European Maritime Safety Agency

CARGOSAFE CORRIGENDUM

Study investigating cost-efficient measures for reducing the risk of cargo fires on container vessels (CARGOSAFE)

EMSA/CARGOSAFE – 2022-2023

Date: 4 October 2023

EMSA

About this study:

This report was commissioned by the European Maritime Safety Agency (EMSA) under framework contract EMSA/OP/17/2021

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1. Changes to the "Executive Summary"

The following tables need to be replaced:

Table 6: CEA of the Generic Ship 1 (Twin Island)

RCO	Initial Investment	Annual Cost	NPV	BCR	CBR	ΔPLL	GCAF	NCAF
D5	1,520 €	243 €	337,414 €	59.092	0.017	7.93E-05	2.9E+6	-170.2E+6
C1	805,000 €	57,500 €	3,721,257 €	3.045	0.328	1.34E-03	54.3E+6	-111.1E+6
C2	711,200 €	0 €	4,377,354 €	7.155	0.140	1.02E-03	27.9E+6	-171.7E+6
D2	458,240 €	2,500 €	1,254,789 €	3.498	0.286	3.95E-04	50.9E+6	-127.1E+6
F1	500,000 €	22,500 €	-205,808 €	0.771	1.298	2.20E-04	163.1E+6	37.4E+6
P1	938,967 €	14,099 €	-151,789 €	0.872	1.147	1.97E-04	241.2E+6	30.8E+6
D1	540,400 €	0 €	-155,300 €	0.713	1.403	1.10E-04	196.5E+6	56.5E+6
D1R	4,365,400 €	0 €	-3,980,300 €	0.088	11.336	1.10E-04	1.6E+9	1.4E+9
P4	0 €	7,360 €	141,246 €	2.087	0.479	5.18E-05	100.3E+6	-109.1E+6
F5	525,000 €	22,500 €	-474,313 €	0.486	2.059	3.82E-05	965.5E+6	496.7E+6
C3	1,116,000 €	11,160 €	-883,962 €	0.327	3.061	2.62E-05	2.0E+9	1.3E+9
F3	15,000 €	0 €	261,728 €	18.449	0.054	1.62E-05	37.0E+6	-646.2E+6
D3	3,600,000 €	36,000 €	-3,975,826 €	0.061	16.322	1.56E-05	10.9E+9	10.2E+9
F4	10,000 €	0 €	107,214 €	11.721	0.085	1.01E-05	39.6E+6	-424.6E+6
F4R	1,037,284 €	0 €	-920,070 €	0.113	8.849	1.01E-05	4.1E+9	3.6E+9
F2	15,000 €	0 €	77,521 €	6.168	0.162	5.43E-06	110.5E+6	-571.1E+6
D4	363,899 €	6,560 €	-401,823 €	0.162	6.162	4.68E-06	4.1E+9	3.4E+9

Table 7: CEA of the Generic Ship 2 (Single Island)

RCO	Initial Investment	Annual Cost	NPV	BCR	CBR	ΔPLL	GCAF	NCAF
C2	480,000 €	0 €	248,698 €	1.518	0.659	3.28E-04	58.5E+6	-30.3E+6
C1	735,000 €	52,500 €	-1,234,360 €	0.257	3.890	2.61E-04	254.6E+6	189.2E+6
D2	170,320 €	2,500 €	93,154 €	1.434	0.697	1.30E-04	66.0E+6	-28.7E+6
P1	391,389 €	5,877 €	-329,011 €	0.335	2.981	6.66E-05	297.4E+6	197.6E+6
F1	500,000 €	22,500 €	-800,858 €	0.107	9.324	6.22E-05	576.9E+6	515.0E+6
D1	225,167 €	0 €	-171,380 €	0.239	4.186	3.30E-05	272.9E+6	207.7E+6
D1R	1,818,917 €	0 €	-1,765,130 €	0.030	33.817	3.30E-05	2.2E+9	2.1E+9
D5	1,520 €	243 €	32,021 €	6.513	0.154	1.81E-05	12.8E+6	-70.8E+6
P4	0 €	4,987 €	-44,539 €	0.494	2.025	1.75E-05	201.2E+6	101.8E+6
C3	687,456 €	6,875 €	-692,648 €	0.144	6.964	1.59E-05	2.0E+9	1.7E+9
F5	525,000 €	22,500 €	-859,189 €	0.068	14.665	1.19E-05	3.1E+9	2.9E+9
D3	3,300,000 €	33,000 €	-3,817,891 €	0.017	60.219	8.34E-06	18.6E+9	18.3E+9
F4	10,000 €	0 €	24,875 €	3.488	0.287	6.59E-06	60.7E+6	-151.0E+6
F4R	490,535 €	0 €	-455,660 €	0.071	14.065	6.59E-06	3.0E+9	2.8E+9
F3	15,000 €	0 €	24,761 €	2.651	0.377	4.99E-06	120.2E+6	-198.5E+6
F2	15,000 €	0 €	12,873 €	1.858	0.538	3.51E-06	170.9E+6	-146.7E+6
D4	151,624 €	6,560 €	-248,049 €	0.072	13.825	2.50E-06	4.3E+9	4.0E+9

Table 8: CEA of the Generic Ship 3 (Feeder)

RCO	Initial Investment	Annual Cost	NPV	BCR	CBR	ΔPLL	GCAF	NCAF
F4	10,000 €	0 €	-281 €	0.972	1.029	3.16E-06	126.6E+6	3.6E+6
C2	184,150 €	0 €	-101,029 €	0.451	2.215	7.38E-05	99.8E+6	54.8E+6
C1	350,000 €	25,000 €	-760,991 €	0.038	26.205	3.72E-05	850.7E+6	818.3E+6
D2	85,440 €	2,500 €	-77,920 €	0.399	2.509	3.03E-05	171.0E+6	102.9E+6
P1	184,417 €	2,769 €	-203,086 €	0.129	7.725	1.93E-05	483.5E+6	420.9E+6
F1	500,000 €	22,500 €	-882,490 €	0.016	61.550	1.35E-05	2.7E+9	2.6E+9
D1	106,038 €	0 €	-98,214 €	0.074	13.553	7.73E-06	548.7E+6	508.2E+6
D1R	856,588 €	0 €	-848,764 €	0.009	109.483	7.73E-06	4.4E+9	4.4E+9
C3	321,408 €	3,214 €	-354,854 €	0.062	16.248	5.74E-06	2.6E+9	2.5E+9
F5	525,000 €	22,500 €	-904,626 €	0.019	52.876	5.67E-06	6.5E+9	6.4E+9
P4	0 €	1,680 €	-21,744 €	0.267	3.751	5.08E-06	233.4E+6	171.2E+6
F4R	283,916 €	0 €	-274,197 €	0.034	29.212	3.16E-06	3.6E+9	3.5E+9
D3	1,800,000 €	18,000 €	-2,104,167 €	0.006	157.046	2.84E-06	29.8E+9	29.6E+9
F3	15,000 €	0 €	-3,574 €	0.762	1.313	2.23E-06	269.1E+6	64.1E+6
F2	15,000 €	0 €	-7,026 €	0.532	1.881	1.57E-06	382.2E+6	179.0E+6
D5	1,520 €	243 €	-3,814 €	0.343	2.912	9.96E-07	233.3E+6	153.2E+6
D4	71,405 €	6,560 €	-184,414 €	0.015	67.876	5.77E-07	13.0E+9	12.8E+9

Table 9: Summary of cost-effectiveness of all RCO's for the 3 generic ships

RCO ID	Description	Twin Island	Single Island	Feeder
P1	Container screening tool	Maybe	No	No
P4	Improved control of lashing	Yes	No	No
D1	Optimizing current smoke detection system	No	No	No
D1R	Optimizing current smoke detection system (retrofitting)	No	No	No
D2	Heat detection looking at individual container temperature rise	Yes	Yes	No
D3	Fixed IR cameras. Coupled to a software solution to automate detection	No	No	No
D4	CCTV - AI - smoke detection	No	No	No
D5	Portable IR cameras for crew to enhance manual detection	Yes	Yes	No
F1	Increasing effectiveness of current CO2 system	No	No	No
F2	Improved manual firefighting tools for individual container breaching and firefighting	Yes	Yes	No
F3	Manual firefighting tools that increase reach	Yes	Yes	No
F4	Methods for unmanned fire fighting	Yes	Yes	Yes
F4R	Methods for unmanned firefighting (retrofitting)	No	No	No
F5	Watermist canon	No	No	No
C1	Active protection underneath hatch covers to protect from fire spread towards the deck	Yes	No	No
C2	Passive protection to protect from fire spread towards the deck	Yes	Yes	No

C3	Fixed external container stack cooling system to stop spread between stacks	No	No	No

2. Changes of figures in 3.8.3 “Structure”

Replace Figures 41 to 46.

