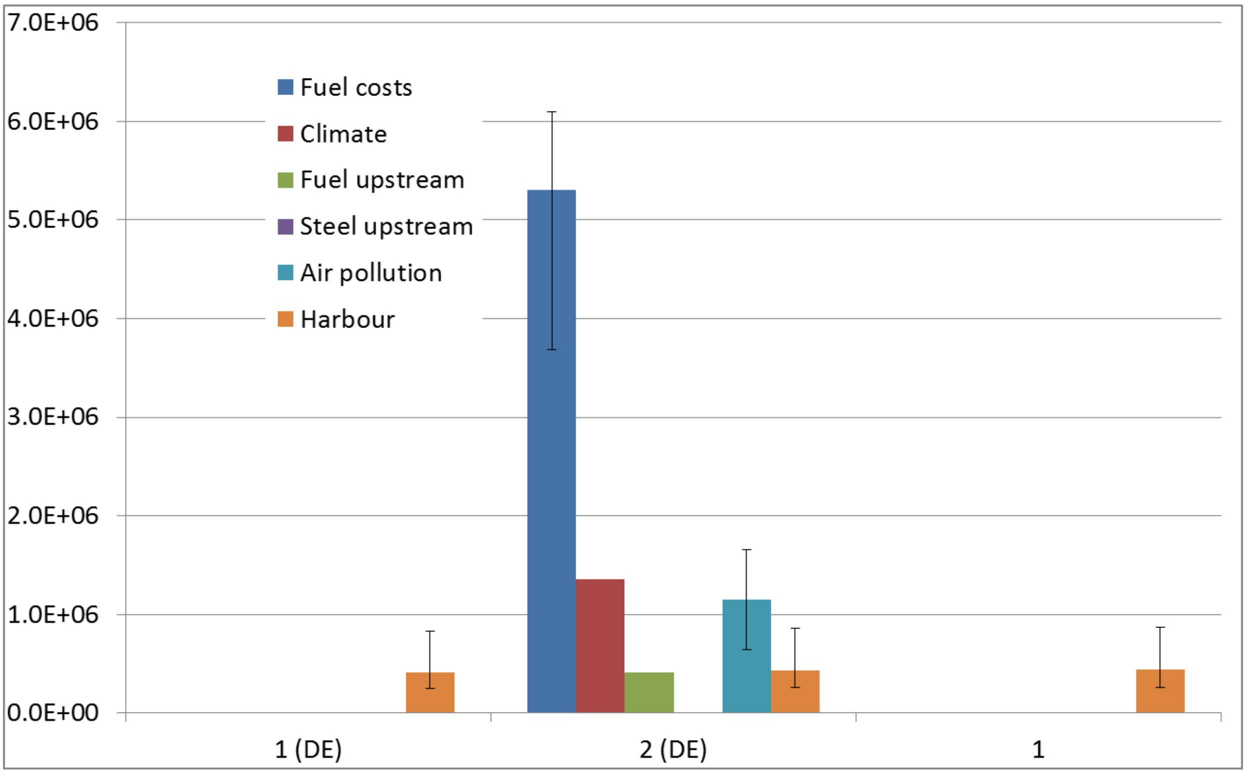

Fig. 11.14: Overview of single impact costs for small / DE RoPax ship RCOs (CN)

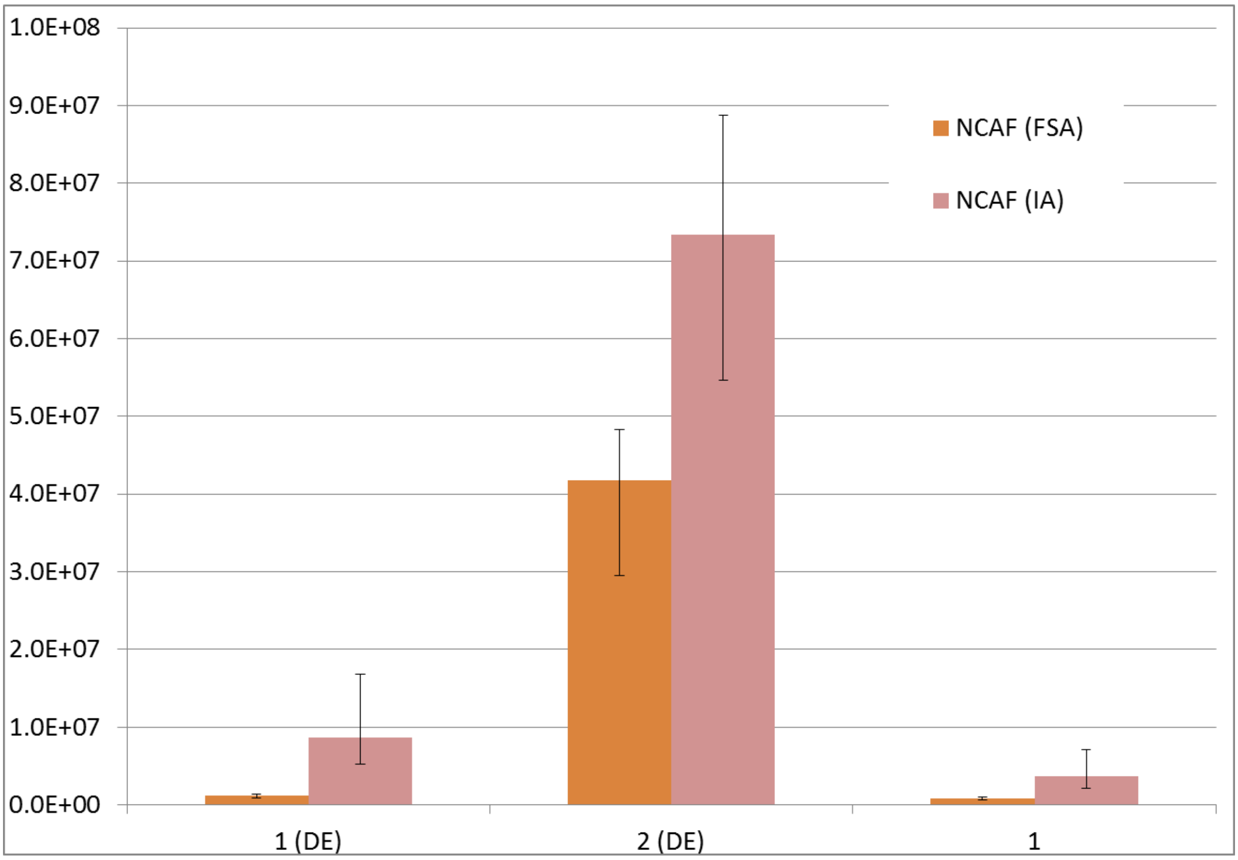

Fig. 11.15: Comparison of NCAF (FSA) and NCAF (IA) for small / DE RoPax ship RCOs (CN)

12 SUMMARY OF RESULTS

This report assesses the potential impacts caused by the introduction of new, increased damage stability requirements for passenger ships. Previous tasks of the EMSA III study have identified possible design changes, known as risk control options (RCOs), which could be applied to representative cruise and RoPax ships, in order to meet the new damage stability requirements. This report provides a justification of these requirements by assessing the impacts of these RCOs and showing that at least some of them are cost-effective on each passenger ship type.

The most promising RCOs have already been subjected to a cost-benefit assessment (CBA) in Tasks 1, 3 and 4 of the EMSA III study; in Task 1 regarding collision risk reduction, in Task 3 regarding grounding risk reduction and finally in task 4 for collision and grounding risk reduction together. That CBA was carried out in compliance with IMO guidelines for Formal Safety Assessment (FSA). The present impact assessment (IA) follows the European Commission guidelines, which have a slightly wider scope covering air pollution, climate change, production of material, business model, infrastructure etc. Both methods require a quantitative assessment of impacts in monetary units.

As a preliminary step, the impacts of the RCOs were reviewed qualitatively, to identify those that were relevant (i.e. making a significant contribution to the total impacts of the RCO) and quantifiable (i.e. there being available data to quantify the benefits within the scope of this study), focussing on those that have not already been quantified in the CBA.

The RCOs are intended to reduce the probability of passenger ships sinking/capsizing after collision or grounding accidents. The positive impacts (i.e. benefits) of RCOs are therefore the components of avoided accident related costs. The following table lists the positive impacts, and summarises the quantification approach that has been adopted.

Impact	**Qualitative assessment & quantification approach**
Loss of human life	The value of human life is represented in the CBA and IA as a value of prevented fatality (VPF).
Loss of ship	The cost of ship sinking/capsize is quantified in the CBA and IA using the actual value of the ship, related to the newbuilding price.
Damage to ship	The cost of repairing damage for a ship that stays afloat is less than for a refloated ship, so this component is neglected.
Loss of cargo	The cost of loss/damage to cargo is quantified in this IA and found to be a small fraction of the ship newbuilding price.
Environmental pollution	The cost of environmental pollution from cargo or fuel oil is not quantified due to lack of suitable data.
Harbour blockage	The cost of a ship sinking and blocking the harbour is relevant but is not quantified due to lack of data.
Wreck removal	The cost of wreck removal is quantified in this IA as a multiple of the ship

	newbuilding price.
Loss of revenue	The reduction in revenue following an accident is investigated in this IA but is considered too uncertain to quantify.
Loss of reputation	Loss of reputation may be the cause of the loss of revenue above, and while it may cause very large costs to the operator, it is considered too uncertain to quantify.
Search and rescue	The cost of SAR is not usually added to the cost of a ship accident, so is not quantified.
Accident investigation	The cost of accident investigation is not usually added to the cost of a ship accident, so is not quantified.
Legal costs	The legal cost of claims is considered to be a small component of the accident cost, so is not quantified.
Insurance /P&I	Long-term premium for insurance and P&I should reflect spending for ship loss/damage and wreck removal, so is considered to be included in those costs.

