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COVER NOTE

From:	Secretary-General of the European Commission, signed by Mr Jordi AYET PUIGARNAU, Director
date of receipt:	13 March 2019
To:	Mr Jeppe TRANHOLM-MIKKELSEN, Secretary-General of the Council of the European Union
No. Cion doc.:	SWD(2019) 109 final
Subject:	COMMISSION STAFF WORKING DOCUMENT For the Council Shipping Working Party IMO - Union submission to be submitted to the 101st session of the Committee on Maritime Safety (MSC 101) of the IMO in London from 5 – 14 June 2019 concerning a summary of the FIRESAFE I and II studies and their results as a Formal Safety Assessment (FSA)

Delegations will find attached document SWD(2019) 109 final.

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COMMISSION STAFF WORKING DOCUMENT

For the Council Shipping Working Party

IMO - Union submission to be submitted to the 101st session of the Committee on Maritime Safety (MSC 101) of the IMO in London from 5 – 14 June 2019 concerning a summary of the FIRESAFE I and II studies and their results as a Formal Safety Assessment (FSA)

COMMISSION STAFF WORKING DOCUMENT
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IMO - Union submission to be submitted to the 101st session of the Committee on Maritime Safety (MSC 101) of the IMO in London from 5 – 14 June 2019 concerning a summary of the FIRESAFE I and II studies and their results as a Formal Safety Assessment (FSA)

PURPOSE

The document in Annex contains a draft Union submission to the 101st session of the Committee on Maritime Safety (MSC 101) of the IMO, taking place in London from 5 – 14 June 2019, concerning a summary of the FIRESAFE I and II studies and their results as a Formal Safety Assessment (FSA). It is hereby submitted to the appropriate technical body of the Council for consideration with a view to its subsequent transmission to the IMO prior to the required deadline of 2 April 2019[1].

Article 6(2)(a)(i) of Directive 2009/45/EC applies SOLAS, as amended, to Class A passenger ships. Moreover, Directive 2009/45/EC, Annex I, Chapter II-2 Fire Protection, Detection and Extinction lays down various and extensive requirements for Class B, C and D passenger ships when engaged in domestic voyages and, in this context, also variously refers to SOLAS as amended. Therefore the said draft Union submission falls under EU exclusive competence[2].

[1] The submission of proposals or information papers to the IMO, on issues falling under external exclusive EU competence, are acts of external representation. Such submissions are to be made by an EU actor who can represent the Union externally under the Treaty, which for non-CFSP (Common Foreign and Security Policy) issues is the Commission or the EU Delegation in accordance with Article 17(1) TEU and Article 221 TFEU. IMO internal rules make such an arrangement absolutely possible as regards existing agenda and work programme items. This way of proceeding is in line with the General Arrangements for EU statements in multilateral organisations endorsed by COREPER on 24 October 2011.

[2] A formal EU position under Article 218(9) TFEU is to be established in due time should, as a result of the works to which the FIRESAFE I and II studies pertain, the IMO Marine Environment Protection Committee eventually be called upon to adopt an act having legal effects. The concept of '*acts having legal effects*' includes acts that have legal effects by virtue of the rules of international law governing the body in question. It also includes instruments that do not have a binding effect under international law, but that are '*capable of decisively influencing the content of the legislation adopted by the EU legislature*' (Case C-399/12 Germany v Council (OIV), ECLI:EU:C:2014:2258, paragraphs 61-64).

Maritime Safety Committee
101st session
Agenda item 17

MSC 101/17
2 April 2019
Original: ENGLISH

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FORMAL SAFETY ASSESSMENT

Firesafe I and II studies – FSA on fires on ro-ro decks of passenger ships

Submitted by the European Commission on behalf of the European Union

SUMMARY	
Executive summary:	This document provides a summary of the FIRESAFE I and II studies and their results as a FSA according to the standard reporting format
Strategic direction, if applicable:	
Output:	OW 8
Action to be taken:	Paragraph 6
Related documents:	SSE 4/19, FSI 21/5, SSE 2/INF.3, SSE 6/6/1, SSE 6/6/2, III 3/4/5

Introduction

1 The Maritime Safety Committee, at its ninety seventh session, agreed to the EU Member States and the European Commission proposed output concerning fires on ro-ro decks of passenger ships. The document SSE 6/6/2 by the European Union presented the main topics of a study, FIRESAFE II, to support this output. The study consisted of two main parts which followed the Formal Safety Assessment (FSA) methodology and two parts which were dedicated to testing. The two main parts of the study were intended to compile, in conjunction with the FIRESAFE I study (SSE 4/INF.6), a full FSA study on fire safety of ro-ro decks of passenger ships.

2 The structure of the FIRESAFE II study is provided in document SSE 6/6/2 while a summary of the main results of the FSA study are provided in the annex. All reports from the study can be downloaded at http://www.emsa.europa.eu/firesafe.html.

Summary of results of the study

3 The FSA study on investigating cost-efficient measures for reducing the risk from fires on ro-ro passenger ships demonstrated that:

.1 the Risk Control Options (RCOs) achieving the highest risk reduction in a cost-effective manner were:

- Regardless of the ship category:
  - Fire monitors on weather decks;
  - Robust connection boxes;
  - Combined heat and smoke and alarm system design and integration;
  - Alarm system design and integration (smoke);
  - IR camera; and
  - Improved markings/signage for wayfinding and localization.

- For Standard RoPax and Ferry RoPax:
  - Precondition for early activation of drencher system
  - CCTV and Remote control;
  - CCTV;
  - Remote control; and
  - Only ship cables.

- For Standard RoPax:
  - Safe distance

- For Ferry RoPax:
  - Safe distance (only for Newbuildings).

.2 In addition to the above RCOs, the following RCOs were found cost-effective and associated with a low cost: training for awareness, efficient activation routines, fresh water activation/flushing and only crew connections.

Proposal

4 Based on the results from the FSA review, it is foreseen that the proposed RCOs may be taken into account in the work of the currently ongoing agenda item under the SSE Sub-Committee. It should be noted that this might lead to changes not only to the Interim Guidelines that are being drafted under the FP Working/Correspondence Group, but also to amendments to SOLAS and relevant instruments and even for existing ships.

5 A summary of the complete FSA report, along with possible recommendations, is set out in the annex according to the standard reporting format of the FSA Guidelines (MSC-MEPC.2/Circ.12/Rev.2). If it is decided to review the FSA study by the FSA Expert Group, it is hereby also proposed that the Expert Group reports directly to the SSE Sub-Committee, since a relevant agenda item is already existing under its remit.

Action requested of the Sub-Committee

6 The Committee is invited to consider the information provided and take action as appropriate.

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Annex

1 TITLE

Formal Safety Assessment on fires on ro-ro decks of passenger ships (FIRESAFE II study)

2 SUMMARY

2.1 Executive summary

The FIRESAFE II study consisted of two main parts which followed the Formal Safety Assessment (FSA) methodology and two parts which were dedicated to testing, namely of alternative detection systems for open ro-ro spaces and weather decks, as well as for alternative fixed fire-extinguishing systems. The main parts of the study were intended to compile, in conjunction with the FIRESAFE I study, a full FSA study of ro-pax ships fire safety. The main topics of the FIRESAFE II study were detection, decision, containment and evacuation concerning the fire safety of ro-ro, special category and vehicle spaces, as well as a combined assessment (with FIRESAFE I) at the end of the study.

2.2 Actions to be taken

The type of action requested is a review of the FSA and in particular the RCOs that were found to be cost efficient and are listed in section 7 of this Annex and which are relevant to the open output currently under discussion at SSE 6. It should be noted that the cost efficiency was investigated separately for newbuildings and existing ships and for the different types of ship types presented below (3.3).