Explanation: The following figures have been updated to match the consequence model that was applied. Page 91 - 93

- **On deck – Slow fire**

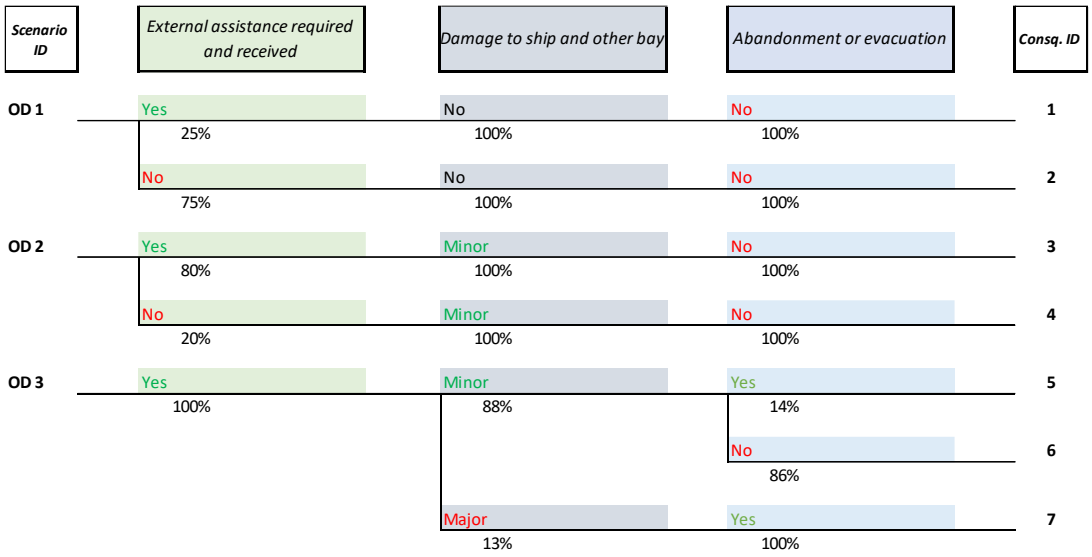

Figure 41: Consequence tree for on deck, with a slow fire

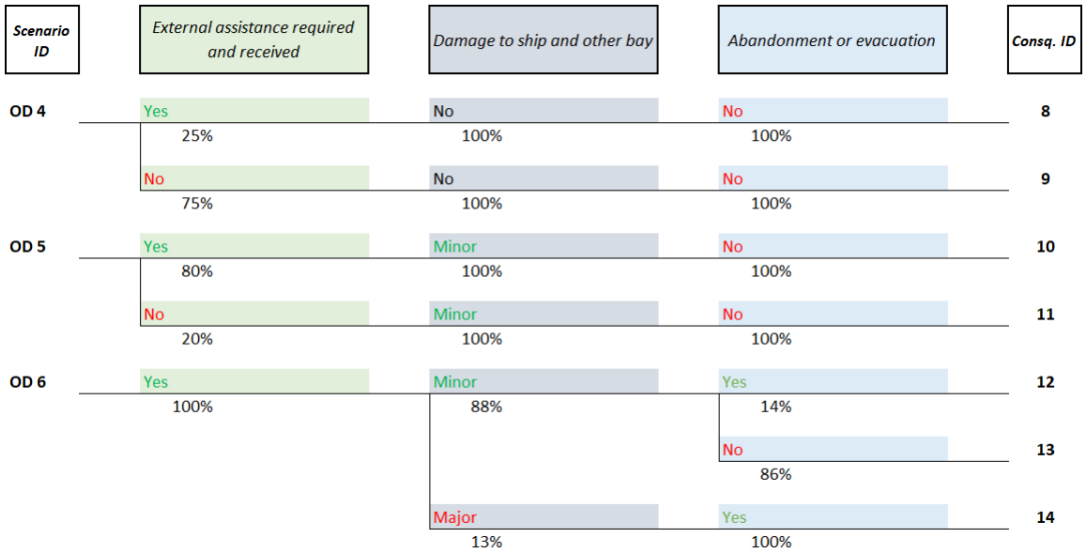

Figure 42: Consequence tree for on-deck, with a fast fire.

- **On deck – Explosion**

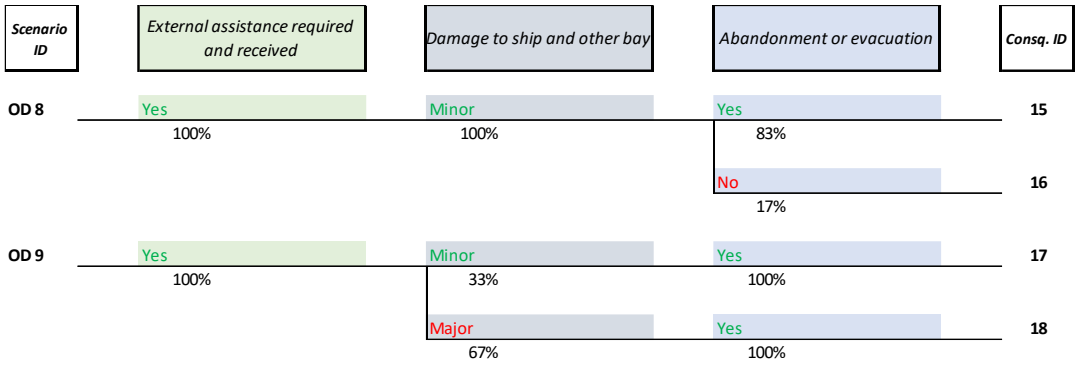

Figure 43: Consequence tree for on-deck, with an explosion leading to fire.