The RCOs also have various negative impacts, as follows.

Impact	**Qualitative assessment & quantification approach**
Newbuilding costs	Higher newbuilding costs (CAPEX) result from increases in material consumption, outfitting etc. These were quantified in the CBA and IA by shipyard design experts.
Fuel consumption	All the RCOs resulted in increases in fuel consumption (a component of OPEX). The additional fuel costs were quantified in the CBA and IA using representative fuel mixes specified by shipyard design experts and a range of fuel prices.
Air pollution	The cost of air pollution due to increased fuel consumption is quantified in this IA. It was sensitive to fuel type.
Climate change	The cost of climate change impacts due to increased steel and fuel consumption, including up- and downstream processes, is quantified in this IA. It was sensitive to fuel type.
Harbour fees	The RCOs resulted in larger ships which may incur higher harbour fees (a component of OPEX). These were quantified in this IA for representative ports. They were only significant for small RoPax making frequent harbour calls.
Revenue/benefit	Higher CAPEX and OPEX can lead to increased ticket prices or reduced benefit from the passenger service, with possible shift to other transport modes in case of RoPax. With respect to leisure activities no impact is expected. The overall cost is considered too uncertain to quantify.
Fleet renewal	Higher CAPEX and OPEX can delay fleet renewal, delayed associated safety and environmental benefits. The cost is considered too uncertain to quantify.
Noise	The cost of underwater noise changes due to increased installed power is expected

	to be small, but is also too uncertain to quantify.
Infrastructure	The cost of infrastructure modifications due to larger ships is too uncertain to quantify.

The relevant and quantifiable impacts have been calculated in Euros (in 2014 prices) and the ship lifetime costs have been cumulated as net present values (NPV) using a depreciation rate of 5%. The results for each RCO have also been expressed as net cost per avoided fatality (NCAF), and these NCAFs from the IA can then be compared with the NCAFs from the FSA. In order to assess the cost-effectiveness of the RCOs, a criterion of €5.9 million is used, as in Tasks 1 and 3 of the EMSA III study. RCOs with NCAF less than this are considered suitable for adoption.

Uncertainties in the calculation are reflected by calculating NPV and NCAF values for "low", "mean", and "high" cases separately. The "low" case includes low estimates of the cost of negative impacts and high estimates of benefits; the "high" case reflects the opposite extreme, and the "mean" case reflects a best-estimate in between. Additionally, the effects from the updated fuel price scenario of 2015 and the Dollar – Euro exchange rate are investigated and no significant sensitivity is observed.

These results have been calculated first for collisions and second, for selected RCOs, for collisions combined with groundings.

A general overview of all RCOs and their evaluation with respect to this criterion is in Table 12-1, Table 12-2, Table 12-3 and Table 12-4. For each vessel type, at least one RCO is found to be cost-effective against collisions alone, except for the Mediterranean RoPax[5]. However, in many cases this is sensitive to the uncertainties in the calculation. When considering collision and grounding together more RCOs become cost-effective for each vessel type including the Mediterranean RoPax, and the results become more robust against uncertainties.

In general these results confirm the results of the FSA CBA. The impact assessment shows higher NCAFs for all RCOs that increase fuel consumption, once air pollution and climate change costs are included, i.e. the RCOs are slightly less cost-effective when evaluated in accordance with EU impact assessment. Other beneficial effects on loss of reputation or loss of income may be significant; however any estimation would be highly uncertain and therefore these effects are not quantified. Therefore the RCOs could be more cost-effective if all effects of an accident were quantified.

The results of this study show the cost effectiveness of RCOs related to collision and grounding risk reduction and hence support the results of Task 4 of the EMSA III study.

[5] The initial design of the Mediterranean RoPax has already a margin versus the required R.

Table 12-1: Overview of results for cruise ship RCOs and collision risk

Type	RCO	A-Index	NCAF (IA)			NCAF<5.9 m€		
			Low	Mean	High	Low	Mean	High
Small cruise	01	0.7263	-2.8E+05	-1.1E+05	5.8E+04	YES	YES	YES
	02	0.7307	5.1E+06	6.6E+06	8.1E+06	YES	NO	NO
	03	0.7442	8.3E+06	9.9E+06	1.1E+07	NO	NO	NO
	04	0.7544	6.9E+06	8.4E+06	9.8E+06	NO	NO	NO
	05	0.7944	1.2E+07	1.3E+07	1.5E+07	NO	NO	NO
	06	0.8281	1.8E+07	2.0E+07	2.2E+07	NO	NO	NO
	07	0.8187	3.8E+07	4.2E+07	4.8E+07	NO	NO	NO
	08	0.8752	3.5E+07	3.9E+07	4.4E+07	NO	NO	NO
	09	0.7789	8.0E+06	9.4E+06	1.1E+07	NO	NO	NO
Large cruise	H4	0.9087	1.7E+07	2.3E+07	3.0E+07	NO	NO	NO
	I3	0.9288	3.3E+07	4.4E+07	5.7E+07	NO	NO	NO
	J1	0.9004	2.2E+07	3.0E+07	3.9E+07	NO	NO	NO
	K1	0.8719	2.1E+06	3.2E+06	4.3E+06	YES	YES	YES
	K2	0.8777	2.0E+07	2.6E+07	3.2E+07	NO	NO	NO
	K3	0.8747	7.2E+06	1.1E+07	2.1E+07	NO	NO	NO
	L1	0.8774	2.2E+07	2.9E+07	3.6E+07	NO	NO	NO

Table 12-2: Overview of results for RoPax ship RCOs and collision risk

Type	RCO	A-Index	NCAF (IA)			NCAF<5.9 m€		
			Low	Mean	High	Low	Mean	High
Baltic RoPax	B	0.8703	5.6E+06	7.3E+06	8.8E+06	YES	NO	NO
	C	0.8670	6.8E+06	9.0E+06	1.1E+07	NO	NO	NO
	D	0.8824	6.8E+06	8.9E+06	1.1E+07	NO	NO	NO
	E	0.8786	9.3E+06	1.2E+07	1.5E+07	NO	NO	NO
	F	0.8997	5.3E+06	6.9E+06	8.3E+06	YES	NO	NO
	I	0.8494	2.2E+07	2.9E+07	3.5E+07	NO	NO	NO
	J1	0.9184	2.8E+07	3.5E+07	4.0E+07	NO	NO	NO
	K2	0.9042	4.3E+06	5.6E+06	7.0E+06	YES	YES	NO
	L	0.9152	5.1E+06	6.7E+06	8.1E+06	YES	NO	NO
Mediterranean RoPax	V1	0.8404	1.1E+08	1.5E+08	1.8E+08	NO	NO	NO
	V12	0.8496	2.0E+07	2.5E+07	3.0E+07	NO	NO	NO
	V14	0.8718	1.8E+07	2.4E+07	2.8E+07	NO	NO	NO
Small	1 (DE)	0.8601	5.3E+06	8.7E+06	1.7E+07	YES	NO	NO
	2 (DE)	0.8782	5.5E+07	7.3E+07	8.9E+07	NO	NO	NO
	1	0.8426	2.2E+06	3.7E+06	7.1E+06	YES	YES	NO

Table 12-3: Overview of results for cruise ship RCOs and collision+grounding risk together

Type	RCO	A-Index			NCAF (IA)			NCAF<5.9 m€		
		CN	GR							
			Side	Bottom	Low	Mean	High	Low	Mean	High
Small	06	0.8281	0.8897	0.9192	3.3E+06	3.7E+06	4.2E+06	YES	YES	YES
	09	0.7789	0.8589	0.9159	1.6E+06	1.8E+06	2.1E+06	YES	YES	YES
Large cruise	G3	0.8643	0.9354	0.9264	-1.9E+06	-1.3E+06	-7.2E+05	YES	YES	YES
	K3	0.8747	0.9522	0.9625	-7.9E+05	5.8E+04	1.2E+06	YES	YES	YES
	K4	0.8792	0.9534	0.9621	-7.8E+05	7.5E+04	1.2E+06	YES	YES	YES
	M1	0.8529	0.9818	0.9406	1.3E+05	1.5E+06	2.3E+06	YES	YES	YES
	M2	0.8747	0.9780	0.9416	2.7E+05	1.6E+06	2.4E+06	YES	YES	YES
	I3	0.9288	0.9520	0.9483	4.7E+06	7.3E+06	1.0E+07	YES	NO	NO
	H4	0.9087	0.9405	0.9437	1.5E+06	2.8E+06	4.1E+06	YES	YES	YES

Table 12-4: Overview of results for RoPax ship RCOs and collision+grounding risk together

Type	RCO	A-Index			NCAF (IA)			NCAF<5.9 m€		
		CN	GR							
			Side	Bottom	Low	Mean	High	Low	Mean	High
Baltic RoPax	L	0.9152	0.9697	0.9737	1.6E+06	2.0E+06	2.8E+06	YES	YES	YES
Mediterranean RoPax	V14	0.8718	0.9519	0.9829	1.0E+07	1.3E+07	1.5E+07	NO	NO	NO
	V15	0.8717	0.9584	0.9823	6.1E+06	8.1E+06	9.7E+06	NO	NO	NO
	V16	0.8809	0.9680	0.9948	3.1E+06	4.3E+06	5.3E+06	YES	YES	YES

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ANNEXES

A Summary of RCOs

In the various tasks of the EMSA III study the following design examples were developed respectively provide the state-of-the-art reference design, named RCOs.