2.3 Related documents

All reports can be downloaded from http://www.emsa.europa.eu/firesafe.html

- WP1 Final Report, Detection and Decision;
- WP2 Final Report, Containment and Evacuation;
- WP2 Combined Assessment;
- WP3 Alternative fire extinguishing systems;
- WP4 Fire detection technologies for use in open ro-ro spaces and on weather decks
- FIRESAFE I report

3 DEFINITION OF THE PROBLEM

3.1 Definition of the problem to be assessed:

The focus of the study is on fires occurring on ro-ro decks of passenger ships. Both the analysis conducted by the Casualty Analysis Correspondence Group some years ago (FSI 21/5) but also an analysis of the European Maritime Safety Agency (EMSA) of more recent accidents have shown that the number of fires on ro-ro decks remains at high levels, including very serious accidents of which the NORMAN ATLANTIC and the SORRENTO are the most recent. Statistics on this issue present a compelling need to consider whether any practicable solutions could be found to reduce the risk posed by fires on ro-ro decks.

3.2 Reference to the regulation(s) affected by the proposal to be reviewed or developed (in an annex).

The SSE Subcommittee at its 4th session under the relevant agenda item (SSE 4/19, 13.9 and 13.10) endorsed five main tasks to be addressed under the review of SOLAS chapter II-2 and associated codes (prevention/ignition, detection and decision, extinguishment, containment; integrity of LSA and evacuation), while it also invited Members States and international organizations to submit relevant proposals for consideration at SSE 5. Furthermore, it endorsed that the work on review of SOLAS chapter II-2 and associated codes could potentially lead to the development of amendments to SOLAS chapters II-2 and III, the FSS and 2010 FTP Codes, the STCW Convention and Code, and relevant guidelines, and invited the Committee to agree with this view, which took place at MSC 98.

Having in mind the wide range of RCOs that were considered in the study and the wide area of application, the approved scope is deemed justified.

3.3 Definition of the generic model

To consider the diverse world fleet of RoPax ships in the study, three generic categories of ships were defined based on a lane meter to passenger capacity ratio:

- Ferry RoPax, represent RoPax ships or ferries with focus on carriage of passengers but which can also carry cargo similar to a Standard RoPax. These ships typically only have closed ro-ro spaces or mainly closed ro-ro spaces and a small weather deck;
- Standard RoPax, represent the RoPax ships with focus on both carriage of cargo and of passengers. These vessels typically have each of the three types of ro-ro spaces: closed ro-ro spaces, open ro-ro spaces and weather decks. The size of the weather deck/s is generally medium to large within this category; and
- Cargo RoPax, represent RoPax ships with focus on carriage of cargo and basically have a passenger capacity just enough to carry the number of drivers necessary to load the ro-ro spaces with accompanied trailers. These vessels typically have closed ro-ro spaces and large weather deck/s.

In this regard, only SOLAS compliant ships were of interest for the study. Therefore, the world fleet of ro-ro passenger ships were restricted to vessels:

- classed as Passenger/Ro-Ro Ship;
- engaged on international voyages or EU domestic class A;
- gross tonnage equal or greater than 1,000;
- with a build date on or after 01/01/1970;
- Froude number less than 0.51; and
- classed or having been classed by one the IACS members.

It should also be noted that environmental risk was not considered in the study.

4 BACKGROUND INFORMATION

4.1 Lessons learned from recently introduced measures to address similar problems.

Study by Germany / DNV-GL on Electric mobility (SSE 2/INF.3), SSE 6/6/1.

4.2 Casualty statistics concerning the problem under consideration including data analysis

The FIRESAFE II fleet is composed of 811 ships active during the period 2002-2016 leading to a total of 7001 shipyears over the period 2002 – 2016 (very slight increase over the years).

The average age of the fleet is 20 years old in 2016, with an average loss age of 32 years old, (and maximum age of 46 years old). The life expectancy (at delivery) over the period 2002-2016 was estimated to 39.2 years old.

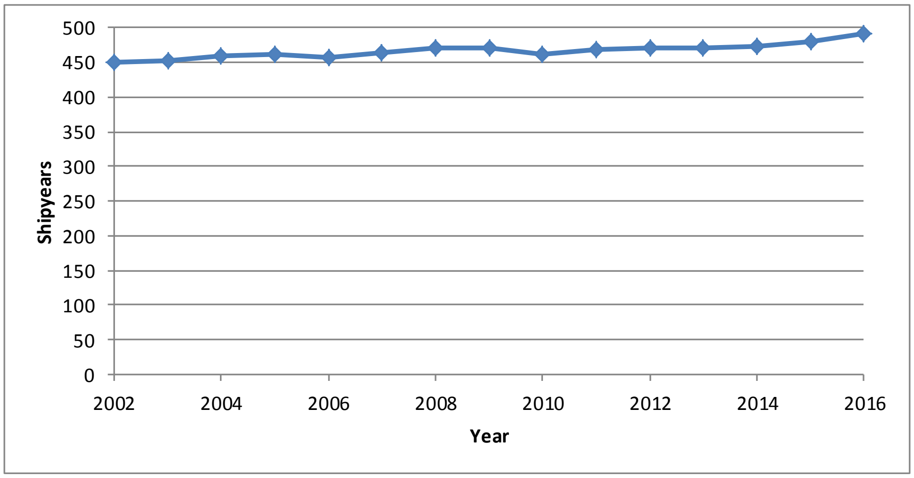

Figure 1: Number of shipyears per year for the FIRESAFE II fleet between 2002 and 2016

Source of data

The dataset used in this study was provided by EMSA. No other sources of data were used. Marinfo: Application developed by EMSA which combines data from four different commercial databases (Lloyds List Intelligence, IHS Maritime, Clarksons Research Services and AXSMarine).

Proportion of fires in ro-ro spaces

From 2002 to 2016, 132 fires were recorded[3], and among 30% of them (37 accidents) originated in a ro-ro space. This result is highly consistent with the findings from FIRESAFE.

Frequency of fires

Over the 15 year-period, the 37 fires in ro-ro spaces recorded lead to an average of 2.5 accidents[4] per year.

Taking into account the exposure time (7 001 shipyears between 2002 and 2016), the 15-year average accident frequency was estimated to 5.28E-03 fires in ro-ro spaces per shipyear ($CI_{90\%}$ [3.72E-03; 7.28E-03]). The annual accident frequency of fires in ro-ro spaces is shown in Figure 2.

3 Unless explicitly stated otherwise, this means “recorded in the database provided by EMSA”.

4 In the following, unless explicitly stated otherwise, “accident” means “fire in ro-ro spaces”.

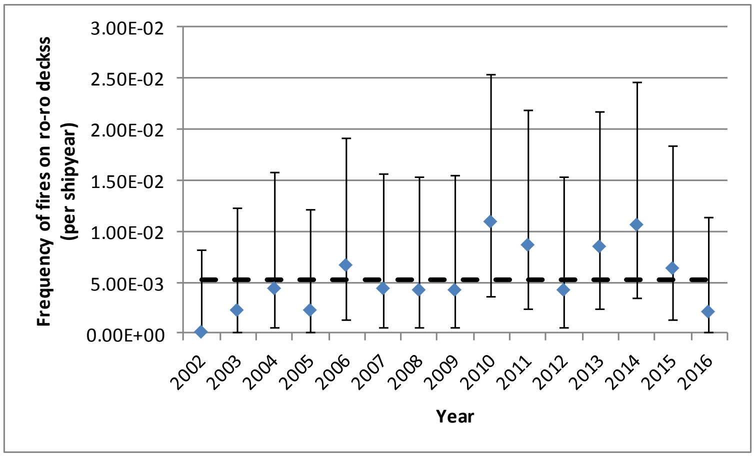

Figure 2: Annual accident frequency of fires in ro-ro spaces with 90% confidence interval between 2002 and 2016 and the 15-year average

Impact of ship age

The accident frequency per ship age at date of incident as shown in Figure 3 was estimated by normalizing the number of accidents for each age categories with the exposure time. As in the first study, it can be seen that a potential impact of ship age on the accident frequency cannot be ascertained. 90% of the fires in ro-ro spaces were originating from the cargo itself which could explain this finding.