- **Below deck – Slow fire**

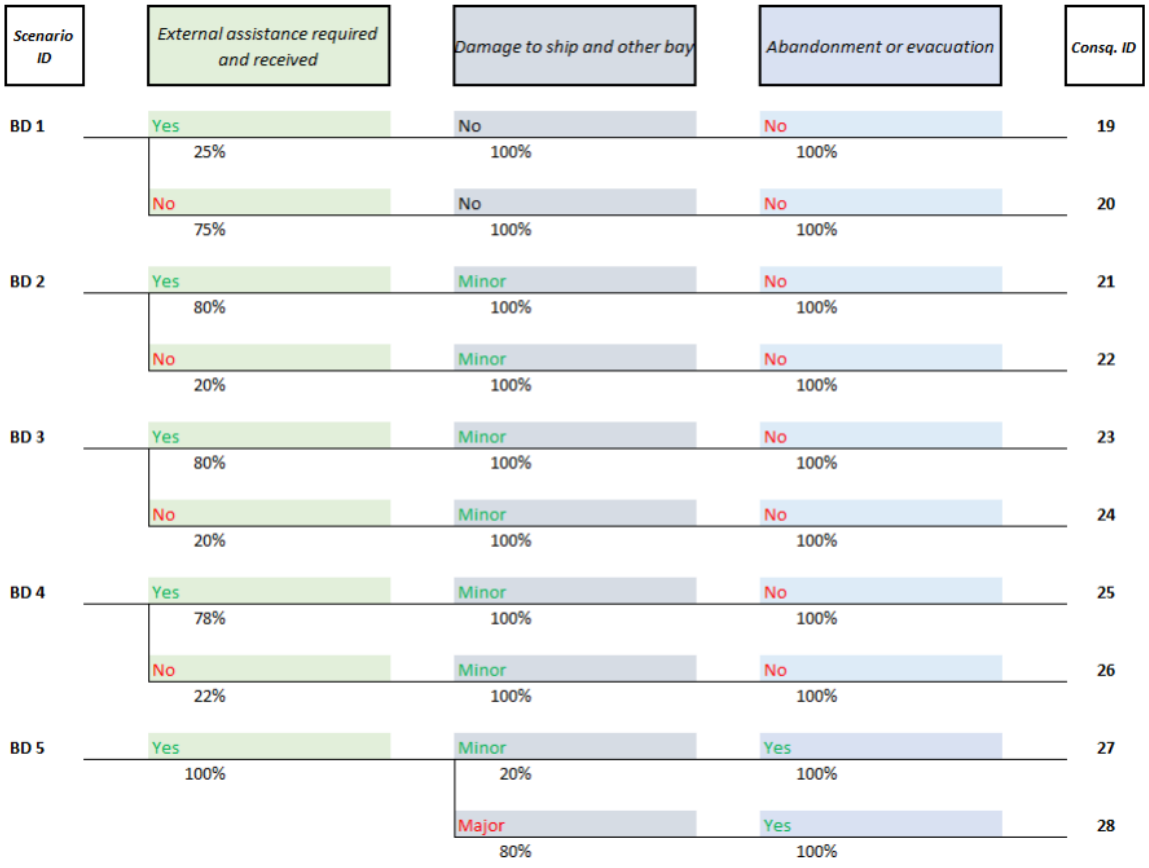

Figure 44: Consequence tree for below-deck, with a slow fire.

- **Below deck – Fast fire**

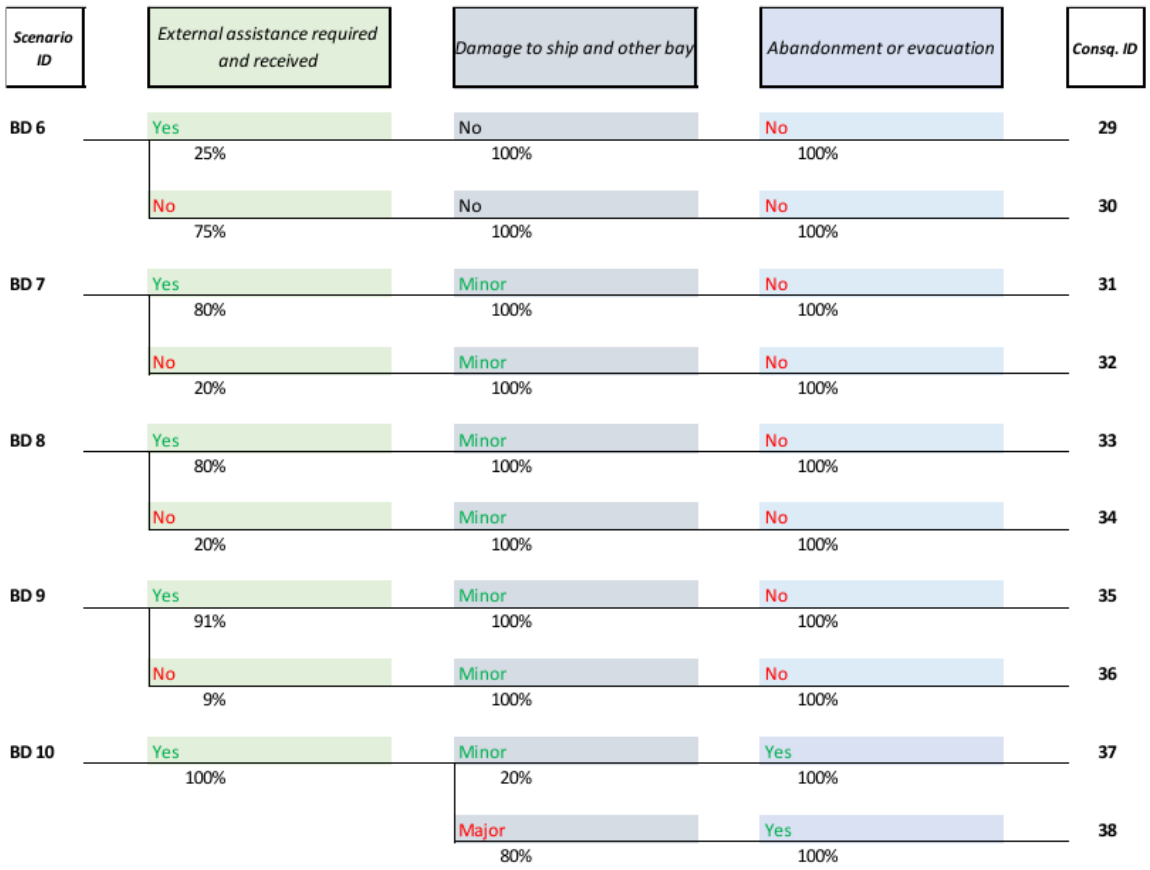

Figure 45: Consequence tree for below-deck, with a fast fire.

- **Below deck – Explosion**

Figure 46: Consequence tree for below-deck, with an explosion leading to fire.

3. Changes in Section 3.8.5 “Loss quantification”

Replace Table 20 in Section 3.8.5.2: Consequence model - Scenarios narrative.

Explanation: For transparency added the consequence aftermath for all the ship types.

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Table 20: Consequence model – Scenarios narrative

ID	Fire type	Event tree outcome	Consequence scenario description	Consequence aftermath		
				Gen ship 1	Gen ship 2	Gen ship 3
				Twin Island	Single Island	Feeder
1	slow fire on deck	COO controlled	External assistance, no damage to the ship	3 container loss, no damage to the ship, 1 minor injury	3 container loss, no damage to the ship, 1 minor injury	3 container loss, no damage to the ship, 1 minor injury
2	slow fire on deck	COO controlled	No assistance, no damage to the ship	5 container loss, no damage to the ship, no fatalities	5 container loss, no damage to the ship, no fatalities	5 container loss, no damage to the ship, no fatalities
3	slow fire on deck	Bay controlled	External assistance, minor damage to the ship	0.6% container loss, superficial damage to the ship, 1 minor injury	0.7% container loss, superficial damage to the ship, 1 minor injury	1.4% container loss, superficial damage to the ship, 1 minor injury
4	slow fire on deck	Bay controlled	No assistance, minor damage to the ship	1.3% container loss, minor damage to the ship, no fatalities	1.4% container loss, minor damage to the ship, no fatalities	2.8% container loss, minor damage to the ship, no fatalities
5	slow fire on deck	Uncontrolled	External assistance, minor damage to the ship had to abandon	5.1% container loss, major damage to the ship, 2 injuries	5.7% container loss, major damage to the ship, 2 injuries	11.3% container loss, major damage to the ship, 2 injuries
6	slow fire on deck	Uncontrolled	External assistance, minor damage to the ship	3.8% container loss, minor damage to the ship, 1 injury	4.3% container loss, minor damage to the ship, 1 injury	8.5% container loss, minor damage to the ship, 1 injury
7	slow fire on deck	Uncontrolled	External assistance, major damage to the ship had to abandon	36.5% container loss, major damage to the ship, 3 injuries	37.9% container loss, major damage to the ship, 3 injuries	40.8% container loss, major damage to the ship, 3 injuries
8	fast fire on deck	COO controlled	External assistance, no damage to the ship	3 container loss, no damage to the ship, 2 minor injuries	3 container loss, no damage to the ship, 2 minor injuries	3 container loss, no damage to the ship, 2 minor injuries
9	fast fire on deck	COO controlled	No assistance, no damage to the ship	5 container loss, no damage to the ship, 1 minor injury	5 container loss, no damage to the ship, 1 minor injury	5 container loss, no damage to the ship, 1 minor injury