Type	RCO	Description	A			Optimised
			CN	GR_{side}	GR_{bottom}	
Small Cruise	00 (Init)	Basic design	0.7202			CN
	01	Sill increased on external weathertight aft doors	0.7263			CN
	02	Deck 3 watertight for comp 2 and 3	0.7307			CN
	03	Cross flooding section within DB void spaces improved adding pipes	0.7442			CN
	04	Two weathertight doors added and 1 watertight door added on BK deck	0.7544			CN
	05	Increased Beam by 0.2m (up to 20.2m)	0.7944			CN
	06	Increased Beam up to 20.5m	0.8281			CN
	07	Increased freeboard by 0.25m	0.8187			CN
	08	Increased Beam up to 21m	0.8752			CN
	09	Beam 20.1m	0.7789			CN
	06	Increased Beam up to 20.5m	0.8281	0.8897	0.9192	CN+GR
	09	Beam 20.1m	0.7789	0.8703	0.9159	CN+GR
Large Cruise	G2	original design	0.8622			CN
	H4	Breadth + 1 m	0.9087			CN
	I3	B+1, DK4 (Z+0.8m)	0.9288			CN
	J1	B+0.6, DK4(Z+0.2m)	0.9004			CN
	K1	change subdivision	0.8719			CN
	K2	change subd. + wt deck	0.8777			CN
	K3	change subd. + increaase freeboard +40cm	0.8754			CN
	L1	"change subdivision	0.8774			CN
	G2	Reference version"	0.8621	0.9135	0.9171	CN+GR
	G3	"as G2 with wt decks"	0.8643	0.9354	0.9264	CN+GR
	K3	"opt. Version for collision"	0.8754	0.9522	0.9625	CN+GR
	K4	"as K3 with wt decks"	0.8792	0.9534	0.9621	CN+GR
	M1	"double hull increased DB height"	0.8529	0.9818	0.9406	CN+GR
	M2	"as M1 with wt decks"	0.8747	0.9780	0.9416	CN+GR
	I3	B+1, DK4 (Z+0.8m)	0.9288	0.9520	0.9483	CN+GR
	H4	Breadth + 1 m	0.9087	0.9405	0.9437	CN+GR

Type	RCO	Description	A_{SLF55}			Optimised
			CN	GR_{side}	GR_{bottom}	
Baltic RoPax	A (Init)	basic design	0.8326			CN
	B	Breadth + 40 cm	0.8703			CN
	C	Breadth +20 cm, Freeboard + 20 cm	0.8670			CN
	D	Breadth +40 cm, Freeboard + 20 cm	0.8824			CN
	E	Breadth +40 cm, Freeboard + 40 cm	0.8786			CN
	F	As version 3 + double hull on blh deck	0.8997			CN
	I	As vers 5 +Impact of LLH	0.8494			CN
	J1	As vers 5 + Subdivided Car Deck	0.9184			CN
	K2	As version 5 + No lower Hold	0.9042			CN
	L	As version F + 40cm Breadth	0.9152			CN
	L	As version F + 40cm Breadth	0.9152	0.9697	0.9737	CN+GR
Mediterranean RoPax	V00 (Init)	Initial version V0	0.8398			CN
	V1	V1 - depth +10	0.8404			CN
	V12	V12 - Add bkds below BHD	0.8496			CN
	V21	V21 - Add bkds on the car deck	0.8778			CN
	V14	V14 - Breadth increased	0.8718			CN
	V14	opt. Version for collision	0.8718	0.9519	0.9829	CN+GR
	V15	Add cross flooding devices and WT boundaries	0.8717	0.9584	0.9823	CN+GR
	V16	Add WT parts of decks	0.8809	0.9680	0.9948	CN+GR
Small RoPax	0 (Init)	Original	0.7947			CN
	1	Raised Main Dk	0.8426			CN
	DE					
	0 (Init)	Original	0.8412			CN
	1 (DE)	Raised Main Dk	0.8601			CN
	2 (DE)	Increased Beam (18m)	0.8782			CN

B Marine Fuels

B.a. Emissions

The specific emissions of marine fuels, i.e. marine diesel oil (MDO)/marine gas oil (MGO), heavy fuel oil (HFO) and LNG are summarised in Table A 1. Details were taken from /23/ and /40/ for MDO with a sulphur content of 0.14% (global average of 2012, /23/) and HFO with 2.51% (Non ECA global average of 2012, /23/). The data for LNG taken from /23/ is based on a study by MARINTEK /28/. SO_2 emissions of fuels with lower sulphur content is calculated in relation to relative sulphur content. It is mentioned that some of the emissions can be reduced by exhaust gas treatment and reach then the emissions of LSFO, e.g. PM by 80% with scrubber. The specific air pollution costs are calculated on basis of the specific emissions.

Table A 1: Specific emissions for ship fuels

	Marine MDO emissions factor[6]	Marine HFO emissions factor	LSFO	LNG
	g/g fuel	g/g fuel	g/g fuel	g/g fuel
CO_2	3.206	3.114	3.114	2.75
SO_2				0.00002
Global average	0.00264[7]	0.04908[8]		
Sulphur 1%		0.0196		
Sulphur 0.1%	0.0019		0.00196[9]	
NOx				
Tier 0 SSD	0.088	0.09282		0.00783
Tier I SSD	0.082	0.08718		0.00783
Tier II SSD	0.074	0.07846	0.07846	0.00783
Tier 0 MSD	0.06121	0.06512		0.00783
Tier I MSD	0.05684	0.06047		0.00783
Tier II MSD	0.04896	0.05209	0.05209	0.00783
NMVOC	0.00308	0.00308	0.00308	0.00301
CH_4	0.00006	0.00006	0.00006	0.05120
N_2O	0.00015	0.00016	0.00016	0.00011
CO	0.00277	0.00277	0.00277	0.00783
$PM_{2.5}$				
Tier I	0.0014	0.0056		
Tier II SSD	0.0015[10]	0.0078	0.0015[11]	
Tier II MSD	0.0013	0.0034	0.0013	

Remark:

From GHG3 Report From EMEP/EEA emission inventory guidebook 2013

6 Third IMO Greenhouse Gas Study 2014
7 Global average sulphur 0.14%
8 Global average sulphur 2.51%
9 Calculated on specific SOx emissions and sulphur content
10 EMEP/EEA emission inventory guidebook 2013
11 Estimated on basis of /27/

Timeline for IMO Tiers for emission

Tier	Geographical scope	Ship construction date (on or after)
I	global	1 January 2000
II	global	1 January 2011
III	in north American and United States Caribbean Sea ECAS	1 January 2016

B.b. Related Costs of Fuel Emissions

In updated Handbook on External Costs of Transport the damage costs of main pollutants from transport covering the effect on human health and other environmental damages. The data did not provide the details for each contributor but only the global costs of main pollutants. These external costs are quantified using monetary values of health end point, i.e. mortatility and morbidity /35/. The value for mortatility is 1,650,000 € which is significantly lower than the VPFs used in EMSA III study (3.3 mio. € + 6.6 mio. €[12]) .

In Table A 2 the damage costs of main pollutants in € per tonne emission are summarised distinguishing different sea regions. Differences in the costs reflect differences inpopulation density and distribution process of pollutants. Based on the damage costs in Table A 2 and the specific emissions in Table A 1 the specific emissions per tonne fuel and sea region are calculated. Exemplary values are shown in Table A 3. These values consider also engine particularities, i.e. distinguish between slow speed diesel (SSD) and medium speed diesel (MSD).

The cost parameters did not consider the climate change costs.

Table A 2: Damage costs of main pollutants in sea areas, in € per tonne (2010)[13]

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

12 Calculated using an exchange rate of 1.22 €/$

13 Handbook 2014

Table A 3: Specific air emissions costs per region

Sea region	MGO / MDO		HFO		LNG
	SSD	MSD	SSD	MSD	
	€/t	€/t	€/t	€/t	€/t
Baltic Sea	382	261	490	305	40
Black Sea	367	257	897	687	35
Mediterranean Sea	185	135	621	490	17
North Sea	500	346	689	419	53
Remaining North-East Atlantic	185	127	364	281	20

B.c. Climate Change Related Costs of Fuel Emissions

Emissions to air may have an impact on the climate, i.e. leading to an increase or decrease of the average temperature. Typically, the impact of different emissions is expressed in terms of global warming potential (GWP) which expresses the impact in relation to CO_2. The ship emissions due to burning of fuel consist of various gases (Table A 1). CO_2, CH_4 and N_2O are gases with relevant GWP. As explained in /41/ the primary climate change effects of nitrogen oxides (i.e., NO and NO_2) are indirect and result from their role in promoting the formation of ozone in the troposphere and, to a lesser degree, lower stratosphere, where it has positive radiative forcing effects. Additionally, NO_x emissions from aircraft are also likely to decrease methane concentrations, thus having a negative radiative forcing effect (IPCC 1999). Concentrations of NOx are both relatively short-lived in the atmosphere and spatially variable.

The Update of the Handbook on External Costs of Transport (/35/) provides total costs for some selected ship types, and using the abatement cost approach. Costs were calculated using a specific cost value of 90 €[14]/tonne CO_{2e} (48 € to 168 €). These costs consider cargo ships only and give no specific values that can be used to calculate values for RoPax and Cruise vessels.

The global warming potential of Methane and N_20 are publicly available (Table A 4). This table also considers the values of Kyoto protocol.

Table A 4: Global warming potential of gases

	/35/	Kyoto
	GWP (100 years)	
CH_4	25	21
N_2O	298	310

Altogether this information was used to estimate the climate change costs for a tonne of fuel (Table A 5).