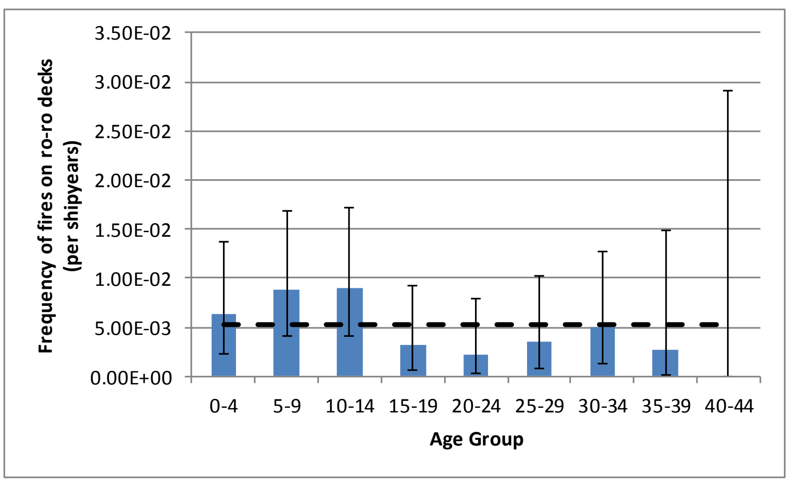

Figure 3: Accident frequency per age at date of incident and 90% confidence interval and average for the whole fleet at risk over the period 2002-2016

Impact of ship size

Figure 4 shows the impact of ship size on the accident frequency on the FIRESAFE II fleet over the period 2002-2016.

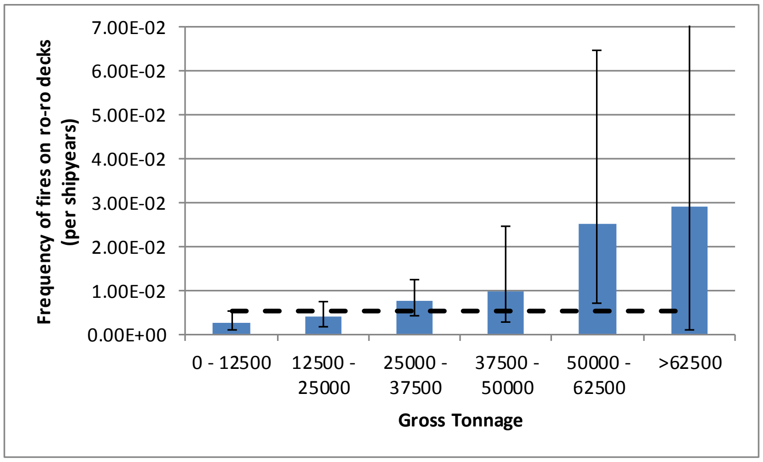

Figure 4: Frequency of fires in ro-ro spaces per size (GT) with 90% confidence interval between 2002 and 2015 and average for all categories

There seems to be an increasing trend for larger ships, as indicated in Figure 4. However, it must be noted that the number of shipyears for the size category (GT > 62 500) is very low (about 35 shipyears over the full period) to provide an accurate estimation of the accident frequency for that period, as clearly shown by the large confidence interval.

The confidence interval for the GT > 62 500 size segment was cut short to maintain the readability of the figure, the upper bound being at 2.6E-01 fires in ro-ro spaces per shipyear.

As mentioned during the analysis of the impact of ship age on the accident frequency, and based on the review of the accident reports, sources of most of the fires in ro-ro spaces were external to the ship itself, i.e. mainly due to cargo.

4.3 Any other sources of data and relevant limitations

N/A

5 METHOD OF WORK (maximum 3 pages)

5.1 Composition and expertise of those having performed each step of the FSA process and contact point of the coordinator of the FSA.

The FIRESAFE II study was performed following the FSA methodology described in the Revised Guidelines for FSA for use in the IMO rule-making process (MSC-MEPC.2/Circ.12/Rev.2) and was carried out with the common tools used in risk analysis described in these Guidelines.

This study was conducted by Bureau Veritas Marine & Offshore (class society), RISE Research Institutes of Sweden (research institute with fire test laboratories), and STENA (ship operator operating RoPax). Support was provided by a Human Factors team of RISE to address specific human element related issues.

The project team comprised personnel with expertise in particularly design, fire safety, human factors, risk analysis, operation and regulations for ro-ro passenger ships. In some specific cases the consortium used on an advisory level the expertise that resides within EMSA and the EU Member States for their input and feedback on some key stages (HAZID/ RCOs selection).

5.2 Description of how the assessment has been conducted in terms of organization of working groups and, method of decision-making in the group(s) that performed each step of the FSA process.

For the first step of the FSA methodology, both hazards that have materialized in the past and those that have not been experienced (yet) were identified through analytical and creative techniques.

Hazard Identification (HAZID) workshops were conducted in FIRESAFE and FIRESAFE II in order to identify the causes and effects of accidents and relevant hazards, in relation to each of the fire protection chain components considered. The HAZID team comprised personnel with expertise in particularly design, fire safety, human factors, risk analysis, operation and regulations for ro-ro passenger ships.

A spreadsheet was developed prior to the HAZID workshops, to guide the procedure and for documentation of results. The spreadsheet and the HAZID procedure was based on a Failure Mode and Effects Analysis (FMEA) procedure, which is commonly used in risk management.

Initially in each workshop, background information, technical elements and relevant regulations were identified and presented. Thereafter, ship conditions, systems, procedures etc. were considered to identify failure modes and resulting effects of failure. These were divided into the three types of ro-ro spaces, namely closed ro-ro space, open ro-ro space and weather deck. Associated risk control measures were also identified in relation to each failure mode and significant related comments were noted. This procedure was repeated, as long as failure modes could be identified.

Furthermore, prior to the FIRESAFE II study, a more extensive fire HAZID workshop with a more general focus on “ro-ro space fire safety” was commercially organized for Stena by RISE Fire Research in 2015. Participants in that HAZID workshop were four research scientists with expertise in risk management, fire safety engineering, fire hazard identification, vehicle fire cause investigation, maritime regulations, ship fire safety and ship surveying, as well as nine senior officers and fleet managers (masters, chief engineers and naval architect) selected for their competence and interest in RoPax fire safety issues. The results from that Fire HAZID were not made publicly available but by acceptance from Stena, the results related to detection were used to complement the results of the workshop organized within FIRESAFE II. Identified hazards and proposed RCMs from other projects were also incorporated as appropriate and the participants were also given the opportunity to make post-HAZID additions.

The purpose of risk analysis in step 2 of the FSA process, as described in MSC-MEPC.2/Circ.12/Rev.2, is to undertake a detailed investigation of the frequencies and consequences of identified accident scenarios. This is achieved by using suitable risk models built by means of standard techniques such as fault trees and event trees. The generic methodology applied during risk analysis consists of linking fault trees with the event trees to represent full accident scenarios.

In particular, the main fire risk model (event tree) identified the pivotal events which affect the outcome of different fire scenarios in ro-ro spaces and had been developed in such a way that it could be used in future investigations into specific nodes beyond the scope of the first FIRESAFE study. The main fire risk model was subsequently updated in the first part of FIRESAFE II where a review and update of the model was conducted, leading to the introduction of dedicated branches in the event tree for Detection, First response, and Decision as well as Containment and Evacuation (or fire integrity of evacuation routes and LSAs).

The main fire risk model and the associated sub-models were developed in such a way that it is possible to assess, in quantitative values, the consequences of additional preventing and mitigating measures addressing the risks of containment and evacuation failures.

For Detection, Decision, Suppression, and Containment, dedicated fault trees were developed focusing on the main fire hazards identified during the HAZID. The trees were quantified to gain an understanding of the impacts on risks and to investigate in further detail the important causes and initiating events of the accident scenarios identified. This allowed quantification of the contributing failures as well as to calculate the overall failure rate. In order to consider the different types of ro-ro spaces, different trees were developed and quantified by investigation of available failure data, fire simulations and expert judgement, in case none of the previous options were available. For Evacuation, a sub-risk model was developed for investigating the impact on the safety distance to protect stowage areas, embarkation stations and LSA from fire.