10	fast fire on deck	Bay controlled	External assistance, minor damage to the ship	1.9% container loss, minor damage to the ship, 1 injury	2.2% container loss, minor damage to the ship, 1 injury	4.3% container loss, minor damage to the ship, 1 injury
11	fast fire on deck	Bay controlled	No assistance, minor damage to the ship	2.5% container loss, minor damage to the ship, 5 minor injuries	2.9% container loss, minor damage to the ship, 5 minor injuries	5.7% container loss, minor damage to the ship, 5 minor injuries
12	fast fire on deck	Uncontrolled	External assistance, minor damage to the ship had to abandon	7.6% container loss, major damage to the ship, 3 injuries	8.6% container loss, major damage to the ship, 3 injuries	17% container loss, major damage to the ship, 3 injuries
13	fast fire on deck	Uncontrolled	External assistance, minor damage to the ship	6.3% container loss, minor damage to the ship, 2 injuries	7.2% container loss, minor damage to the ship, 2 injuries	14.2% container loss, minor damage to the ship, 2 injuries
14	fast fire on deck	Uncontrolled	External assistance, major damage to the ship had to abandon	48.7% container loss, major damage to the ship, 4 injuries	50.5% container loss, major damage to the ship, 4 injuries	54.5% container loss, major damage to the ship, 4 injuries
15	explosion on deck	Bay controlled	External assistance, minor damage to the ship had to abandon	3.2% container loss, minor damage to the ship, 2 injuries	3.6% container loss, minor damage to the ship, 2 injuries	7.1% container loss, minor damage to the ship, 2 injuries
16	explosion on deck	Bay controlled	External assistance, minor damage to the ship	3.2% container loss, minor damage to the ship, 2 injuries	3.6% container loss, minor damage to the ship, 2 injuries	7.1% container loss, minor damage to the ship, 2 injuries
17	explosion on deck	Uncontrolled	External assistance, minor damage to the ship had to abandon	10.1% container loss, major damage to the ship, 5 injuries	11.5% container loss, major damage to the ship, 5 injuries	22.7% container loss, major damage to the ship, 5 injuries
18	explosion on deck	Uncontrolled	External assistance, major damage to the ship had to abandon	60.9% container loss, major damage to the ship, 1 fatality	63.2% container loss, major damage to the ship, 1 fatality	68.1% container loss, major damage to the ship, 1 fatality
19	slow fire below deck	Extinguished	External assistance, no damage to the ship	3 container loss, no damage to the ship, 1 minor injury	3 container loss, no damage to the ship, 1 minor injury	3 container loss, no damage to the ship, 1 minor injury
20	slow fire below deck	Extinguished	No assistance, no damage to the ship	5 container loss, no damage to the ship, 1 minor injury	5 container loss, no damage to the ship, 1 minor injury	5 container loss, no damage to the ship, 1 minor injury
21	slow fire below deck	Extinguished	External assistance, minor damage to the ship	0.9% container loss, superficial damage to the ship, 1 minor injury	0.9% container loss, superficial damage to the ship, 1 minor injury	1.6% container loss, superficial damage to the ship, 1 minor injury
22	slow fire below deck	Extinguished	No assistance, minor damage to the ship	0.9% container loss, superficial damage to the ship, no fatalities	0.9% container loss, superficial damage to the ship, no fatalities	1.6% container loss, superficial damage to the ship, no fatalities
23	slow fire below deck	Hold controlled	External assistance, minor damage to the ship	1.8% container loss, minor damage to the ship, 2 minor injuries	1.8% container loss, minor damage to the ship, 2 minor injuries	3.2% container loss, minor damage to the ship, 2 minor injuries

24	slow fire below deck	Hold controlled	No assistance, minor damage to the ship	1.8% container loss, minor damage to the ship, no fatalities	1.8% container loss, minor damage to the ship, no fatalities	3.2% container loss, minor damage to the ship, no fatalities
25	slow fire below deck	Hold controlled	External assistance, minor damage to the ship	3.6% container loss, minor damage to the ship, 1 injury	3.7% container loss, minor damage to the ship, 1 injury	6.4% container loss, minor damage to the ship, 1 injury
26	slow fire below deck	Hold controlled	No assistance, minor damage to the ship	5.3% container loss, minor damage to the ship, 1 minor injury	5.5% container loss, minor damage to the ship, 1 minor injury	9.6% container loss, minor damage to the ship, 1 minor injury
27	slow fire below deck	Uncontrolled	External assistance, major damage to the ship had to abandon	18.3% container loss, major damage to the ship, 1 fatality, 5 injuries	19.7% container loss, major damage to the ship, 1 fatality, 5 injuries	36.2% container loss, major damage to the ship, 1 fatality, 5 injuries
28	slow fire below deck	Uncontrolled	External assistance, major damage to the ship	24.4% container loss, major damage to the ship, 3 fatalities, 5 injuries	26.2% container loss, major damage to the ship, 3 fatalities, 5 injuries	48.2% container loss, major damage to the ship, 3 fatalities, 5 injuries
29	fast fire below deck	Extinguished	External assistance, no damage to the ship	3 container loss, no damage to the ship, 2 injuries	3 container loss, no damage to the ship, 2 injuries	3 container loss, no damage to the ship, 2 injuries
30	fast fire below deck	Extinguished	No assistance, no damage to the ship	5 container loss, no damage to the ship, 2 injuries	5 container loss, no damage to the ship, 2 injuries	5 container loss, no damage to the ship, 2 injuries
31	fast fire below deck	Extinguished	External assistance, minor damage to the ship	1.8% container loss, superficial damage to the ship, 2 minor injuries	1.8% container loss, superficial damage to the ship, 2 minor injuries	3.2% container loss, superficial damage to the ship, 2 minor injuries
32	fast fire below deck	Extinguished	No assistance, minor damage to the ship	1.8% container loss, superficial damage to the ship, 1 minor injury	1.8% container loss, superficial damage to the ship, 1 minor injury	3.2% container loss, superficial damage to the ship, 1 minor injury
33	fast fire below deck	Hold controlled	External assistance, minor damage to the ship	2.7% container loss, minor damage to the ship, 5 minor injuries	2.8% container loss, minor damage to the ship, 5 minor injuries	4.8% container loss, minor damage to the ship, 5 minor injuries
34	fast fire below deck	Hold controlled	No assistance, minor damage to the ship	2.7% container loss, minor damage to the ship, 2 minor injuries	2.8% container loss, minor damage to the ship, 2 minor injuries	4.8% container loss, minor damage to the ship, 2 minor injuries
35	fast fire below deck	Hold controlled	External assistance, minor damage to the ship	4.4% container loss, minor damage to the ship, 2 injuries	4.6% container loss, minor damage to the ship, 2 injuries	8% container loss, minor damage to the ship, 2 injuries
36	fast fire below deck	Hold controlled	No assistance, minor damage to the ship	6.2% container loss, minor damage to the ship, 1 injury, 5 minor injuries	6.4% container loss, minor damage to the ship, 1 injury, 5 minor injuries	11.2% container loss, minor damage to the ship, 1 injury, 5 minor injuries
37	fast fire below deck	Uncontrolled	External assistance, minor damage to the ship had to abandon	30.5% container loss, major damage to the ship, 1 fatality, 5 injuries	32.8% container loss, major damage to the ship, 1 fatality, 5 injuries	60.3% container loss, major damage to the ship, 1 fatality, 5 injuries
38	fast fire below deck	Uncontrolled	External assistance, major damage to the ship had to abandon	69.6% container loss, total loss damage to the ship, 3 fatalities, 5 injuries	68.4% container loss, total loss damage to the ship, 3 fatalities, 5 injuries	66% container loss, total loss damage to the ship, 3 fatalities, 5 injuries

39	explosion below deck	Uncontrolled	External assistance, minor damage to the ship	2.7% container loss, minor damage to the ship, 5 minor injuries	2.8% container loss, minor damage to the ship, 5 minor injuries	4.8% container loss, minor damage to the ship, 5 minor injuries
40	explosion below deck	Hold controlled	External assistance, minor damage to the ship had to abandon	3.6% container loss, minor damage to the ship, 1 injury	3.7% container loss, minor damage to the ship, 1 injury	6.4% container loss, minor damage to the ship, 1 injury
41	explosion below deck	Hold controlled	External assistance, minor damage to the ship	3.6% container loss, minor damage to the ship, 5 minor injuries	3.7% container loss, minor damage to the ship, 5 minor injuries	6.4% container loss, minor damage to the ship, 5 minor injuries
42	explosion below deck	Hold controlled	External assistance, minor damage to the ship had to abandon	7.1% container loss, minor damage to the ship, 5 injuries	7.4% container loss, minor damage to the ship, 5 injuries	12.8% container loss, minor damage to the ship, 5 injuries
43	explosion below deck	Hold controlled	External assistance, minor damage to the ship	5.3% container loss, minor damage to the ship, 5 injuries	5.5% container loss, minor damage to the ship, 5 injuries	9.6% container loss, minor damage to the ship, 5 injuries
44	explosion below deck	Uncontrolled	External assistance, major damage to the ship had to abandon	100% container loss, total loss damage to the ship, 3 fatalities	100% container loss, total loss damage to the ship, 3 fatalities	100% container loss, total loss damage to the ship, 3 fatalities

4. Changes in Section 3.8.5.3.1 “Containers and cargo”

This section is amended. After a thorough review, we have refined the values related to container costs, cargo, and their respective salvage values. **Consequently, updates to the figures in the report will be implemented.** It is essential to emphasize that these adjustments have **not altered the conclusions** drawn in the report or the prioritization of the RCOs.