[14] Central value

Table A 5: Climate change costs per unit fuel for ship fuels used onboard

			CO_2	CH_4	N_2O	SUM
Fuel	MDO	kg/kg_{fuel}	3.206	6E-05	0.0002	
	HFO/LSFO	kg/kg_{fuel}	3.114	6E-05	0.0002	
	LNG	kg/kg_{fuel}	2.75	0.0512	0.0001	
	GWP		1	25	298	
CO_{2e} .	MDO	kg/kg_{fuel}	3.206	0.0015	0.0447	3.25
	HFO/LSFO	kg/kg_{fuel}	3.114	0.0015	0.0477	3.16
	LNG	kg/kg_{fuel}	2.75	1.28	0.03278	4.06
Climate change costs	MDO	€/t_{fuel}	288.54	0.14	4.02	292.7
	HFO/LSFO	€/t_{fuel}	280.26	0.14	4.29	284.69
	LNG	€/t_{fuel}	247.5	115.2	2.95	365.65

C Costs of Up- and Downstream Processes

The up- and downstream processes can consider a lot of influences and become rather complex, for instance, steel production considering mining of iron ore and coal, and related impacts environment and human. In this section the costs of up- and downstream processes are estimated based on published data focusing on the most relevant contributors.

Following /35/ the most relevant processes to be considered in this study are

- Energy production: the production of the fuel causes additional nuisances due to extraction, transport and transmission;
- Material production: RCOs considered often led to an increase in lightweight. Though different material will be used in the RCOs for this study the process of steel production is considered.

C.a. Fuel Oil

In /35/ information are summarised on the costs for up- and downstream processes covering the well-to-tank part as well as related climate change costs not allowing to separating between both aspects. Unfortunately, /35/ did not provide data for RoPax and cruise ships but for other ship types (Table A 6). Following this study marginal up- and downstream costs are independent from the operational area but depend on the ship size. Additionally, /35/does not cover LNG. Due to the fact that the details are not explained for determining the values in Table A 6, it is not possible to estimate the costs for RoPax and cruise ships.

Table A 6: Marginal costs of up- and downstream processes (well-to-tank emissions and climate change costs) in € per 1,000 tkm for maritime transport (prices of 2010) /35/

Ship type		European sea area				
	Average load, tonnes	Baltic Sea	Black Sea	Mediterranean-Sea	North Sea	Remaining North-East Atlantic
Crude oil tanker 0-10 kt	1761	0.9	0.9	0.9	0.9	0.9
Crude oil tanker 10-60 kt	18413	0.3	0.3	0.3	0.3	0.3
Crude oil tanker 80-120 kt	49633	0.1	0.1	0.1	0.1	0.1
Products tanker 0-5 kt	810	1.4	1.4	1.4	1.4	1.4
Products tanker 5-10 kt	3150	0.8	0.8	0.8	0.8	0.8
General Cargo 0-5 kt	1527	0.4	0.4	0.4	0.4	0.4
General Cargo 5-10 kt	4174	0.6	0.6	0.6	0.6	0.6
Bulk carrier (feeder)	1440	0.9	0.9	0.9	0.9	0.9
Bulk carrier (handysize)	14300	0.2	0.2	0.2	0.2	0.2
Bulk carrier (handymax)	24750	0.1	0.1	0.1	0.1	0.1

Following Table 14 in /3/ the average external costs of up- and downstream processes for waterborne freight transport are between 1.3 and 0.8 €/1,000 tkm*a, which is between 15% and 25% of the external costs for air pollution (5.4 €/1,000 tkm*a).

A simple application of these relative cost parameter on the data given in Chapter 4 of /35/ would led to sea area dependent costs which is in conflict with the data for cargo ships which are area independent. As outlined in /35/ for up- and downstream emissions an average value for Europe based on fuel production in Europe is adequate.

Therefore, the additional costs per tonne of fuel oil were estimated using the data of Table A 6 for estimating for the average fuel consumption for these ship types and afterwards estimate related up- and downstream processes cost related to the fuel consumption, i.e. costs per tonne fuel Based on this estimation the costs for up- and downstream processes are between ~60 €/t_{fuel} and ~110 €/t_{fuel} with the higher values for the smaller ships.

For the quantitative analysis the average value of 85 €/t_{fuel} is used.

C.b. Fuel LNG

In /26/ greenhouse gas emissions for the LNG production in British Columbia are assessed and benchmarked. In this report the global average of CO_{2e} emissions is given with 0.58 t/t_{LNG} which is equivalent to 52.2 €/t_{LNG}. In an ICCT study it was mentioned that large scale gas production will generate GHG emissions of about 3.4 g_{CO2e}/MJ equivalent to 0.17 kg_{CO2e}/kg_{LNG} (~15.3 €/t_{LNG}). Additional GHG emissions for transport, distribution and storage would account for 0.49 kg kg_{CO2e}/kg_{LNG} (~44 €/t_{LNG}).

C.c. Steel

Some of the RCOs require additional steel. Steel production and transport lead to additional emissions and related costs for air pollution and climate change. In this section the external costs of steel production are estimated for a typical European steel production.

Fig. A: 1 shows the typical lifecycle of steel starting with the mining of the raw material (coal and iron ore) followed by the production of steel, manufacturing of components, the usage and finally the recycling. Like for fuel oil the total impact consists of direct emissions, i.e. steel production, and indirect emissions of up- and downstream processes. Direct emissions of the steel used depend on whether "new material", i.e. new material made of iron ore, or of recycling material is used. In general, the direct emissions of iron and steel production lead are $CO_2$and CH_4, and following /24/ likely small N_2O emissions.

Details of steel typical production and related CO_2 emissions are shown in Fig. A: 2. Following this figure and /14/ on average 1.8 t of CO_2 is emitted for every tonne of steel produced considering a fraction of about 13% of recycling material. In this case the recycling material is re-melted. Another possible way of recycling was mentioned in /36/; the rerolling of plates from recovered scrapping material. In this process about 90% of steel structure can be recycled which subsequently reduces CO_2 emissions to about 1.3 tonnes CO_2 per tonne steel.

The climate change costs of the direct CO_2 emissions are about 162 €/t_{Steel} for the process typically applied in Europe and 117 €/t_{Steel} for the rerolling process.

For this investigation the value of 162 €/t_{Steel} is used.

Additional to the CO_2 and CH_4 emissions in /10/ emission factors (tier I averaged or typical) for NMVOC and $PM_{2,5}$ were summarised for iron and steel production and in /11/ the combustion related emissions, i.e. NO_x, SO_x and CO for different elements of iron and steel production. All values are summarised in Table A 7. Following /12/ the production of one tonne of iron requires 1.4 tonnes of ore or other iron bearing material.

Typically, in steel production about 13% are recycling material which means that for one tonne of steel about 1.2 tonnes of iron (sinter) are required. Based on this the air pollution costs of steel manufacturing are estimated to 26 €/t (95% confidence interval: 11 €/t to 77 €/t).

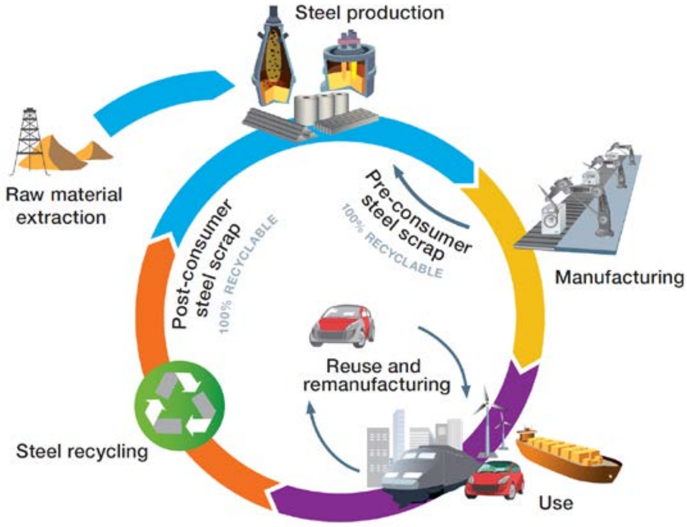

Fig. A: 1: Lifecycle of steel (/43/)

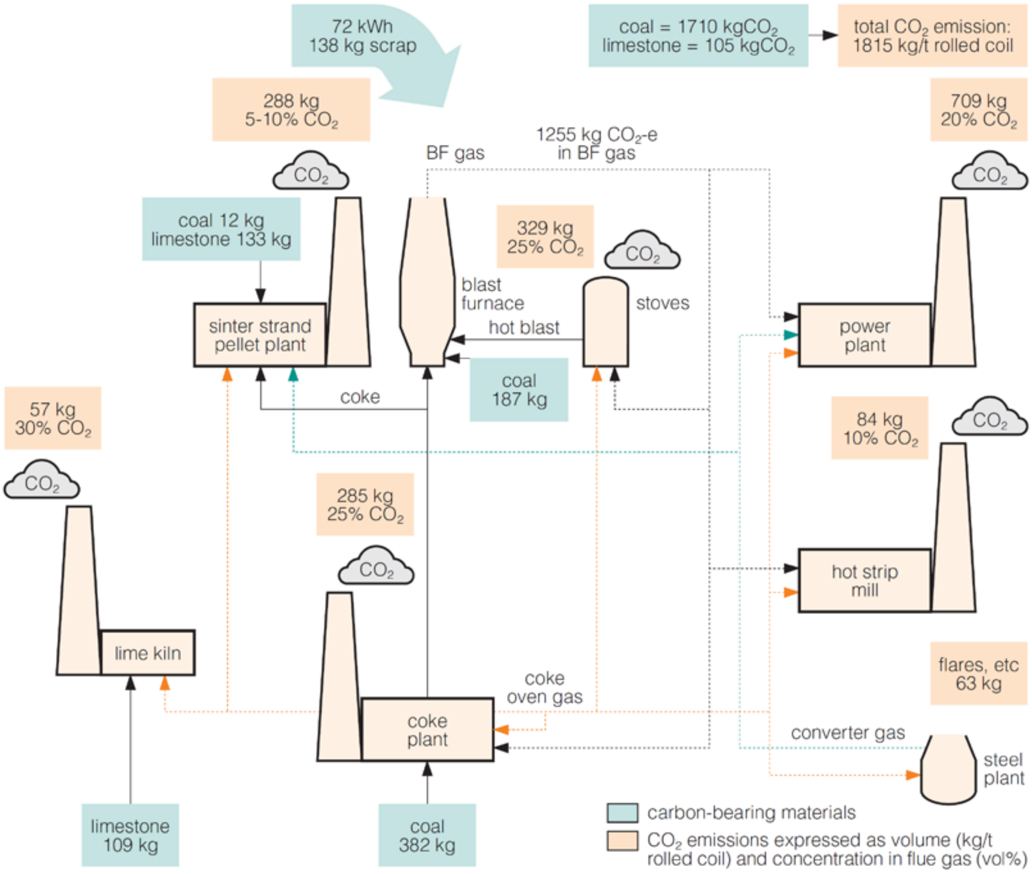

Fig. A: 2: CO_2 emissions from a typical steel mill (/19/)