In order to populate the branches in the fault tree, and to remove the judgemental aspects of expert judgement, when expert judgement was used, the 'expert information' approach was followed, where the experts are asked for information and evidence rather than for their opinions. Therefore, fire specialists, class society representatives and both on-shore and on-board personnel from ship operators were involved to provide information with a view of quantifying the tree.

For each of the parts, a range of Risk Control Measures (RCM) was identified based on the hazards identified in previous steps and on proposals of RCMs identified in former projects. The RCMs were ranked by experts with regard to risk reduction potential and estimated costs. Some of these RCMs were considered as “low hanging fruit”, meaning RCMs with low estimated cost that do not necessitate further evaluation and which can be recommended as voluntary measures to reduce the risk.

Among the RCMs, Risk Control Options (RCOs) were selected for further quantitative cost-effectiveness analysis, based on their perceived cost-effectiveness, Technology Readiness Level (TRL), and availability: 3 for Detection, 3 for Decision, 2 for Containment, 1 for Evacuation.

The estimated risk reduction effect of the above RCOs were quantified by investigation of available failure data, fire simulations and expert judgement, in case none of the previous options were available. By applying each of the RCOs to the risk model (event tree), the risk reduction of all selected RCOs was calculated.

Costs for the implementation of these RCOs were estimated. Technical items available on the market were as far as possible quantified by system supplier offers. In addition, cost estimations were based on existing costs for material from ship operator’s internal projects, specifications, reconstructions, etc. The main component systems of each RCO were identified and respective costs were estimated. For any operational RCOs, manning and training costs were used based on ship operator’s experience. Other cost items affecting for example operations were included in the quantification when necessary.

Combined Assessment

The main fire risk model developed in FIRESAFE and upgraded in FIRESAFE II was consolidated with all the fault trees and sub-risk models that were previously developed with an aim to analytically investigate each of the fire protection chain components separately (namely Ignition, Detection, First Response, Decision, Extinguishment, Containment and Evacuation).

The Potential Loss of Life (PLL) for the three ship categories considered was estimated on the basis of the consolidated main fire risk model.

A review of the RCOs investigated in FIRESAFE and FIRESAFE II was made to identify and quantify effects on other parts of the main fire risk model than that for which they were identified, with a view to conduct a combined cost-effectiveness assessment.

The comprehensive quantifications of the RCOs were integrated into the consolidated main fire risk model, from which effects on the overall risk could be calculated, thereby providing the benefit part of the cost-effectiveness assessment.

Thereafter, the costs associated with the implementation of the RCOs, estimated in FIRESAFE and FIRESAFE II, were recapitulated. However, the costs for the RCOs Electrical fire and Suppression, were only estimated for Standard RoPax in FIRESAFE and were hence necessary to derive also for Cargo and Ferry RoPax.

Based on the overall risk reductions and costs of the RCOs, the combined assessment was conducted with estimations of the Gross Cost of Averting a Fatality (GCAF) and Net Cost of Averting a Fatality (NCAF) for each RCO.

Testing parts of FIRESAFE II (WP3 & WP4)

It should be noted that both of these parts of FIRESAFE II were not considered in the combined assessment and the cost effectiveness analysis that was performed in each of them should be seen as a standalone document. More specifically WP3 on alternative fire extinguishing means did not identify any cost effective RCOs, while on the contrary WP4 on alternative detection systems found both systems that were tested to be cost effective. The work on this part of the study was based on the risk analysis that was performed in the main detection part of the study (i.e. the same fault tree models were used), while the expected risk reduction of the RCOs was quantified based on the experimental tests and the costs were evaluated separately. Therefore, the results of this part of the study should also be considered in the review as a FSA.

5.3 Start and finish date of the assessment.

In June 2016, EMSA initiated the first FIRESAFE study in order to investigate cost-efficient measures for reducing the risk from fires on ro-ro spaces with a focus on electrical fire as ignition source as well as fire extinguishing failure. Finish date: December 2016

In October 2017, following the progress of the first report, EMSA initiated a second study (FIRESAFE II) to investigate risk control options in relation to detection and decision as well as containment and evacuation, following a ro-ro space fire incident on any ro-ro passenger ship. Finish date: December 2018.

6 DESCRIPTION OF THE RESULTS ACHIEVED IN EACH STEP

STEP 1 – HAZARD IDENTIFICATION

For the detection part, some notable results drawn from the hazard identification were as follows:

- The detection system is often deactivated during loading and discharging, as well as maintenance operations. This often implies the deactivation of many or all ro-ro spaces.
- It is difficult to detect the fire at its early stage if the fire develops inside cargo or a vehicle.

- The environment in ro-ro spaces is quite harsh and it is not uncommon that dirt, salt, exhaust fumes, etc. clog the detectors.
- The detection system alarm panel can be illogical (confusion regarding the detection of frame number and section, drencher section, CCTV numbering, etc.) which could imply delayed first response and delayed extinguishing system activation.
- No detection system is required for weather deck.
- The frequency of fire patrols is undefined and generally quite low.
- The accessibility within ro-ro spaces is very limited, which makes manual detection and fire localization difficult.
- Many false alarms reduce the motivation of crew to quickly respond to the alarms.

Notable hazards identified for decision making when activating the extinguishing systems included the following:

- alarm system management (e.g. information presentation, coherence, noise levels);
- runner deployment (e.g. speed of deployment);
- way finding, localization and relevant support (e.g. familiarity, markings, signage);
- assembly of key decision-makers (e.g. availability);
- resource management on the bridge (e.g. competing goals/processes, fire management in relation to regular operations);
- drencher activation mandate (including hierarchy, blame culture);
- assessment of fire characteristics, environment and fire spread;
- ventilation management (smoke removal vs. supply of more oxygen to the fire);
- maintaining knowledge and competence (e.g. realism in training); and
- 10 communication issues (among bridge, fire scene, drencher station, engine room).

For the containment part, some notable results from the hazard identification were:

- Side openings were considered a major hazard for fire and smoke spread to Life Saving Appliances (LSAs), ventilation inlets, decks above, but also end openings pose a significant hazard;
- Openings provide oxygen to the fire;
- A major concern with ro-ro space fires is that the space is not sub-divided, meaning that an uncontrolled ro-ro space fire may involve the whole length of the ship. The fire will quickly grow intense and could last for a very long time (days);
- On general ro-ro cargo ships, fire insulation (A-30) is required between decks, but this is not required on RoPax ships (except every 10 meters in height). Without insulation, fire vertical spread after about 10 minutes is possible (without extinguishing system activated);
- Fire spread to weather deck, due to flame spread though openings or heat transfer through the deck, is difficult to avoid due to lack of fire integrity and limited possibilities for management (only manual efforts, limited equipment, accessibility problems, etc.). Fire spread to weather deck is associated with high risk since there are no fixed means for extinguishment and the accessibility for safe manual firefighting is limited, which gives a high probability of an uncontrolled fire;

- Smoke spread from the ro-ro space to the accommodation part of the ship is a major concern and it is difficult to achieve an over pressure in all spaces adjacent to a ro-ro space; and
- Doors to the ro-ro space are generally not smoke tight, since this is not tested in accordance with the Fire Test Procedure (FTP) Code.

For the evacuation part, some notable results from the hazard identification were:

- Side openings were considered a major hazard for fire and smoke spread to LSA, but also end openings pose a significant hazard;
- Smoke may spread from side openings and ventilation outlets and affect the possibilities for using LSA, escape routes, embarkation stations, etc.;
- A fire in ro-ro space may block the use of LSA by hindering embarkation or deployment, burning guiding ropes, etc.;
- Many critical cables run through the ro-ro space and fire deterioration may cause loss of power, navigation impossibility, black out, etc., regardless of the current provisions;
- Heat spread to escape routes and embarkation stations is critical, in particular if the use of LSA is hindered and since a ro-ro space fire can be very intense and long-lasting;
- It is seldom possible to provide of a secondary means of conventional disembarkation of the ship (not considering use of LSA) when berthing a foreign harbour (where gangways are not usable). Evacuation through the stern ramp may not be possible due to fire; and
- Passengers are generally not allowed in the ro-ro space before the ship is alongside, but if this occurs, fire in a ro-ro space full of passengers is a worst possible evacuation scenario.