The value of cargo has been estimated considering the average value of the goods / commodities, and the average value of the container itself.

Explanation:

Upon careful review, values pertaining to the cost of containers, their cargo and their associated salvage values have been refined. As a result, updates to figures in the report will be made. It is important to emphasize that these adjustments **have not altered the conclusions drawn in the report or the prioritization of the RCOs**. Revisions to the intermediate tables are scheduled to be made to reflect these changes.

The tables within this amendment document have been accurately updated to represent these modifications.

Container Value

Containers come in many sizes and types. To simplify, there are TEUs, which are 20-foot containers and FEUs which are 40-foot containers. The two most common container types are refrigerated containers and dry containers. Therefore, the cargo value estimate will be based on the ratio between these common cargo unit sizes and types.

Ships are most commonly described by the TEU-capacity, though the FEU is actually the most common type of container on large container vessels. The ratio of cargo is therefore set at 80/20, with 80% of cargo being FEUs.

The amount of refrigerated cargo on the container vessels varies significantly across trade lanes and services. Vessels sailing from Asia to Europe do not carry a high load of perishable goods that require refrigeration, so the ratio of dry vs reefer cargo split might be 95/5. Other services such as those from South America to Asia is an often-used trade for fruit transportation, so the ratio might for example be 40/60. The study assumes an average ratio of 75/25 for any vessels, with 25% being refrigerated cargo.

The value of the containers is based on the price of acquiring a new container of the same type. Prices for purchasing new containers have been estimated via various information sources[2], and are shown in Table 21.

Table 21: Container pricing

Container Type	Price (EUR)	Amount (%)
20FT Container – Dry	3,000	15 %
40FT Container – Dry	5,000	60 %
20FT Refrigerated Container	19,000	5 %
40FT Refrigerated Container	22,000	20 %

Based on the above data, the weighted average value of containers can be calculated to be 4,889 € / TEU.

Cargo Value

The value of the cargo itself has been estimated using, among others, data from the IHM Markit study[3].

[2] For an insight into prices and recent historical developments of ISO containers, check for example:https://www.shippingcontainerdepot.com/how-much-are-shipping-containers/ or https://www.container-xchange.com/

[3] https://cdn.ihs.com/www/pdf/Vessel-Accumulation-Cargo-Value-Estimation.pdf

There is huge variation in cargo value across commodities. One container full of jewellery or rare metals can be worth many million Euro, and one with trash or scrap metal or plastics might be worth a thousand Euros. This study assumes a 2022 average value of 45,000 € per TEU of cargo. The total value of one TEU with both the cargo and container value included, is 49,888.9 €.

The number of containers onboard an average vessel should be estimated, as a container ship rarely carries only full containers and is at 100% capacity utilization. Most tradelines and services between regions / countries are characterized by trade imbalances with respect to export and import cargo. For services between for example Asia, Europe and America, vessels are generally carrying many full containers in the main trade direction (head haul direction) vs many empty containers in the opposite direction (backhaul direction). The UNCTAD Review of Maritime Transport for 2021 give an indication of trade imbalances between the main regions, see Table 22.

Table 1: Container volumes between main regions for Asia, EU, and US trade lanes / services.

Route	mTEU to	mTEU return	% return
Asia to US	24.1	7.1	29 %
Asia to EU	18.5	7.8	42 %
EU to US	5.2	2.8	54 %

A simple calculation of average across trade routes, indicates that backhaul voyages on average carry 41.8 % export cargo compared to shipped export cargo volumes on head haul voyages. On average for the entire round trip, a vessel will be utilized with what is equivalent to 70.9% full containers.

Due to the trade imbalances, many empty containers must be shipped back empty to where cargo was exported from, as for example to Asia from Europe and the US. The empty containers are relatively easy to transport since they barely add anything to weight and balance constraints of the vessel compared to a full box. Assuming that backhaul vessels are filled to max nominal slot capacity with empty containers, this means 58.2 % of the cargo is empty containers[4]. It was above mentioned that an empty container on average is worth 9.8 % of a full box with cargo (4,889 € empty, 49,889 € full). For the return trip, converting the value of 58.2% empty containers to an equivalent value of full containers, gives equal to additional 5.7% utilization. The cargo value for backhaul trips is therefore assumed to be 47.5 % of a head haul voyage. This increases the average cargo fill calculated only as full container equivalents to 73.8 % for the round trip. The cargo value estimated to create a monetary value for the PLC, will be calculated with the formula below:

$$Cargo\,Value = TEUCapacity * 0.738 * 49889EUR$$

With this formula, the following average cargo values have been set for the chosen generic ships, see Table 23: Average cargo values for the three generic ships.

Table 2: Average cargo values for the three generic ships.

Ship	TEU	Cargo value in million € (EUR)
Twin Island	18,000	€ 662 million
Single Island	7,500	€ 276 million
Feeder	3,532	€ 130 million

[4] The average vessel utilization measured in slots filled with full and empty containers will in realty be less than 100% on most trips and legs.

5. Changes in Section 3.8.5.3.3 “Salvage and other cost”

Explanation: See item 3. For transparency the explanation of the salvage cost is added.

As part of the CARGOSAFE study, a model was developed to estimate costs for salvage operations and related services in case of fire incidents onboard container vessels for 4 different damage scenarios and 3 vessel types. The model was developed based on research into public information available from a small sample of fire related salvage cases as well as interviews with salvage experts. The cost models for salvage and related services coupled to fire onboard container vessels, is assumed to include the following cost components:

• The Lloyd's Open Form (LOF) premium/costs for salvage operations are estimated as a premium, calculated based on the ratio of the remaining value of the vessel and cargo onboard after salvage operations.

• Off-hire costs for the vessel when it is not operational (equivalent to charter rate for a replacement vessel).

• Cargo and Waste handling costs in one or more ports after salvage operations.

• Fees for surveyor investigations, legal services for court cases to determine accountability, general average, insurance pay-outs, etc.

LOF Salvage Costs

In line with section 3.8.5.2, a set of assumptions have been made on fire damage and impact on remaining value of ship and cargo (incl. box) which have formed basis for calculating the LOF premium, see new table to be added below.

Damage Scenario	Remaining Ship Value (%)	Remaining Cargo Value (%)	Salvage (LOF) premium (% of Ship and Cargo Value remaining)
Superficial	100	100	0
Minor	100	100	2[5]
Major	67	33	15
Total Loss	0	33	15

It has been assessed that a superficial damage scenario will be handled on the vessel by the crew alone without engaging a salvage firm, however in the minor damage case, a salvage company might occasionally be called in for support. In line with section 3.8.5.3.3 of the CARGOSAFE study, it is assumed that a vessel on average is utilized with 74% of its nominal slot TEU capacity of full container equivalents for which value (cargo and container) is set at an average of 49,889 EUR. TEU impacted are thus calculated as shown in the new table that was added for the 3 vessel categories.

Ship Category	Twin Island	Single Island	Feeder
Ship Value (EUR)	130 million €	64 million €	39 million €
TEU Impacted	13277	5532	2605
Cargo and Box Value	662 million €	276 million €	130 million €

[5] Only ship value has been included as basis for calculation of LOF Premium for the Minor Damage Scenario.