Table A 7: Emission factors and related damage costs (/11/)

	Emission factors			Damage costs of main pollutants			
				Specific for pollutant	Per tonne steel or iron		
		95% confidence interval				95% confidence interval	
	Mean	Lower	Upper		Mean	Lower	Upper
	g/t	g/t	g/t	€/t	€/t	€/t	€/t
Iron and steel production							
NMVOC	150	55	440	1566	0.23	0.09	0.69
$PM_{2,5}$	140	40	500	70258	9.84	2.81	35.13
Blast furnace cowpers (per tonne pig iron)							
NO_x	8	2	30	10640	0.09	0.02	0.32
CO	27	22	36				
SO_x	38	7	194	10241	0.39	0.07	1.99
Sinter plants (per tonne sinter)							
NO_x	558	302	1030	10640	5.94	3.21	10.96
CO	18000	8780	37000				
SO_x	463	220	973	10241	4.74	2.25	9.96
Pelletizing plants (per tonne pellet)							
NO_x	287	150	550	10640	3.05	1.60	5.85
CO	64	10	410				
SO_x	48	11	213	10241	0.49	0.11	2.18
Reheating furnace (per tonne steel)							
NO_x	170	80	360	10640	1.81	0.85	3.83
CO	65	5	850				
SO_x	13	0.3	600	10241	0.13	0.00	6.14
Grey iron foundries (per tonne charged)							
NO_x	548	300	1000	10640	5.83	3.19	10.64
CO	2236	500	10000				
SO_x	1732	1000	3000	10241	17.74	10.24	30.72

Mining

Two main raw materials are used for steel production ore and coal.

Following an Internet research the upstream process of coal mining is mainly characterised by CO_2 and CH_4 emissions. Spath et al. (/37/) investigated the life cycle of coal fired power production for US power plants and in this context gave also information on upstream process of coal mining. Thereafter, CO_2 emissions for surface mining and river based transport are about 180 $kgCO_2/t_{coal}$ and CH_4 mining emissions are between 1.91 kg/t_{coal} and 0.84 kg/t_{coal}. In /25/ more detailed information for surface and underground mining were provided based on default IPCC emission factors (Table A 8). These are global values and it was mentioned that emissions vary significantly with mining site, e.g. in 1990 emissions in China are about ten times higher than in Germany.

Table A 8: Default IPCC Emissions Factors

Category	m^3 CH_4/t		kg CH_4/t	
	Low	High	Low	High
Underground Mining	10	25	7.14	17.86
Surface Mining	0.3	2.0	0.214	1.43

As shown above, the climate change related costs for coal mining and transport depend significantly on kind of mining, mining site and transport distance. For Europe no information was found in the Internet review.

For the purpose of this study climate change related costs of upstream processes is estimated as summarised in Table A 9 and the lower (8 €/t_{Steel}) and upper bound (32 €/t_{Steel}) value for 581 kg coal per tonne steel determined.

Table A 9: Climate change costs of upstream process coal (90 €/t_{CO2e})

Category	Emissions		Climate Change Costs	
CH_4				
	kg CH_4/t_{Coal}		€/t_{Coal}	
	Low	High	Low	High
Underground Mining	7.14	17.86	16	40
Surface Mining	0.214	1.43	0.5	3.2
CO_2				
	kgCO_2/t_{Coal}		€/ t_{Coal}	
Mining and transport	180		16.2	
Total Underground			32.2	56.2
Total Surface			16.7	19.4

Relevant information on the GHG emissions of iron ore mining is scarce on Internet. In /39/ the energy consumption for mining and processing of iron ore for pelletisation was given (Table A 10). Thereafter, for this process and assuming 300 km of rail transport and 4000 km of ship transport the total climate change costs related to CO_2 emissions are equivalent to about 40 € per tonne of iron ore (assuming 50% efficiency in energy production by coal). Typically, the iron content of ore is between 30% and 70%. For this study a content of 50% is used and therefore the climate change costs are about 80 €/t_{steel}.

Table A 10: Energy consumption during mining and processing of ore (/39/)

Stage	Consumption	Units
Perforation	1.8	MJ/t
Blasting	3.1	MJ/t
Loading	6.7	MJ/t
Transport to treatment	53.7	MJ/t
Primary crushing	0.83	MJ/t
Coarse screening	0.04	MJ/t
Secondary crushing	2.2	MJ/t
Grinding	69.7	MJ/t
Magnetic separation	3.6	MJ/t
Fines screening	0.72	MJ/t
Agglomeration	1.5	MJ/t
Transport to port	1.2	MJ/t
Transport to market	0.003	MJ/t

The external costs used for this investigation and their composition is summarised in Table A 11.

Table A 11: External costs of steel used for IA

Steel production		€/t_{steel}
CO_2	1.8 $t_{CO2}/_{tSteel}$	162
NVOV	150	.2
PM	140	9.8
Iron		
NOx + CO + SOx		16.6
Transport + energy		80
Coal		20
SUM		288.6

D Turnover / benefit

Stakeholders views on the relation between newbuilding prices (increased by RCOs) and ticket prices as well as on the effect on harbour fees are collected by questionnaires.

EMSA III – Task 5 – Impact assessment

In task 5 of the EMSA III project an impact assessment study is performed in accordance with the EU guidelines.
The objective is to map and assess the possible economic, social and environmental impacts of the suggested actions. The suggested action in this context is to raise the level of R to the formulations suggested by the project.
In order to adequately characterise the impact we need your support.

The main question relates to whether it is possible to quantify the effect an increased newbuilding price can have on the ticket price (or the economic consequences for the operator).
We have formulated some questions that may contribute to clarify, and we would like to have your answers and views on the following.

The effect of increased new-building cost on ticket price should be estimated. Please answer the following question from the perspective of your business case.

1. Assuming that the new-building price of a RoPax vessel increases by 5% then the ticket price may increase by X%

for normal passenger (car) %

for a truck %

2. Assuming that the new-building price of a Cruise vessel increases by 5% then the ticket price may increase by X%

for normal passenger %

3. Increased ticket prices may have a negative impact on the transport of passenger and cargo. Following your experience, an increase in ticket prices of

5% would imply a reduction in tickets sold by %

10% would imply a reduction in tickets sold by %

4. Following your experience which group of RoPax customers may be more affected?

Passenger/car ○

Truck ○

5. Following your experience which additional effects may occur if new damage stability requirements will be introduced?

From RoPax operator the following response was received:

EMSA III – Task 5 – Impact assessment

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The effect of increased new-building cost on ticket price should be estimated. Please answer the following question from the perspective of your business case.

1. Assuming that the new-building price of a RoPax vessel increases by 5% then the ticket price may increase by X%

for normal passenger (car) 3 %

for a truck 3 %

2. Assuming that the new-building price of a Cruise vessel increases by 5% then the ticket price may increase by X%

for normal passenger NA %

3. Increased ticket prices may have a negative impact on the transport of passenger and cargo. Following your experience, an increase in ticket prices of

5% would imply a reduction in tickets sold by ? %

10% would imply a reduction in tickets sold by ? %

4. Following your experience which group of RoPax customers may be more affected?

Passenger/car ○

Truck ◉

5. Following your experience which additional effects may occur if new damage stability requirements will be introduced?

There is a risk that the loading capacity of the ship will decrease if long lower hold is no longer feasible. Then the ticket price will increase by 10-15%.

Also the market for the time being is very tough, so no newbuildings are planned because of the high prices from the yards. Further increase of cost for RoPax will only lengthened the period until we order new ships.

From Cruise Line International Association we received the following information:

Celebrating its 40th Anniversary in 2015, Cruise Lines International Association (CLIA) is the unified voice and leading authority of the global cruise community. As the largest cruise industry trade association with 15 offices globally, CLIA has representation in North and South America, Europe, Asia and Australasia. CLIA's mission is to support policies and practices that foster a safe, secure and healthy cruise ship environment for the more than 22 million passengers who cruise annually, as well as promote the cruise travel experience. Members are committed to the sustained success of the cruise industry and are comprised of the world's most prestigious ocean, river and specialty cruise lines; a highly trained and certified travel agent community; and other cruise industry partners, including ports, destinations, ship developers, suppliers, business services and travel operators.

In response to your questionnaire on task 5 impact assessment for the EMSA 3 study, neither CLIA nor its individual member lines are able to quantitatively answer questions 2 or 3 as there is no direct (linear or non-linear) relationship between the cost to build a new cruise ship and the price for tickets.