From the initial workshop that was conducted as mentioned prior to the FIRESAFE I study, the following items were extracted regarding ignition hazards:

- Reefer unit;
- Conventional vehicle (truck, bus, car);
- Special vehicle (tractor, wheel loader, sky lift, process machinery, forest vehicle/rebuild truck, forklift, military vehicle, recreational vehicle, etc.);
- New energy carriers (vehicles with CNG, methanol, hydrogen fuel-cell, battery, LNG/CNG, etc.);
- Dangerous goods;
- Palletized goods (paper rolls, paper pulp, fibre boards, cardboard boxes, etc.);
- Ship equipment and activity (connection boxes for reefers, transformers for reefers, lighting, hoist able decks/hydraulics, welding/hot works, hoisting operations close to ro-ro space other equipment and activity); and
- Unsolicited activity (campers, stowaways, arson, etc.).

Each of these categories of fire origins were first considered with regards to fire causes. When it comes to the cargo units, fire is generally caused by electrical fault, mechanical overheating, leakage of easily flammable substance or chemical reaction, which were used as leading factors in identifying fire causes. Each fire cause was then connected to potential challenges or failures which could be the reason for the fire cause. Thereafter potential safety measures were identified for each challenge. Then potential failures/challenges and safety measures were identified for the next fire cause. A field was also provided for comments regarding each fire cause.

STEP 2 – RISK ANALYSIS

The generic methodology applied during the risk analysis of FIRESAFE II consisted of linking fault trees with the event trees to represent full accident scenarios. This methodology was acknowledged in document III 3/4/5 (IMO, 2016) and used in the FIRESAFE study where risk models (one event tree, two "fault trees") were developed to investigate the topics Electrical Fires as ignition risk and Fire Extinguishing Failure.

In particular, the main fire risk model (event tree) identified the pivotal events which affect the outcome of different fire in ro-ro space scenarios and had been developed in such a way that it could be used in future investigations into specific nodes that were not within the scope of the first FIRESAFE study.

Means for early detection as well as the decision making and operations involved in extinguishing system activation were not investigated in detail in FIRESAFE. These aspects were then assessed and considered in the same node of the risk model, namely early decision for activation. However, in this study, the node was analytically investigated and separated into its two main components, detection and decision. This led to the development of a formal definition of what was considered as an early or late detection.

Based on these definitions and prior to the in-depth analysis of detection and decision failures, a review and update of the main fire risk model was conducted, leading to the introduction of dedicated branches in the main fire risk model event tree for Detection, First response, and Decision. The updated main fire risk model is depicted in Figure 5.

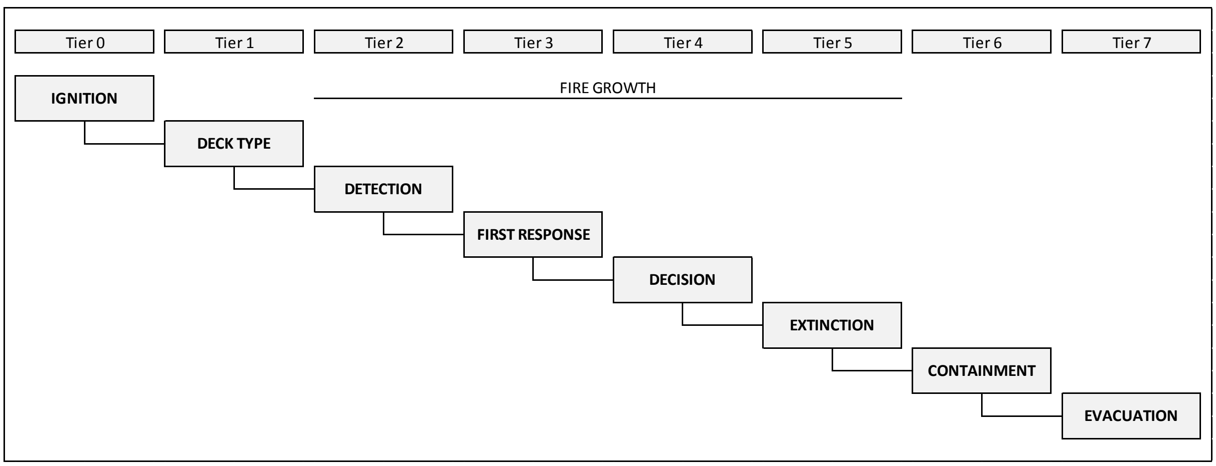

Figure 5 - Updated chain of events for FIRESAFE II

The main fire risk model and the associated sub-models were developed in such a way that it is possible to assess, in quantitative values, the consequences of additional preventing and mitigating measures addressing the risks of detection and decision failures.

Dedicated fault trees were developed focusing on the main hazards identified during the HAZID. The trees were quantified to gain an understanding of the impacts on risks and to investigate in further details the important causes and initiating events of the accident scenarios identified. This allowed quantification of the contributing failures as well as to calculate the overall detection failure rate. In order to consider the different types of ro-ro spaces, different trees were developed and quantified by investigation of available failure data, fire simulations, and expert judgement, in case none of the previous options were available. Similarly, fault trees for decision failure were developed and quantified through dedicated human-element techniques.

In addition, dedicated fault trees were developed for each generic ship (*Cargo RoPax*, *Standard RoPax* and *Ferry RoPax*) and the potential differences between Newbuildings and Existing ships were taken into account in the detection and decision fault trees. This led to the development of 6 different risk models (*Cargo RoPax Newbuildings*, *Cargo RoPax Existing ships*, *Standard RoPax Newbuildings*, *Standard RoPax Existing ships*, *Ferry RoPax Newbuildings*, *Ferry RoPax Existing ships*). The structure of the trees is identical but the quantification differs.

Altogether, the consolidated main fire risk model for the *Standard RoPax* (used as an example) consists of:

- The main event tree;
- One “fault tree” for the Ignition risk;
- Three fault trees for Detection (considering separately closed ro-ro spaces, open ro-ro spaces and weather decks);
- Four fault trees for Decision (focusing on decision following an early detection and decision following a late detection, separating the closed and open ro-ro spaces fires where fixed detection systems are available from the weather deck case);
- Four fault trees for Suppression (considering the suppression of a fire in a closed ro-ro space following an early decision and following a late decision, and the suppression of a fire in an open ro-ro space taking into account the decision time);
- Six fault tree for Containment (for the following cases: Suppressed fire in a closed ro-ro space, Unsuppressed fire in a closed ro-ro space, Suppressed fire in an open ro-ro spaces, Unsuppressed fire in an open ro-ro space, Suppressed fire in a weather deck, Unsuppressed fire in a weather deck)
- Six sub-risk models for Evacuation (uncontained suppressed fire and uncontained unsuppressed fire for fires in a closed ro-ro space, in an open ro-ro space, and on a weather deck).

STEP 3 – RISK CONTROL OPTIONS:

For the detection part, a range of RCMs was identified based on the hazards identified in previous steps and on proposals of RCMs identified in former projects. All the measures presumed an existing fire and were classified as mitigating, rather than preventive. The RCMs were ranked by experts with regard to risk reduction potential and estimated costs. Some of these RCMs were considered as “low hanging fruit”, meaning RCMs with low estimated cost that do not necessitate further evaluation and which can be recommended as voluntary measures to reduce the risk.

Based on the ranking and on the high-risk areas needing control in the fault tree, the RCMs with the highest potential were judged to be:

- Combined smoke and heat detection;
- Fibre optic linear heat detection (for open and closed ro-ro spaces);
- Ban / closure of side (Portside & Starboard) openings (open ro-ro spaces);
- Increased frequency of fire patrols;
- CCTV covering all decks;

- Thermal imaging cameras on weather decks;
- Flame detection on weather decks;
- Better addressability;
- Detector drone or camera on rail; and
- Additional detection means in Alternatively Fuelled Vehicles areas.