For the 3 types of container vessels this gives the following Salvage LOF premium costs:

Ship Type/Damage Category	Twin Island	Single Island	Feeder
Superficial	0	0	0
Minor	2.6 million €	1.3 million €	0.8 million €
Major	46 million €	20 million €	10 million €
Total Loss	33 million €	14 million €	6.5 million €

Off hire Costs

The Off-hire costs have been calculated via assessing number of fire incident related Off-hire days multiplied with the assumed charter rates for the 3 vessel types as also explained in the Cargosafe study report, see table below.

Ship Category	Twin Island	Single Island	Feeder
Ship Value (EUR)	80,000 €	40,000 €	20,000 €

For the 3 types of container vessels this gives the following Off-hire costs:

Ship Type/Damage Category	Off – hire Period (days)	Twin Island	Single Island	Feeder
Superficial	2	160,000 €	80,000 €	40,000 €
Minor	14	1.1 million €	560, 000 €	280,000 €
Major	180	14.4 million €	7.2 million €	3.6 million €
Total Loss	365	29.2 million €	14.6 million €	7.3 million €

Cargo and Waste Handling Costs

The Cargo and Waste handling costs typically incurs at one or several port locations after salvage operations and have thus been assessed as a fixed amount or percentage of the total cargo and box value onboard for the 3 vessel types per 4 different damage scenarios as explained in table below.

Ship Category	Superficial	Minor	Major	Total Loss
Damage cost ratio of total cargo and box value %	Fixed	2	8	10

For the 3 types of container vessels this gives the following Cargo and Waste handling costs:

Ship Type/Damage Category	Twin Island	Single Island	Feeder
Superficial	250,000 €	250,000 €	250,000 €
Minor	13 million €	5.5 million €	2.6 million €
Major	53 million €	22 million €	10.4 million €
Total Loss	66.2 million €	27.6 million €	13 million €

Investigation and legal services costs

The costs for post salvage operations inspections of vessel and cargo, as well as additional expenses for legal advisors used for subsequent court cases aimed at settling accountability, general average, insurance coverage for payments etc. have been estimated as a fixed amount per vessel type, but based on damage scenario, see table below.

Ship Type/Damage Category	Twin Island	Single Island	Feeder
Superficial	100,000 €	100,000 €	100,000 €
Minor	2 million €	2 million €	2 million €
Major	3 million €	3 million €	3 million €
Total Loss	5 million €	5 million €	5 million €

Total costs for Salvage Operations and all related services

Based on results obtained for the 4 main cost components of the model, the following overview of estimated total costs for salvage operations and related services coupled to the 4 damage scenarios and 3 vessel types has been developed, see table below:

Ship Type/Damage Category	Twin Island	Single Island	Feeder
Superficial	510,000 €	430,000 €	390,000 €
Minor	19 million €	9.3 million €	5.6 million €
Major	116.5 million €	52.5 million	27.4 million €
Total Loss	133.6 million €	61 million €	31.8 million €

The numbers in the table above are used in the CARGOSAFE study report.

6. Changes in Section 3.9.2.1 “Assumptions made on the three generic ships”.

Replace **Table 30.** Values used in consequence model for generic ships 1, 2, 3 (18000TEU, 7500TEU and 3500 TEU) Page 104 Explanation: Updated to match the latest version of the model.

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Table 30: Values used in consequence model for generic ships 1,2,3 (18000 TEU, 7500 TEU, 3500 TEU)

		Monetary assignment (in Euros)		
Ship Type		**Generic ship 1**	**Generic ship 2**	**Generic ship 3**
		Twin Island	**Single Island**	**Feeder**
TEU price		36,799 €	36,799 €	36,799 €
Qualitative ship damage categories	None	-	-	-
	Superficial	649,380 €	318,630 €	193,638 €
	Minor	3.9 million €	1.9 million €	1.2 million€
	Major	30 million €	14.6 million €	8.9 million €
	Total loss	130 million €	63.7 million €	38.7 million €

7. Changes in Section 3.10.2.2 “Results”

Replace Figure 60 and 61

Explanation: See item 3. Updated figures. Page 114

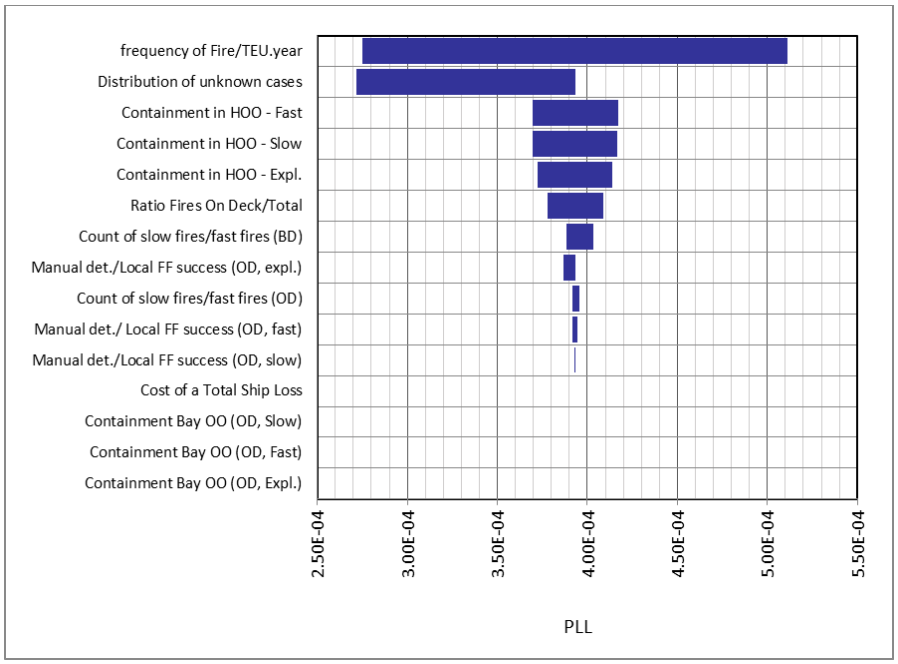

Figure 1: Tornado diagram - Effects on the reference PLL.

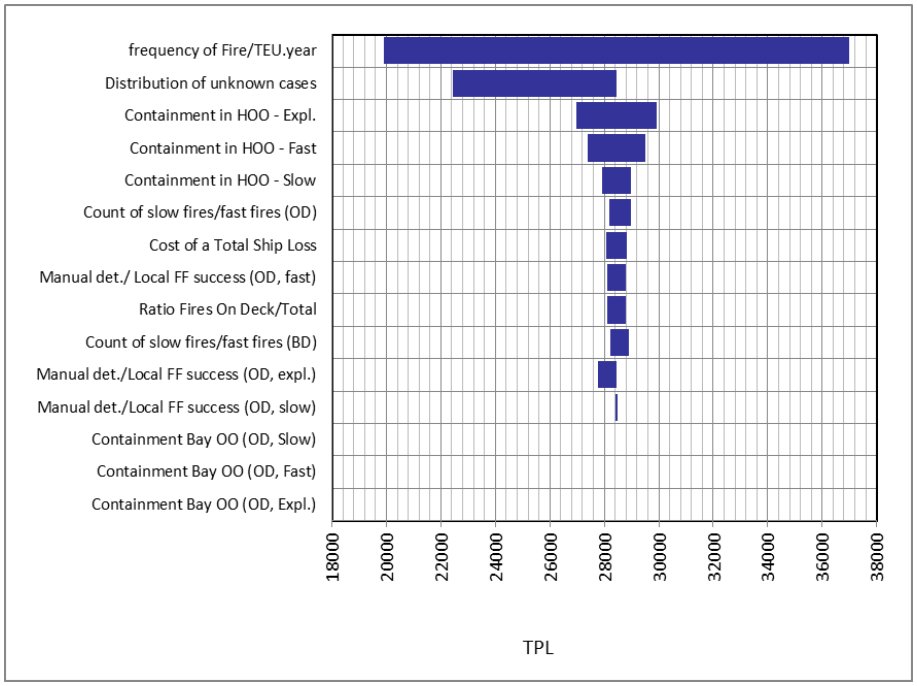

Figure 2: Tornado diagram - Effects on the reference TPL.