Qualitatively speaking, as a consumer-based business, ticket prices are set individually by each owner/operator according to market demand and prevailing economic conditions, which vary substantially over time. Supply and demand are key considerations in any market economy and discretionary businesses that operate within it.

The cruise industry's ships generally operate at full capacity and dynamic pricing to maintain that demand keeps the number of tickets sold for a given fleet size nearly constant. In other words, it is the pricing that varies much more so than the number of tickets sold, and that pricing is driven by market demand and not by costs to the company.

Regulatory-driven increases to newbuilding costs could result in a company over time deciding to *inter alia* build fewer cruise ships or to build the same number of cruise ships but at a lower cost while preserving overall product quality and image that the consumer demands. Actions of this nature to control scarcity on the supply side are common in a range of businesses to overcome excessively higher operating costs.

A recent example of this in the transportation sector occurred several years ago when individual airlines substantially reduced capacity to improve pricing to overcome adverse cost factors.

Economic knock-on effects to building fewer ships include significant potential limitations on the number of seafarers/crew employed by the cruise industry; decreased revenue at ports and destinations; reduced demand on newbuilding and revitalization shipyards; and so on.

Beyond initial newbuilding costs are lifecycle costs, which when driven up by regulation, could have the unintended consequence of not only increased consumption of fuel but also increased maintenance costs or reduced energy efficiency to name only a few.

With respect to the following questionnaire no feedback was received.

With respect to the Task 5 impact assessment we kindly ask for your input / comments regarding the following.

1. Some of the RCOs will change the dimensions of the ship. Calculation of harbour and terminal fees is based on different parameter, for instance ship size in terms of GT. In order to consider substantial data in impact assessment we ask you for your estimation of the additional fees. In the table below we summarised the RCOs and the change in GT. Please enter your estimation in this table.

	Version	Brief description of RCO	ΔGT	Harbour	Terminal
			t	€/visit	€/day
		Cruise			
Small	00(Init)	**Reference version**	--		
Small	06	Increase breadth by 0.5 m	170		
Small	09	Increase breadth by 0.6 m	30		
Large	G2	**Reference version**	--		
Large	G3	as G2 with wt. decks	0		
Large	I3	Breadth increased by 1.0 m, Freeboard increased by 0.8	4727		
Large	K3	Opt. version for collision, changed internal subdivision, freeboard increased by 0.4 m	1600		
Large	K4	Developed for grounding CBA, as K3 with wt. decks	1600		
Large	M1	Developed for grounding CBA, double hull increased DB height	2703		
Large	M2	Developed for grounding CBA, as M1 with wt. decks	2703		

RoPax					
Large	A (Init)	**Reference version**			
	L	Increase breadth by 0.80 m	1097		
Medium	V00	**Reference version**	--		
	V14	Optimized for collision: Internal subdivision (bulkheads below bulkhead deck), breadth increased by 0.2 m	270		
	V15	Cross flooding devices + watertightness of longitudinal bulkheads	270		
	V16	Additional watertight parts of decks	270		
Small	1(Init)	**Reference version**	--		
	2	Raising main deck by 0.3 m	150		
Small (De)	0(Init)	**Reference version**	--		
	1	Raising main deck by 0.3 m	143		

2. Emission costs depend on the sea region. In order to limit the effort for calculating the damage costs of main pollutants in sea areas for cruise vessel we would like to work with an averaging value for Baltic, Black Sea, Mediterranean, North Sea and remaining North Atlantic. Therefore, please indicate how many percent of the year a cruise ship operates in these areas.

Baltic %

Black Sea %

Mediterranean %

North Sea %

Remaining North Atlantic %

0.0

E Salvage

E.a. **Insurance** and P&I

Two forms of insurance exist, the marine insurance and P&I (/32/). Maritime insurance covers measurable risks for hull, machinery and cargo. P&I clubs provide insurance for broader, indeterminate risks. Whereas a marine insurance company provides "hull and machinery" cover for shipowners, and cargo cover for cargo owners, a P&I Club provides cover for open-ended risks that traditional insurers are reluctant to insure.

Until the relatively recent focus on the environment, particularly oil pollution resulting from casualties, the P&I Clubs had little involvement with salvage (/13/). Conversely, P&I Clubs are very much involved with wreck removal. Indeed, the International Group of P&I Clubs, with its approximate USD 4.2 billion claims limit for any one vessel in one event, is one of the few facilities for covering the expenses modern wreck removal may entail.

Insurance and/or P&I will cover the claims except franchise which is paid by owner. It is mentioned that premiums for insurance and P&I should not be included in an FSA or IA because most of the risks are already considered explicitly.

E.b. Regulation

As explained by Gard (/13/) "the law of salvage is of ancient origin and generally based upon principles of equity. Simply put, it means the act of saving or rescuing the vessel and its cargo, without any prior legal or contractual obligation, from danger at sea. Compensation has historically depended on success – the so-called "no cure, no pay" principle."

Furthermore Gard gives also a specification of wreck; a ship becomes a wreck from the perspective of insurance when, following a casualty, the cost of repair effectively exceeds the value of the vessel. For example, under the Norwegian Marine Insurance Plan a vessel is considered a constructive total loss when the cost of repair exceeds 80% of the insurable value, or 80% of the value of the ship after repairs if the latter is higher than the insurable value. Before the hull insurer accepts that the vessel is a total loss and abandons her to the owner, she is not a wreck for purposes of P&I insurance and any removal order is the concern of the hull underwriter rather than the owner (and his P&I Club).

Following Gard currently there is no international convention covering wreck removal, although there is discussion at the International Maritime Organization (IMO). Coastal states do have authority to demand removal of wrecks within their territorial waters. While this is generally done because of a threat to navigation, that is not always the case.

The limitation of liability is regulated by coastal state and many coastal states have specified that the liability for wreck removal shall be unlimited, e.g. the United States and the United Kingdom.

Some basics regarding the relation between owner and salvor are regulated in IMO, International Convention On Salvage from 1989. The basics pertain to responsibilities of the parties and the conditions for reward. Thereafter the payment or reward should be fixed in relation to all of the vessel and other property interests in portion of their salved values.

E.c. Information

The costs of wreck removal depend on various influences like water depth, national regulations and season. Therefore, every case is unique and the costs can provide only an indication.

An internet review was carried out in order to collect information that allows estimating the salvage costs irrespectively who is finally paying. The results are summarised below.

Costa Concordia (2012)

The salvage costs for Costa Concordia are estimated to €1.5 bn including compensation to passengers (/16/) which is about three times the value of the new building price of $612 million (/15/). These costs are so high because of the way or removing the wreck in one piece (/18/).

Sea Diamond (2007)

https://en.wikipedia.org/wiki/MS_Sea_Diamond: wreck was not re-floated, but 450 tonnes of oil recovered. Fine of €1.17 million for oil pollution.

Following http://www.seanews.com.tr/news/62960/Salvage-of-Sea-Diamond-too-expensive.html the raising of the wreck was estimated to cost more than €150 million which is about three times the new building prices of €58.9 million.

MV Salem Express (1991)

Wreck not raised.

Estonia (1994)

Swedish government: SEK 1500 million (~ €180 million)

https://pandorasbox2014.wordpress.com/2015/09/10/the-sinking-of-the-estonia-in-1994/ : $69 million to $138 million (€61 million to €121 million).

Herald of Free Enterprise (1987)

The hulk was draped in 160 meters of netting to prevent bodies or cargo floating away during the salvage operation, estimated to cost $6.4 million. (http://articles.sun-sentinel.com/1987-04-08/news/8701220753_1_zeebrugge-makeshift-morgue-divers)

The salvage operation, conducted with the help of three giant floating cranes, was mounted in a calm sea in almost perfect weather conditions, salvage experts said.

F Economic Impact

Herald of Free Enterprise (1987) (/30/)

The accident's impact on Townsend Thoresen was severe and it took the company years to recover from it. Bad press from the accident affected its business across Europe and caused the company to repaint it's entire fleet from the traditional red hull to a new dark navy blue. Another part of its rebranding effort was removing the "TT" logo from the exhaust pipe and changing the company's name to P&O European Ferries. When the Herald of Free Enterprise was refloated and brought back into Zeebrugge it was believed that it would be repaired and put back into use, however, no buyer came forward. Eventually the boat was sold to a scrap yard in Taiwan.

Sources: e.g. Wikipedia

G Impact on marine insurance

As mentioned in the previous section marine insurance and P&I club cover the claims related to collision accidents.

Information regarding the impact of ship loss (ship sinks in collision accident) are collected below.

The losses of the MV RENA and MV COSTA CONCORDIA were significant to the hull market (especially the latter), but nonetheless the exposure was limited to the insurance values and terms (/17/). E.g. the salvage costs for Costa Concordia are estimated to €1.5 bn including compensation to passengers (/16/).

From the P&I perspective the impact was much more significant as liabilities were a great unknown on day one, and even after a significant passage of time it proved very difficult to accurately estimate the likely final cost of either incident as new claims and demands were raised, at times from entirely unforeseen angles.

As a consequence, reinsurance costs have risen sharply in the last two years after falling before 2012. Today a passenger ship pays USD 3.7791 per GT and year for its International Group P&I reinsurance whereas in 2012 it had paid USD 1.3992 per GT and year, which represents an increase of 170% (/17/).

A slightly different description of the situation is given in /42/ with deviating development in increase in premiums and expenses. Between 2011/12 and 2012/13 premiums increased only by 0.6% whereas club expenses increased by 8.5%. The development of claims is characterised as volatile, driven by single events. However, the 170% increase in premium for passenger ships is confirmed.

For a large cruise ship of 153,000 GT the annual premium is estimated to 430,000 €. Anyway, considering the difference in annual probability of sinking (about 3E-05) the effect of increased damage stability on premium is negligible.