Three of the above RCMs were selected as RCOs for further quantitative cost-effectiveness analysis, based on their perceived cost-effectiveness, Technology Readiness Level (TRL), and availability:

- Combined smoke and heat detection: A review of the regulations and common practices showed that smoke detection is often the only means for fire detection used in ro-ro spaces. However, the review of previous accidents and the HAZID showed that heat detection could provide a way to detect some types of fire earlier and an alternative way of detecting a fire when smoke detectors are deactivated during loading and discharging of the decks. Combined point heat and smoke detectors were investigated to replace conventional smoke detectors;
- Ban / closure of side (Portside & Starboard) openings (open ro-ro spaces): Heat and smoke movements are affected by the airflow and hence by the gusts coming from the side openings. This results in increased detection times, and in case the fire is close to an opening it can remain unnoticed for a long time. Closing the side openings of open ro-ro spaces was investigated for existing ships and the ban of open ro-ro spaces was considered for newbuildings; and
- Increased frequency of fire patrols: Many fires are caused due to electrical problems, which often means overheated components or cables and a long incipient phase with smouldering fire. These may produce too little smoke to be detected by the smoke detectors. However, if passing through the space, fire patrols are more likely to give early detection of incipient fires compared to automatic fire detection systems. An increased frequency of fire patrols would imply an increased probability of a patrol passing the fire during the incipient phase and thus a higher probability of early detection. A half-hour interval between fire patrols was investigated in this study.

For the decision part, the hazards identified in previous steps and feedback collected from crew members revealed a number of conditions that may have profound impacts on early decision of extinguishing system activation. A wide range of RCMs was listed and this list was narrowed down to focus on the RCMs that are directly related to decision-making, as defined in FIRESAFE II. All the measures that have a too low TRL were discarded before the preliminary assessment and the measures left were structured into 6 realistic and self-sufficient RCMs:

- Alarm System Design & Integration;
- Improved markings/signage for way-finding and localization;
- Technical aids for fire identification and monitoring;
- CCTV system for fire identification and monitoring;
- Spacing of cargo for accessibility; and
- Preconditions for Early Activation of Drencher System.

These RCMs were ranked by experts with regard to risk reduction potential and estimated costs. Based, on this ranking, three RCOs were selected for further quantitative cost-effectiveness analysis:

- Alarm System Design & Integration: Reviews and interviews made within FIRESAFE II have shown that alarm systems and their interfaces are often lacking both in terms of the information they offer and how this information is presented to the user. A lack of relevant and immediately accessible information can cause severe delays in decision-making, allowing the fire to expand, thereby creating an even more difficult operative situation. This RCO considers an alarm system that fully supports fire incident decision-making, as well as other resources on the bridge relevant for fire-related decision-making designed to provide immediate, precise and accessible information to support the localisation of a fire;
- Improved markings/signage for way-finding and localization: A common response in the event of a fire alarm is to send a runner to the point of detection with the task of confirming or disconfirming the existence of a fire. Crew familiarization plays a part in this task, as well as the tightly packed ro-ro space environment. Furthermore, given that the situation might be stressful, runners may sometimes have difficulties in determining their exact location, which is important information to the bridge e.g. for drencher activation. This RCO investigates the impact of improved signage and markings in the ro-ro space supporting wayfinding and orientation in case of fire. They shall be designed for easy identification and interpretation by a variety of users representing normal individual variations; and
- Preconditions for Early Activation of Drencher System: Studies within FIRESAFE II have shown that there will often be a reluctance towards drencher activation among the crew, either because of a lack of decision mandate, unfamiliarity with the drencher system and drencher room environment, or fear of any negative consequences that could be the result of faulty activation. This RCO consists in the inclusion of the early activation of the drencher system in fire management procedures while also ensuring that a large portion of the crew has the knowledge and mandate for drencher activation, without fear of negative consequences for the individual crewmember.

Similarly to the detection part, the RCMs with the highest potential for the containment part were judged to be:

- Ban/Closure of side and end openings;
- Requirement for fire insulation (at least) A-30 instead of A-0 between ro-ro decks;
- Implementation of new test and requirement for enhanced smoke-tight A-60 divisions for ro-ro space boundaries;
- Fire monitors on weather deck;
- Subdivision between ro-ro space without openings and space with openings;
- Closure of side openings on ro-ro spaces; and
- Increased fire insulation for ro-ro space boundaries, e.g. A-180 towards accommodation areas.

Two of the above RCMs were selected as RCOs for further quantitative cost-effectiveness analysis, based on their perceived cost-effectiveness, Technology Readiness Level (TRL), and availability:

- Ban/closure of side & end openings: From a containment point of view, the main benefit of fewer openings is to avoid smoke and flames escaping from the fire enclosure, preventing propagation of the fire to spaces above the opening and harmful exposure to smoke. Both open and closed ro-ro spaces have openings that could be closed. Ro-ro spaces are defined as closed also if there is an opening at one end and side openings are less than 10% of the total area of the space sides. (SOLAS II-2/3.12). This risk control measure implies to forbid open ro-ro spaces on new ships and to reduce openings (including aft openings) in general as far as practicable; and

- Fixed fire-extinguishing systems (e.g. fire monitors) on weather deck: Weather deck is fairly unprotected both with regard to fire prevention (fire spread) and fire extinguishment. In case of a fire in the ro-ro space underneath, fire monitors could prevent flame spread through openings or heat spread through the un-insulated deck. In a case of a fire on weather deck, the use of fire monitors may extinguish or avoid propagation of the fire by reducing the amount of radiation from flames. This RCO implies that weather deck on ro-ro passenger ships shall be provided fixed fire protection arrangements (here fire monitors) for the purpose of containing a fire in the space/area of origin.

Regarding the failure of evacuation the main issue addressed was related to SOLAS Ch. II-2, Reg. 20.3.1.5: “Permanent openings in the side plating, the ends or deckhead of the space shall be so situated that a fire in the cargo space does not endanger stowage areas and embarkation stations for survival craft and accommodation spaces, service spaces and control stations in superstructures and deckhouses above the cargo spaces.” Based on simulations, the safe distance and arrangement of such openings were estimated. Although other means of failure of evacuation following a fire on a ro-ro deck were also identified, the focus of the study was that of protection of stowage areas, embarkation stations and LSA failure due to heat but not LSA failure due to intrinsic or environmental issues.

Several design solutions were investigated to achieve the RCO Safe distance on the Standard RoPax and Ferry RoPax, on which the LSAs were within the hazardous zone. Although the stowage areas, embarkation stations and LSAs were located outside of this zone on the Cargo RoPax, the closure of the aft opening was investigated to identify whether the safety level on this ship could be improved in a cost-effective manner.

Regarding the two parts where RCOs were drawn from the FIRESAFE I study, a wide selection of RCOs was initially done in three sessions with RISE, BV, STENA experts and EMSA. Six RCOs were then selected for quantitatively analysis in the risk models for the risk of electrical fire and six for drencher failure. The selected RCOs were as follows on the Ignition part:

- Robust connection boxes
- Only ship cables
- IR camera
- Training for awareness
- Only crew connections
- Cable reeling drums

And on the Suppression part:

- Remote control
- Rolling shutters
- Efficient activation routines
- Fresh water activation/flushing
- CCTV

- CCTV + Remote control

Regarding the part on the alternative detection systems on weather decks and open ro-ro decks, since it was focussing on a very specific problem (whether detection can be done cost effectively on these decks), there were nine identified technologies (RCOs), seven of which were further evaluated and their expected efficiency was discussed in terms of activation time and sensitivity to weather conditions, loading conditions and deck configuration:

- Fibre optic linear heat detection;
- Aspirating smoke detection;
- Gas detection in combination with ASD;
- Video detection: Smoke or combined smoke and flame detection;
- Video detection: Thermal imaging camera;
- Video detection: Flame video detection; and
- Flame detection.

The evaluation of activation time was primarily based on a literature review of performed detection system tests. Based on the theoretical evaluation of the identified systems, a selection process was carried out to select two alternative detection systems to be tested for open ro-ro space and weather deck. The process was based on a decision-support matrix and resulted in the selection of Fibre Optic Linear Heat detection for the open ro-ro space, and thermal imaging camera detection for the weather deck.