8. Changes in Section 6 “RECOMMENDATIONS FOR DECISION - MAKING”

Explanation: Improved the prioritization of the tables to avoid confusion.

Table 87 compiles the RCOs that were evaluated during the cost-effectiveness assessment.

Table 3: Compilation evaluated RCOs.

Layer of protection	RCO ID	Name	OD/BD
Prevention	P1	Container screening tool	OD/BD
	P4	Improved control of lashing	OD
Detection	D1	Optimizing current system	BD
	D2	Heat detection looking at individual container temperature rise	OD/BD
	D3	Fixed IR cameras. Coupled to a software solution to automate detection	OD
	D4	CCTV - AI - smoke detection	OD
	D5	Portable IR cameras for crew to enhance manual detection	OD/BD
Firefighting	F1	Increasing effectiveness of current CO2 system	BD
	F2	Improved manual firefighting tools for individual container breaching and firefighting	OD
	F3	Manual firefighting tools that increase reach	OD
	F4	Methods for unmanned fire fighting	OD
	F5	Water mist turbine	OD
Containment	C1	Active protection underneath hatch covers to protect from fire spread towards the deck	BD
	C2	Passive protection to protect from fire spread towards the deck	BD
	C3	On-deck container stack cooling/ containment system	OD
	C4	Flooding cargo hold to limited degree	BD

Below are tables organized for each generic ship. The RCOs that satisfy both GCAF and NCAF criteria are presented first. They are then sorted by GCAF, followed by NCAF. Lastly, they are prioritized based on the highest potential for life risk reduction (ΔPLL). RCOs highlighted in green are those with a BCR above 1 and those that meet the CAF criterion of 8.7M €

An important outcome is that the GCAF is never met except for portable IR camera on the generic ship 1. Although for some of the RCOs the NCAF is positive, most of them are higher than the criteria. In addition, the negative NCAF can be justified by the limited life threat of cargo fires and hence life risk reduction. According to the FSA guidelines (Appendix 7, section 1.3.4.) those RCOs with negative NCAF should be associated with their risk reduction capability (ΔPLL)

On the other hand, the benefit-cost ratio (BCR) is simply a mathematical formula that represents benefits in terms of costs avoided divided by RCO costs. It should be understood that BCR should not be the sole determining factor. Nevertheless, it was decided to retain RCOs with BCRs close to 1 to ensure that potentially relevant RCOs were not overlooked. Those identified during the sensitivity analysis are highlighted in yellow.

Finally, based on the sensitivity analysis, we can be confident that the RCOs presented here as cost-effective truly are. Even a significant increase in price would not alter this conclusion.

RCOs ending in an “R” are referring to the retrofitted version of the RCO with a different cost estimation.

Table 88 shows result for the Feeder. The values listed in Table 88 **should be also incorporated into Table 83**

Table 4: BCR-sorted RCOs for the Feeder (generic ship 3).

RCO	Initial Investment	Annual Cost	NPV	BCR	CBR	ΔPLL	GCAF	NCAF
F4	10,000 €	0 €	-281 €	0.972	1.029	3.16E-06	126.6E+6	3.6E+6
C2	184,150 €	0 €	-101,029 €	0.451	2.215	7.38E-05	99.8E+6	54.8E+6
C1	350,000 €	25,000 €	-760,991 €	0.038	26.205	3.72E-05	850.7E+6	818.3E+6
D2	85,440 €	2,500 €	-77,920 €	0.399	2.509	3.03E-05	171.0E+6	102.9E+6
P1	184,417 €	2,769 €	-203,086 €	0.129	7.725	1.93E-05	483.5E+6	420.9E+6
F1	500,000 €	22,500 €	-882,490 €	0.016	61.550	1.35E-05	2.7E+9	2.6E+9
D1	106,038 €	0 €	-98,214 €	0.074	13.553	7.73E-06	548.7E+6	508.2E+6
D1R	856,588 €	0 €	-848,764 €	0.009	109.483	7.73E-06	4.4E+9	4.4E+9
C3	321,408 €	3,214 €	-354,854 €	0.062	16.248	5.74E-06	2.6E+9	2.5E+9
F5	525,000 €	22,500 €	-904,626 €	0.019	52.876	5.67E-06	6.5E+9	6.4E+9
P4	0 €	1,680 €	-21,744 €	0.267	3.751	5.08E-06	233.4E+6	171.2E+6
F4R	283,916 €	0 €	-274,197 €	0.034	29.212	3.16E-06	3.6E+9	3.5E+9
D3	1,800,000 €	18,000 €	-2,104,167 €	0.006	157.046	2.84E-06	29.8E+9	29.6E+9
F3	15,000 €	0 €	-3,574 €	0.762	1.313	2.23E-06	269.1E+6	64.1E+6
F2	15,000 €	0 €	-7,026 €	0.532	1.881	1.57E-06	382.2E+6	179.0E+6
D5	1,520 €	243 €	-3,814 €	0.343	2.912	9.96E-07	233.3E+6	153.2E+6
D4	71,405 €	6,560 €	-184,414 €	0.015	67.876	5.77E-07	13.0E+9	12.8E+9

Analysis of the results of Table 88 makes it possible to draw the following conclusions for the Feeder (generic ship 3) regarding cost-effectiveness of the RCOs:

• From a GCAF perspective, none of the RCOs are attractive as they do not meet the CAF criterion of 8.7M €.

• From a NCAF perspective, F4 (3.6M €) is attractive as it meets the CAF criterion of 8.7M €.

• From an NPV and BCR perspective only F4 is close with an NPV of -281 € and BCR of 0.972. However, D5 is also near to being positive with an NPV of –3814 € and BCR of 0.343. Same as F3 with an NPV of -3574 € and BCR of 0.762.

• From Table 88 it should be observed that F4 becomes much less attractive for the retrofitting scenario where NPV and BCR falls visible to –274,197 € and a BCR of 0.034.

• From a life risk reduction potential, C2, C1 and D2 are the top RCOs more attractive to be implemented.

For the Feeder (generic ship 3) it is therefore mainly **F4**, however only **for newly built vessels** and optionally **D5** and **F3** which can be recommended for further implementation taking both loss of life and economic aspects into consideration.

Table 89 shows result for the Single Island. The values listed in the **Table 89 should be incorporated into Table 82**

Table 89: BCR-sorted RCOs for the Single Island (generic ship 2).

RCO	Initial Investment	Annual Cost	NPV	BCR	CBR	ΔPLL	GCAF	NCAF
C2	480,000 €	0 €	248,698 €	1.518	0.659	3.28E-04	58.5E+6	-30.3E+6
C1	735,000 €	52,500 €	-1,234,360 €	0.257	3.890	2.61E-04	254.6E+6	189.2E+6
D2	170,320 €	2,500 €	93,154 €	1.434	0.697	1.30E-04	66.0E+6	-28.7E+6
P1	391,389 €	5,877 €	-329,011 €	0.335	2.981	6.66E-05	297.4E+6	197.6E+6
F1	500,000 €	22,500 €	-800,858 €	0.107	9.324	6.22E-05	576.9E+6	515.0E+6
D1	225,167 €	0 €	-171,380 €	0.239	4.186	3.30E-05	272.9E+6	207.7E+6
D1R	1,818,917 €	0 €	-1,765,130 €	0.030	33.817	3.30E-05	2.2E+9	2.1E+9
D5	1,520 €	243 €	32,021 €	6.513	0.154	1.81E-05	12.8E+6	-70.8E+6
P4	0 €	4,987 €	-44,539 €	0.494	2.025	1.75E-05	201.2E+6	101.8E+6
C3	687,456 €	6,875 €	-692,648 €	0.144	6.964	1.59E-05	2.0E+9	1.7E+9
F5	525,000 €	22,500 €	-859,189 €	0.068	14.665	1.19E-05	3.1E+9	2.9E+9
D3	3,300,000 €	33,000 €	-3,817,891 €	0.017	60.219	8.34E-06	18.6E+9	18.3E+9
F4	10,000 €	0 €	24,875 €	3.488	0.287	6.59E-06	60.7E+6	-151.0E+6
F4R	490,535 €	0 €	-455,660 €	0.071	14.065	6.59E-06	3.0E+9	2.8E+9
F3	15,000 €	0 €	24,761 €	2.651	0.377	4.99E-06	120.2E+6	-198.5E+6
F2	15,000 €	0 €	12,873 €	1.858	0.538	3.51E-06	170.9E+6	-146.7E+6
D4	151,624 €	6,560 €	-248,049 €	0.072	13.825	2.50E-06	4.3E+9	4.0E+9

Analysis of the results of Table 89 makes it possible to draw the following conclusions for the Single Island (generic ship 2) regarding cost-effectiveness of the RCOs:

• None of the RCOs are attractive from a GCAF perspective as they do not meet the CAF criterion of 8.7M € though D5 comes close with a GCAF value of 12.8M €.