H Search and Rescue

It is quite obvious that direct effort for search and rescue depends on the scenario, i.e. how long, what equipment, how many persons involved. Investigation carried out (see Annex) delivered a relatively high independency of costs and number of missions. An example from US Coast Guard: a patrol boat 1,150 US$/hr and a search plane ~7,600 US$/hr. However, the US Coast Guard and many other governments do not charge for at sea search and rescue missions and therefore no information regarding typical costs of missions were found.

In /44/ it is explained that search and rescue in Sweden is intended to be covered from dues and tariffs on merchant shipping. Two organisations are members of International Maritime Rescue Federation (IMRF), Swedish Sea Rescue Society and Swedish Maritime Administration. Swedish Sea Rescue Society is responsible for 70 per cent of all sea rescues in Sweden and receives no government funding. The Society is financed by membership fees, donations and voluntary work.

In Germany Search and Rescue is carried out by DGzRS which is totally financed by donation. The annual budget in 2014 was about 36 million Euros.

In a discussion the manager of the German rescue service mentioned that an important factor regarding annual budget is the target reaction time which influence number stations, ships and staff. This factor is independent of the number of missions and therefore no effect of reduced number of accidents is expected.

In USA the US Coast Guard is responsible for SAR. But this task is performed among others, e.g. general survey of traffic, and therefore it is impossible to assign a fraction of annual budget to SAR activities.

I Effect of future regulations – EEDI

As a part of Marpol Annex VI Ch.4 Reg.20 and Reg. 21, RoPax and Cruise ships will be required both to calculate the EEDI and to be in compliance with the required EEDI.

The basic concept is that the attained EEDI shall be less than the required EEDI. The calculation methods and formulations are given in Reg. 20. of /20/.

Extract from table 1 Reduction factors (in percentage) for the EEDI relative to the EEDI Reference line (Table A 12).

Table A 12: Extract from table 1

Ship Type	Size	Phase 0 1 Jan 2013 – 31 Dec 2014	Phase 1 1 Jan 2015 – 31 Dec 2019	Phase 2 1 Jan 2020 – 31 Dec 2024	Phase 3 1 Jan 2025 and onwards
Ro-ro passenger ship***	1000 DWT and above	n/a	5**	20	30
	250 –1,000 DWT	n/a	0-5***	0-20*	0-30*
Cruise passenger ship*** having non-conventional propulsion	85,000 GT and above	n/a	5**	20	30
	25,000 –85,000 GT	n/a	0-5***	0-20*	0-30*

* Reduction factor to be linearly interpolated between the two values dependent upon vessel size. The lower value of the reduction factor is to be applied to the smaller ship size.

** Phase 1 commences for those ships on 1 September 2015.

*** Reduction factor applies to those ships delivered on or after 1 September 2019, as defined in paragraph 43 of regulation 2.

Note: n/a means that no required EEDI applies.

If new rules concerning the level of R is approved and adopted in SOLAS as suggested in this project it will be applicable for ships built after an agreed date which is currently unknown. However this means that both phase 2 and 3 need to be considered.

The results from the calculation of the EEDI are presented for the sample ship and the RCOs in the following table. The calculations have been carried out in accordance with the guidelines in /29/.

These results are presented as the difference (in percent) in the EEDI compared with the initial design. This should be considered as an indication only based on some simplified assumptions and the information included in the Final Report from Task 1.

Assumptions:

The same assumptions were done for all the design variations for each design in order to allow for comparison.

The auxiliary engine sizes used for the calculations were based on the hotel load stated in the report. In the EEDI formula, the 75% of the installed propulsion power was used for the cruise ships and the

75% of the total installed power for the RoPax vessels. The EEDI speed was computed based on the speed power-curves found in the report. For the Mediterranean RoPax, two shaft generators, 2500 kW each were assumed.

The SFC was assumed based on the IMO GHG Studies.

The results for the cruise ships are presented in the Table A 13.

Table A 13: EEDI values for cruise ship RCOs

Large Cruise ship			
	GT	Attained EEDI	relative change compared to reference design
G2	153400	7.40	
H4	154671	7.34	-0.81 %
I3	158127	7.26	-1.78 %
J1	155221	7.32	-1.05 %
L1	153745	7.36	-0.41 %
Small Cruise ship			
	GT	Attained EEDI	relative change compared to reference design
00 (Init)	11800	22.51	
03	11800	22.51	0.00 %
04	11800	22.51	0.00 %
05	11869	22.39	-0.51 %
06	11971	22.10	-1.80 %
07	12173	21.79	-3.20 %
08	12349	21.39	-4.96 %
09	11834	22.46	-0.23 %

The attained EEDI compared to the requirements is shown in the Table A 14 below for the Large Cruise Ship.

Table A 14: Attained EEDI for Large cruise ship

Large Cruise ship										
Attained EEDI	Reference line (Phase 0)	x	Phase 1	difference from ref line	x	Phase 2	difference from ref. line	x	Phase 3	difference from ref. line
7.40	13.27595	5	12.61	-44.3 %	20	10.62	-30.37 %	30	9.29	-20.4 %
7.34	13.24512	5	12.58	-44.6 %	20	10.60	-30.77 %	30	9.27	-20.9 %
7.26	13.18264	5	12.52	-44.9 %	20	10.55	-31.13 %	30	9.23	-21.3 %
7.32	13.23499	5	12.57	-44.7 %	20	10.59	-30.89 %	30	9.26	-21.0 %
7.36	13.26216	5	12.60	-44.4 %	20	10.61	-30.58 %	30	9.28	-20.7 %

For the Small Cruise Ships there are no reduction factors to the reference line in the next phases, given the low GT (Table A 15).

Table A 15: Attained EEDI for small cruise ship

Small Cruise ship		
Attained EEDI	Reference line (Phase 0)	difference from ref line
22.51	22.97	-2.03 %
22.51	22.97	-2.03 %
22.51	22.97	-2.03 %
22.39	22.94	-2.40 %
22.10	22.90	-3.50 %
21.79	22.82	-4.53 %
21.39	22.75	-5.97 %
22.46	22.96	-2.19 %

The results for RoPax ships are shown in the Table A 16.

Table A 16: EEDI for RoPax RCOs

Mediterranean RoPax			
	DWT	Attained EEDI	relative change compared to reference design
V00 (Init)	6755	24.59	
v1	6755	24.86	1.07 %
v12	6755	24.63	0.13 %
v21	6755	20.86	-15.18 %
v14	6755	24.54	-0.22 %

Baltic RoPax			
	DWT	Attained EEDI	relative change compared to reference design
A (Init)	5450	23.16	
B	5450	23.10	-0.26 %
C	5450	23.01	-0.66 %
D	5450	22.98	-0.80 %
E	5450	23.03	-0.57 %
F	5450	23.00	-0.70 %
I	5450	23.04	-0.53 %
J1	5450	24.01	3.67 %
K2	5450	23.01	-0.67 %
L	5450	22.94	-0.99 %

The attained EEDI compared to the requirements is shown in the table below:

Mediterranean RoPax										
Attained EEDI	Reference line (Phase 0)	x	Phase 1	difference from ref line	x	Phase 2	difference from ref. line	x	Phase 3	difference from ref. line
24.59	26.14	5	24.83	-5.9 %	20	20.91	17.6 %	30	18.29	34.4 %
24.86	26.14	5	24.83	-4.90 %	20	20.91	18.9 %	30	18.29	35.9 %
24.63	26.14	5	24.83	-5.8 %	20	20.91	17.8 %	30	18.29	34.6 %
20.86	26.14	5	24.83	-20.2 %	20	20.91	-0.2 %	30	18.29	14.0 %
24.54	26.14	5	24.83	-6.1 %	20	20.91	17.4 %	30	18.29	34.1 %
Baltic RoPax										
Attained EEDI	Reference line (Phase 0)	x	Phase 1	difference from ref line	x	Phase 2	difference from ref. line	x	Phase 3	difference from ref. line
23.16	28.36	5	26.94	-18.3 %	20	22.69	2.1 %	30	19.85	16.7 %
23.10	28.36	5	26.94	-18.5 %	20	22.69	1.8 %	30	19.85	16.4 %
23.01	28.36	5	26.94	-18.9 %	20	22.69	1.4 %	30	19.85	15.9 %
22.98	28.36	5	26.94	-19.0 %	20	22.69	1.3 %	30	19.85	15.7 %
23.03	28.36	5	26.94	-18.8 %	20	22.69	1.5 %	30	19.85	16.0 %
23.00	28.36	5	26.94	-18.9 %	20	22.69	1.4 %	30	19.85	15.9 %
23.04	28.36	5	26.94	-18.8 %	20	22.69	1.6 %	30	19.85	16.1 %
24.01	28.36	5	26.94	-15.3 %	20	22.69	5.8 %	30	19.85	21.0 %
23.01	28.36	5	26.94	-18.9 %	20	22.69	1.4 %	30	19.85	15.9 %
22.94	28.36	5	26.94	-19.1 %	20	22.69	1.1 %	30	19.85	15.5 %

J Details of quantitative IA

J.a. Small Cruise

The external costs for air pollution and climate change are calculated for all RCOs investigated using the fuel mix model of the cost-benefit assessment (100% MDO) and considering operation in each of the five sea regions Baltic, Black Sea, Mediterranean, North Sea and remaining North Atlantic plus a mean operation in all these regions assuming 20% Baltic, 20% Black Sea, 35% Mediterranean, 15% North Sea and remaining 10% North Atlantic. The results are summarised Table A 17 and Table A 18.