In terms of risk reduction, Figure 6 shows the relative risk reduction in terms of Potential Loss of Life (PLL) for newbuildings following the combined assessment of the study, while Figure 7 provides the results of the risk reduction for newbuildings of the two selected detection systems after the performance of the relevant tests.

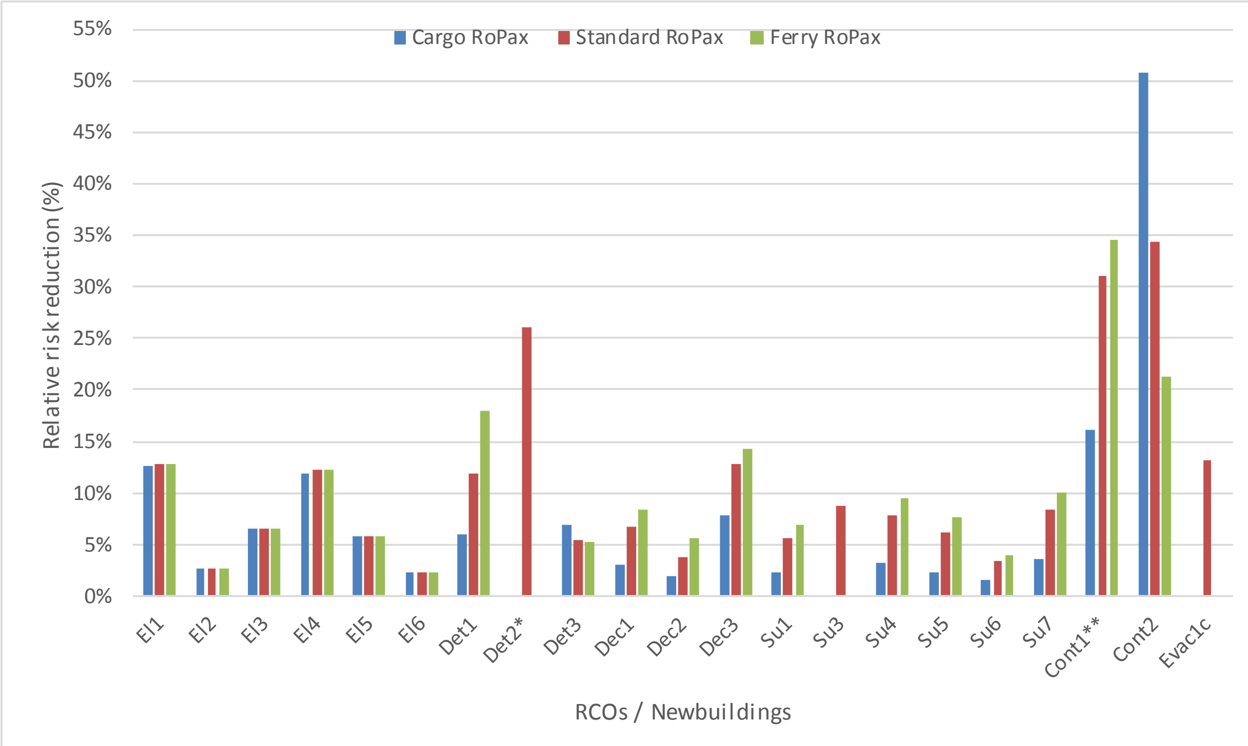

Figure 6 - Combined Relative Risk Reduction of RCOs investigated in FIRESAFE and FIRESAFE II for NB

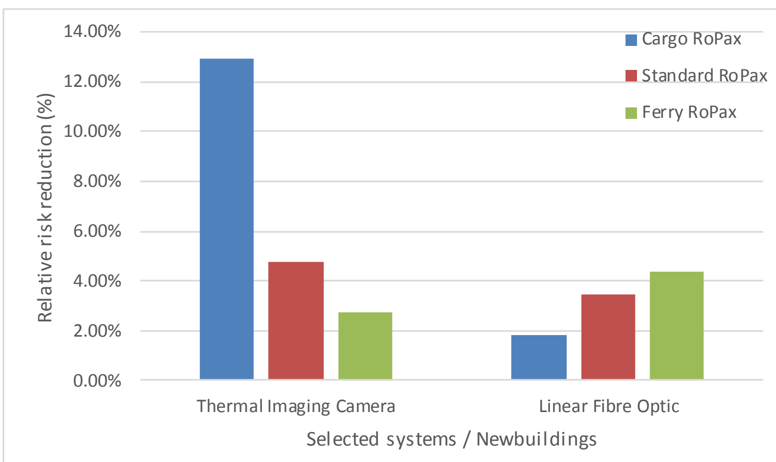

Figure 7 - Relative Risk Reduction of the two selected systems on NB

STEP 4 – COST-BENEFIT ASSESSMENT

Cost-effectiveness criteria

In the FIRESAFE I study, 6 913 600€ was selected as the CAF criterion. This value ($7.45m converted in Euro with the November 2016 exchange rate) was calculated by use of the formula based on the Life Quality Index (LQI) during the GOALDS study (IMO, 2012). This criterion had been used in the FSA for ro-ro and ro-pax ships regarding the transport of electrically powered vehicles and vehicles with refrigeration units carried out in 2016 (IMO, 2016).

If updated according to the average risk free rate of return of 5%, and taking a value of preventing a fatality (VPF) of $3m in 1998 as a basis, as provided in the FSA Guidelines, the VPF in 2017 is estimated to $7.58m (6.52m€). If updated according to the LQI formula with the GDP per capita and life expectancy at birth in 2017 from OECD stats (OECD, 2018) and portion of life spent in economic production of 0.1, the VPF in 2017 is estimated to $7.96m (6.85m€).

For consistency with the previous studies on the topic and taking into account the values updated with the above-mentioned methods, it is decided to use 7 000 000€ as the criterion in FIRESAFE II.

Assumptions

The expected lifetime (T) of a RoPax was set to 40 years (which correspond to the life expectancy at delivery calculated in the section Analysis of the FIRESAFE II Fleet). As identified in GOALDS (IMO, 2012), "most owners will use a shorter investment period for a new ship; however, the costs are to be seen from the society's point of view. Therefore, the investment time will be equal to the ship's expected lifetime." This value was used to calculate the reduced risk in terms of fatalities averted:

($\Delta Risk = \Delta PLL * T$)

The average age of the fleet was estimated to 20 years old, this was considered in the calculation of the cost effectiveness for existing ships.

The delta cost and benefits were calculated in Net Present Value (NPV) with a discount rate of 3.5% for the period of years 1 – 30 and 3.0% for the period of years 31 – 40 (HM Treasury, 2018).

Cost benefit assessment

In the combined assessment, a review of the RCOs investigated in FIRESAFE and FIRESAFE II was conducted to identify and quantify effects on other parts of the main fire risk model than that for which they were identified, with a view to conduct a combined cost-effectiveness assessment. The comprehensive quantifications of the RCOs were integrated into the consolidated main fire risk model, from which effects on the overall risk could be calculated, thereby providing the benefit part of the cost-effectiveness assessment.

Thereafter, the costs associated with the implementation of the RCOs, estimated in FIRESAFE and FIRESAFE II, were recapitulated. However, the costs for the RCOs Electrical fire and Suppression, were only estimated for Standard RoPax in FIRESAFE and were hence necessary to derive also for Cargo and Ferry RoPax. Based on the overall risk reductions and costs of the RCOs, the combined assessment was conducted with estimations of the Gross Cost of Averting a Fatality (GCAF) and Net Cost of Averting a Fatality (NCAF) for each RCO.

A few RCOs that were not found cost-effective in FIRESAFE and the first parts of FIRESAFE II were found cost-effective when considering their additional impacts on the rest of the fire protection chain as can be seen in Figure 8.