• From a NCAF perspective C2, D2, D5, F4, F3, F2 are all negative indicating either a large economic benefit, or a small risk reduction.

• From an NPV and BCR perspective, D5, F4, F3, F2, C2, D2 (in ranked order) are positive with NPV results between 12,873 and 248,698 € and BCR values at between 1.434 and 6.513.

• From Table 89, it can be observed that F4 becomes significantly less appealing in the retrofitting scenario, where the NPV drops to -455,660 € and the BCR reduces to 0.071.

• From a life risk reduction potential, C2, C1 and D2 are the top RCOs more attractive to be implemented.

For the Single Island (generic ship 2), from an economic perspective, 6 RCOs being D5, F4 (only new building), F3, F2, C2, D2 (in ranked order) are very attractive and should also be considered as recommendable for implementation.

Table 90 shows result for the Single Island. The values listed in **Table 90 should also be incorporated into Table 81.**

Table 90 shows result for the Twin Island (generic ship 1). Bold text highlights the proposed RCOs.

Table 90: BCR-sorted RCOs for the Twin Island (generic ship 1).

RCO	Initial Investment	Annual Cost	NPV	BCR	CBR	ΔPLL	GCAF	NCAF
D5	1,520 €	243 €	337,414 €	59.092	0.017	7.93E-05	2.9E+6	-170.2E+6
C1	805,000 €	57,500 €	3,721,257 €	3.045	0.328	1.34E-03	54.3E+6	-111.1E+6
C2	711,200 €	0 €	4,377,354 €	7.155	0.140	1.02E-03	27.9E+6	-171.7E+6
D2	458,240 €	2,500 €	1,254,789 €	3.498	0.286	3.95E-04	50.9E+6	-127.1E+6
F1	500,000 €	22,500 €	-205,808 €	0.771	1.298	2.20E-04	163.1E+6	37.4E+6
P1	938,967 €	14,099 €	-151,789 €	0.872	1.147	1.97E-04	241.2E+6	30.8E+6
D1	540,400 €	0 €	-155,300 €	0.713	1.403	1.10E-04	196.5E+6	56.5E+6
D1R	4,365,400 €	0 €	-3,980,300 €	0.088	11.336	1.10E-04	1.6E+9	1.4E+9
P4	0 €	7,360 €	141,246 €	2.087	0.479	5.18E-05	100.3E+6	-109.1E+6
F5	525,000 €	22,500 €	-474,313 €	0.486	2.059	3.82E-05	965.5E+6	496.7E+6
C3	1,116,000 €	11,160 €	-883,962 €	0.327	3.061	2.62E-05	2.0E+9	1.3E+9
F3	15,000 €	0 €	261,728 €	18.449	0.054	1.62E-05	37.0E+6	-646.2E+6
D3	3,600,000 €	36,000 €	-3,975,826 €	0.061	16.322	1.56E-05	10.9E+9	10.2E+9
F4	10,000 €	0 €	107,214 €	11.721	0.085	1.01E-05	39.6E+6	-424.6E+6
F4R	1,037,284 €	0 €	-920,070 €	0.113	8.849	1.01E-05	4.1E+9	3.6E+9
F2	15,000 €	0 €	77,521 €	6.168	0.162	5.43E-06	110.5E+6	-571.1E+6
D4	363,899 €	6,560 €	-401,823 €	0.162	6.162	4.68E-06	4.1E+9	3.4E+9

Analysis of the results of Table 90 makes it possible to draw the following conclusions for the Twin Island (generic ship 1) regarding cost-effectiveness of the RCOs:

• Only one of the RCOs, D5 is attractive from a GCAF perspective as it within a value of 2.9M € meets the CAF criterion of 8.7M € and no others are in the proximity of the criterion.

• From a NCAF perspective, D5, C1, C2, D2, P4, F3, F4, and F2 are all negative indicating that either for those eight RCOs the economic benefits are likely much bigger than required investment and running costs. Alternatively, for some of the eight RCO's, the high positive values could also be explained by RCOs having limited impact on fatality and PLL compared to history.

• From an NPV and BCR perspective, D5, F3, F4, C2, F2, D2, C1 and P4 (in ranked order) are positive with NPV results between 77,521 and 4,377,354 € and BCR values at between 2.087 and 59.092. P1 is also very close to being positive for calculated BCR, but less close for NPV values.

• From Table 90, it can be observed that F4 becomes less attractive in the retrofitting scenario, where the NPV drops noticeably to –920,070 € and the BCR falls to 0.113.

• From a life risk reduction potential, C1, C2 and D2 are the top RCOs more attractive to be implemented.

For the Twin Island (generic ship 1), only D5 can be recommended for further implementation from a strict loss of life perspective. However, from an economic viewpoint, eight other RCOs—namely D5, F3, F4 (for new builds only), C2, F2, D2, C1, and P4 (listed in order of ranking)—are highly attractive and should be considered for implementation.

9. Changes in Section 6.4 “Final conclusion and summary”

Replace Table 91. Summary of cost-effectiveness of all RCO’s for the three generic ships

Explanation: NCAF for the Feeder (3.6 M €) is attractive as it meets the CAF criterion of 8.7 M €

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Table 91: Summary of cost-effectiveness of all RCO’s for the generic ships

RCO ID	Description	Twin Island	Single Island	Feeder
P1	Container screening tool	Maybe	No	No
P4	Improved control of lashing	Yes	No	No
D1	Optimizing current smoke detection system	No	No	No
D1R	Optimizing current smoke detection system (retrofitting)	No	No	No
D2	Heat detection looking at individual container temperature rise	Yes	Yes	No
D3	Fixed IR cameras. Coupled to a software solution to automate detection	No	No	No
D4	CCTV - AI - smoke detection	No	No	No
D5	Portable IR cameras for crew to enhance manual detection	Yes	Yes	No
F1	Increasing effectiveness of current CO2 system	No	No	No
F2	Improved manual firefighting tools for individual container breaching and firefighting	Yes	Yes	No
F3	Manual firefighting tools that increase reach	Yes	Yes	No
F4	Methods for unmanned fire fighting	Yes	Yes	Yes
F4R	Methods for unmanned firefighting (retrofitting)	No	No	No
F5	Watermist canon	No	No	No
C1	Active protection underneath hatch covers to protect from fire spread towards the deck	Yes	No	No
C2	Passive protection to protect from fire spread towards the deck	Yes	Yes	No
C3	Fixed external container stack cooling system to stop spread between stacks	No	No	No

Add explanation paragraph on section 6.4. (Page 225)

Explanation: Include clarification for the recommended RCO's. The two additional paragraphs added to this section provide further clarification on the recommended RCOs. They go deeper into the evaluation and scope of the RCOs, explaining how both human impact and economic considerations were balanced during the assessment.

When evaluating the effectiveness of the RCOs, it's essential to account for both the potential impact on human life and the associated economic factors. The proposed solutions take both critical aspects into account, ensuring a thorough assessment. However, it's worth noting that, from an economic perspective, some RCOs can be implemented without substantial financial constraints.

To clarify, the RCOs assessed in this report are specific to the functions evaluated, including prevention, detection, firefighting, and containment. It's important to understand that the recommendations in this report do not cover other safety functions or potential benefits. For instance, monitoring temperature in a hold to optimize ventilation for feeders was not considered in this analysis and should not be inferred as one of the recommended RCOs.

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