Table A 17: Fuel and steel related impact of increased R-Index in terms of NPV represented by RCOs for small cruise (Part I)

			RCO				
			01	**02**	**03**	**04**	**05**
			€	€	€	€	€
CAPEX			-690	69,365	142,917	193,419	233,852
Fuel	FUELEX	Low	0	0	36,877	36,877	258,141
		Ref	0	0	53,083	53,083	371,583
		High	0	0	61,034	61,034	427,240
	Air Pollution	Baltic	0	0	16,877	16,877	133,063
		Black Sea	0	0	16,625	16,625	226,333
		Med.	0	0	8,690	8,690	151,448
		North Sea	0	0	22,326	22,326	174,904
		North Atlantic	0	0	8,213	8,213	96,941
		Mixed	0	0	13,912	13,912	160,815
	Climate		0	0	18,381	18,381	131,382
	Fuel upstream		0	0	5,488	5,488	38,416
Steel	Steel upstream		0	150	150	150	8,400

Table A 18: Fuel and steel related impact of increased R-Index in terms of NPV represented by RCOs for small cruise (Part I)

			RCO			
			06	07	08	09
			€	€	€	€
CAPEX			258188	727675	805160	224793
Fuel	FUELEX	Low	673,011	1,226,171	1,871,524	119,851
		Ref	968,770	1,765,019	2,693,976	172,521
		High	1,113,876	2,029,391	3,097,492	198,362
	Air Pollution	Baltic	308,007	561,164	856,513	54,851
		Black Sea	303,412	552,791	843,734	54,032
		Med.	158,599	288,954	441,035	28,244
		North Sea	407,456	742,351	1,133,061	72,561
		North Atlantic	149,880	273,068	416,788	26,691
		Mixed	253,900	462,584	706,050	45,215
	Climate		335,450	611,162	932,826	59,738
	Fuel upstream		100,155	182,475	278,514	17,836
Steel	Steel upstream		20,700	45,000	66,000	4,200

J.b. Large Cruise

The external costs for air pollution and climate change are calculated using the fuel mix model of the cost-benefit assessment and considering operation in each of the five sea regions Baltic, Black Sea, Mediterranean, North Sea and remaining North Atlantic plus a mean operation in all these regions assuming 20% Baltic, 20% Black Sea, 35% Mediterranean, 15% North Sea and remaining 10% North Atlantic. The results are summarised in Table A 19 and Table A 20 for RCOs focusing on CN as well as Table A 21 for RCOs focusing on CN+GR.

Table A 19: Fuel and steel related impact of increased R-Index in terms of NPV represented by RCOs for large cruise and RCOs for collision (Part I)

			RCO			
			H4	I3	J1	K1
			€	€	€	€
CAPEX			5,756,754	12,347,240	4,868,904	529,200
Fuel	FUELEX	Low	2,907,978	8,685,349	3,411,594	0
		Ref	4,185,906	12,502,179	4,910,840	0
		High	4,812,890	14,374,812	5,646,407	0
	Air Pollution	Baltic	1,919,573	5,733,250	2,252,013	0
		Black Sea	3,345,079	9,990,854	3,924,394	0
		Med.	2,254,430	6,733,379	2,644,862	0
		North Sea	2,522,239	7,533,250	2,959,051	0
		North Atlantic	1,425,506	4,257,605	1,672,382	0
		Mixed	2,362,867	7,057,251	2,772,079	0
	Climate		1,883,964	5,626,896	2,210,238	0
	Upstream		550,114	1,643,042	645,385	0
Steel	Upstream		144,162	296,541	145,824	15,000

Table A 20: Fuel and steel related impact of increased R-Index in terms of NPV represented by RCOs for large cruise and RCOs for collision (Part II)

			RCO		
			K2	K3	L1
			€	€	€
CAPEX			723,600	1,177,200	1,877,472
Fuel	FUELEX	Low	0	0	1,377,086
		Ref	0	0	1,982,256
		High	0	0	2,279,167
	Air Pollution	Baltic	0	0	909,023
		Black Sea	0	0 0	1,584,078
		Med.	0	0	1,067,596

		North Sea	0	0	1,194,418
		North Atlantic	0	0	675,055
		Mixed	0	0	1,118,947
	Climate		0	0	892,160
	Upstream		0	0	260,509
Steel	Upstream		24,000	45,000	74,700

Table A 21: Fuel and steel related impact of increased R-Index in terms of NPV represented by RCOs for large cruise and RCOs for collision+grounding (Part III)

			RCO				
			G3 (CN+GR)	K3 (CN+GR)	K4 (CN+GR)	M1 (CN+GR)	M2 (CN+GR)
			€	€	€	€	€
CAPEX			259,200	5,756,754	6,015,954	5,417,304	5,676,504
Fuel	FUELEX	Low	0	0	0	3,860,526	3,860,526
		Ref	0	0	0	5,557,058	5,557,058
		High	0	0	0	6,389,419	6,389,419
	Air Pollution	Baltic	0	0	0	2,548,356	2,548,356
		Black Sea	0	0	0	4,440,806	4,440,806
		Med.	0	0	0	2,992,900	2,992,900
		North Sea	0	0	0	3,348,433	3,348,433
		North Atlantic	0	0	0	1,892,450	1,892,450
		Mixed	0	0	0	3,136,857	3,136,857
	Climate		0	0	0	2,501,083	2,501,083
	Upstream		0	0	0	730,311	730,311
Steel	Upstream		4,500	144,162	144,162	270,300	270,300

J.c. Baltic RoPax

The external costs for air pollution and climate change are calculated using the fuel mix model of the cost-benefit assessment and considering operation in each of the four sea regions Baltic, Black Sea, Mediterranean and North Sea. This fuel mix considers only MDO (5%) and LNG (95%). Upstream cost for MDO/LNG production is estimated considering the fuel mix.

The results are summarised in Table A 22 and Table A 23 considering all investigate designs.

Table A 22: Fuel and steel related impact of increased R-Index in terms of NPV represented by RCOs (Part I)

			RCO				
			B	C	D	E	F
			€	€	€	€	€
CAPEX			1,570,968	1,480,248	2,447,496	3,503,196	2,716,416
Fuel	FUELEX	Low	1,239,573	1,404,850	1,875,888	2,074,220	1,875,888
		Ref	1,784,312	2,022,220	2,700,258	2,985,748	2,700,258
		High	2,051,574	2,325,117	3,104,715	3,432,967	3,104,715
	Air Pollution	Baltic	118,199	133,959	178,874	197,786	178,874
		Black Sea	105,482	119,546	159,629	176,506	159,629
		Med.	52,539	59,544	79,509	87,916	79,509
		North Sea	156,188	177,013	236,364	261,354	236,364
	Climate		833,806	944,981	1,261,827	1,395,236	1,261,827
	Upstream		106,185	120,343	160,694	177,683	160,694
Steel	Upstream		34,200	46,800	73,800	124,200	95,100

Table A 23: Fuel and steel related impact of increased R-Index in terms of NPV represented by RCOs (Part II)

				RCO		
			I	J1	K2	L
				€	€	€
CAPEX			3,298,428	3,572,316	3,575,340	3,337,740
Fuel	FUELEX	Low	1,545,335	15,726,056	1,115,616	2,173,386
		Ref	2,224,442	22,636,967	1,605,880	3,128,493
		High	3,413,688	34,739,294	1,846,417	3,597,093
	Air Pollution	Baltic	147,354	1,499,548	106,379	207,242
		Black Sea	131,501	1,338,214	94,934	184,945
		Med.	65,499	666,547	47,285	92,119
		North Sea	194,714	1,981,504	140,569	273,850
	Climate		1,039,479	10,578,223	750,426	1,461,940
	Upstream		132,378	1,347,136	95,567	186,178
Steel	Upstream		132,300	95,100	102,000	100,800

J.d. Mediterranean RoPax

The external costs for air pollution and climate change are calculated using the fuel mix model of the cost-benefit assessment and considering operation in each of the four sea regions Baltic, Black Sea, Mediterranean and North Sea. This fuel mix considers HFO380, LSFO and MDO.

The results are summarised in Table A 24. CAPEX costs were estimated by the designers in Euros and FUELEX using the scenarios and an exchange rate of 1.35 $/€. As shown the main cost contributors are CAPEX, FUELEX and air pollution including climate change whereas upstream processes are not relevant.

Table A 24: Impact of design changes in terms of NPV

			RCO				
			V1	V12	V14	V15	V16
			€	€	€	€	€
CAPEX			51,840	488,484	1,670,220	1,683,180	1,764,612
Fuel	FUELEX	Low	194,741	498,154	1,510,415	1,526,769	1,589,086

		Ref	284,422	727,562	2,207,118	2,229,872	2,320,887
		High	327,429	837,573	2,539,544	2,560,146	2,673,218
	Air Pollution	Baltic	119,686	306,161	928,764	938,339	976,638
		Black Sea	170,622	436,456	1,324,024	1,337,674	1,392,273
		Med.	108,689	278,029	843,425	852,120	886,900
		North Sea	150,681	385,446	1,169,281	1,181,335	1,229,553
	Climate		117,466	300,481	911,535	920,932	958,521
	Upstream		34,300	87,740	266,166	266,166	268,910
Steel	Upstream		2,400	21,600	35,325	35,325	35,775

J.e. Small RoPax

Table A 25: Impact of design changes in terms of NPV

			RCO		
			1 (DE)	2 (DE)	1
			€	€	€
CAPEX			67,392	498,312	129,600
Fuel	FUELEX	Low	0	3,684,043	0
		Ref	0	5,303,019	0
		High	0	6,097,329	0
	Air Pollution	Baltic	0	1,248,906	0
		Black	0	1,230,273	0
		Med	0	643,086	0
		North	0	1,652,149	0
	Climate		0	1,360,180	0
	Fuel upstream		0	406,109	0
Steel	Upstream		3,120	6,900	6,000

About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.