		Newbuildings			Newbuildings		
RCO #	Description	Cargo RoPax	Standard RoPax	Ferry RoPax	Cargo RoPax	Standard RoPax	Ferry RoPax
El 1	Robust connection boxes	0.08	0.04	0.03	0.08	0.04	0.03
El 2	Only ship cables	1.49	0.49	0.32	1.49	0.49	0.32
El 3	IR camera	0.19	0.06	0.04	0.19	0.05	0.04
El 4	Training for awareness	0.02	0.01	0.00	0.02	0.01	0.00
El 5	Only crew connections	0.02	0.01	0.00	0.02	0.01	0.00
El 6	Cable reeling drums	5.07	3.88	2.55	5.07	3.88	2.55
Det1	Combined heat & smoke detection	3.66	0.53	0.28	0.16	0.02	0.01
Det2	Ban / closure of side (PS & SB) openings (open ro-ro spaces)	N/A	210.36	N/A	N/A	1.83	N/A
Det3	Increased frequency of fire patrols	10.80	2.49	3.12	10.05	2.09	2.51
Dec1	Alarm System Design & Integration	0.40	0.05	0.03	0.35	0.04	0.02
Dec2	Improved markings/signage for wayfinding and localisation	0.12	0.02	0.01	0.08	0.01	0.01
Dec3	Preconditions for Early Activation of Drencher System	1.48	0.26	0.15	1.48	0.26	0.15
Su 1	Remote control	4.34	0.44	0.24	2.32	0.28	0.15
Su 3	Rolling shutters (PS & SB side) (Open ro-ro spaces)	N/A	13.55	N/A	N/A	2.01	N/A
Su 4	Efficient activation routines	0.00	0.00	0.00	0.00	0.00	0.00
Su 5	Fresh water activation/flushing	0.17	0.02	0.01	0.17	0.02	0.01
Su 6	CCTV	11.27	1.00	0.62	2.25	0.28	0.16
Su 7	CCTV + Remote control	5.94	0.60	0.32	2.45	0.30	0.16
Cont1	Ban/closure of side & end openings (closed and open ro-ro spaces)	2.43	3.30	1.99	2.31	1.77	0.39
Cont2	Fire monitors on weather deck	0.13	0.07	0.04	0.10	0.05	0.04

Figure 8 - GCAF Factors for the different RCOs on each generic vessel (before and after the combined assessment)

It should particularly be noted for the closing of the openings that yearly losses for the newbuildings are difficult to estimate and very vessel dependent. It is believed that the Ferry RoPax in this study with minor changes would not suffer loss of cargo and hence only €25 000 is left in yearly cost for running fans. By redesigning for more weather decks this might be reduced slightly. The Cargo RoPax costs remain the same. For the Standard RoPax the loss of cargo is mainly due to the closing of the side openings and hence only a major change on ship design could accommodate for this loss. That cost has not been evaluated and hence the figure for yearly losses is kept.

Sensitivity and uncertainty analyses

Most of the assumptions made in the risk assessment part are conservative, leading to a potential over estimation of the societal risk. As far as practicable, a high level of attention was given to explicit all assumptions used in the study with the aim to ease any potential modifications or updates of the assumptions with new data sets, different expert judgements or if new knowledge in any area of the study is obtained.

Sensitivity and uncertainty analyses were performed as part of the study, where the quantifications of the risk model and in the effectiveness quantifications of RCOs were evaluated. No uncertainty was considered for the cost estimations.

Uncertainty of the estimated parameters was explicitly modelled with probability distributions for each bottom nodes of the sub risk models. The risk assessment software @Risk (Palisade Decision Tool ©), an add-in to Microsoft Excel, was then used to perform Monte Carlo simulations (sampling of the parameters from their probability distribution) to estimate confidence intervals for the PLL and GCAF Factors.

The uncertainty analysis of the detection RCOs showed that most of the results from the static values are reliable. Analysing the RCOs with GCAF close to 1 showed that combined smoke & heat detection involves the most uncertainty, with only a 22% confidence of GCAF<1 for *Standard RoPax* Newbuildings and 9% confidence for *Ferry RoPax* Newbuildings and 14% for existing *Ferry RoPax*. Hence, combined smoke & heat detection involved significant uncertainties which makes it uncertain whether this RCO will in fact be cost efficient for other RoPax ships than *Cargo RoPax*.

For the decision RCOs, the uncertainty analysis also mainly strengthened the results from the static values. The only minor deviation to be noted is that Preconditions for Early activation of Drencher System, which was cost-efficient for *Standard* and *Ferry RoPax* based on static values, has a 10% confidence of being cost-efficient also for *Cargo RoPax* Newbuildings. However, for existing ships, the corresponding confidence was only 3%.

The uncertainty analysis of the Containment and Evacuation RCOs showed that most of the results from the static values are reliable. Most of the RCOs achieved static GCAF factor well below or well above 1. For the design *Closing all significant openings* on *Ferry RoPax* Newbuildings, the static GCAF factor was 0.46 and therefore considered cost-efficient. The uncertainty analysis mainly strengthened this results by showing a very high confidence (98%) for cost-efficiency.

STEP 5 – RECOMMENDATIONS FOR DECISION-MAKING:

The RCOs achieving the highest risk reduction in a cost-effective manner were:

- Regardless of the ship category:
    - Fire monitors on weather decks;
    - Robust connection boxes;
    - Combined heat and smoke and alarm system design and integration;
    - Alarm system design and integration (smoke);
    - IR camera; and
    - Improved markings/signage for wayfinding and localization.
- For Standard RoPax and Ferry RoPax:
    - Precondition for early activation of drencher system
    - CCTV and Remote control;
    - CCTV;
    - Remote control; and
    - Only ship cables.
- For Standard RoPax:
    - Safe distance

- For Ferry RoPax:
    - Safe distance (only for Newbuildings).

In addition to the above RCOs, the following RCOs were found cost effective and associated with a low cost:

- Training for awareness;
- Efficient activation routines;
- Fresh water activation/flushing; and
- Only crew connections

In view of the above combined cost-effectiveness assessment results, proposed amendments to IMO regulations are discussed in the next section of this Annex for the implementation of RCOs that proved to be cost-effective when considering their impacts along the whole fire protection chain.

7 FINAL RECOMMENDATIONS FOR DECISION-MAKING

It should be clearly stated that based on the combined cost-effectiveness assessment results, proposed amendments in IMO Rules for the implementation of some of the Risk Control Options that proved to be cost-effective when considering their impacts along the whole fire protection chain are discussed in part 9.2 of the combined assessment report. Additionally, in the report of WP4 part 16 makes specific proposals for rule making. It is hereby proposed that the FSA review considers all these proposals as possible amendments to the relevant instruments.

It is further expected in any case that all these proposals will be further discussed within the work of the Fire Protection Working/Correspondence Group under its currently ongoing agenda item from a technical point of view to also decide how to best implement them. It is in any case strongly recommended that particular weight should be given to RCOs that are in the first stages of the chain of events which are presented in Figure 5. Furthermore, particular weight should be given to RCOs which achieve the highest relative risk reduction as presented in Figure 6 and in Figure 7

In addition to the recommendations of the above RCOs, the following recommendations were formulated based on the combined assessment:

It should be noted that the assumptions made to estimate the cost of implementing the RCO Ban of side openings on Standard RoPax (not considering any major change on ship design to accommodate for the loss of cargo due to the closure of the side openings) was very influential on the cost effectiveness results (high recurring costs for 40 years instead of a significant investment cost). In view of the results of the Combined Assessment (GCAF factor below 2), it is recommended to further investigate this RCO considering a reconstruction of the ships layout or adding safety systems to allow for "no cargo loss".

Although not studied as a RCO, the findings of the simulations and the risk assessment part indicated that a fire detection system in ro-ro spaces based on heat detection only (considering conventional point heat detectors) should not be allowed.

Some RCOs are already (voluntarily or mandatory) implemented by some ship owners, operating their ship above minimum SOLAS requirements. Such actions, based on commercial considerations, or possibly requirements from certain port states, is encouraged regardless of the cost-effectiveness reported above. The results of the cost-effectiveness assessment reported in FIRESAFE II are believed to be representative of the world fleet, but may be impacted by the intrinsic safety culture and specific procedures of some ship operators.