Horizon 2020

Project acronym: **LASH FIRE**

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Ship integration evaluation

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Abstract

In the LASH FIRE project, technical ship integration evaluations have been performed, regarding design, production, operational and environmental aspects, on the solutions developed to address the fire safety challenges identified in the project. Further, input has been provided to the cost assessment, formal safety assessment and demonstration on board. This report presents the ship integration evaluation addressed to all the developments within the LASHFIRE project. It is important to highlight that the assessments were performed during the development process in order to obtain as high as possible impact on the developments from relevant maritime stakeholders included. The evaluation results have been exchanged with the development teams to further improve the developed solution and ensure a feasible solution to be assessed through the life cycle cost, formal safety assessment and finally demonstration of the most promising solutions.

This deliverable reflects an intermediate stage of the project and shall not be understood or used as a final outcome of the LASH FIRE project.

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Content

1 Executive summary

1.1 Problem definition

The LASH FIRE project aims to develop and demonstrate operational and design solutions which strengthen the fire protection of ro-ro ships in all stages of a fire. Twenty specific challenges, also called Actions, have been identified, which were addressed by new solutions developed and demonstrated with regards to performance and ship integration feasibility. Real ship application cases shall be the focus of the development to achieve feasible and integrable solutions. Therefore, it is crucial that ship designers and operators are involved in the development process, considering the design, production, operational and environmental aspects.

The main challenges were to address all the application areas, targeted by developed solutions, and providing a clear picture of the relevant maritime stakeholders' aspects.

1.2 Technical approach

To address the described problems and challenges above, a technical ship integration evaluation was performed by WP05 Ship Integration, and input was provided to the development teams, adjusted to each developed solution separately, considering the design, production, operational and environmental aspects as well as proposals for the developments. Further, all types of ro-ro ships and all types of ro-ro spaces were considered where appropriate.

It is important to highlight that the assessments were performed during the development process in order to obtain as high as possible impact on the developments from relevant maritime stakeholders included, as illustrated on Figure 1. The evaluation results were exchanged with the development teams to further improve the developed solution and to ensure a feasible and integrable solution to be assessed through the life cycle cost, formal safety assessment and final demonstration for the most promising solutions, as illustrated on Figure 2. Further, the information was exchanged with WP04 (Formal safety assessments) to reach a common understanding of the solutions and reduce the uncertainties for further assessments. It is worth mentioning that the established MAAG and MOAG advisory groups within LASH FIRE WP03 supported the ship integration evaluation within the project, providing valuable feedback through dedicated workshops.

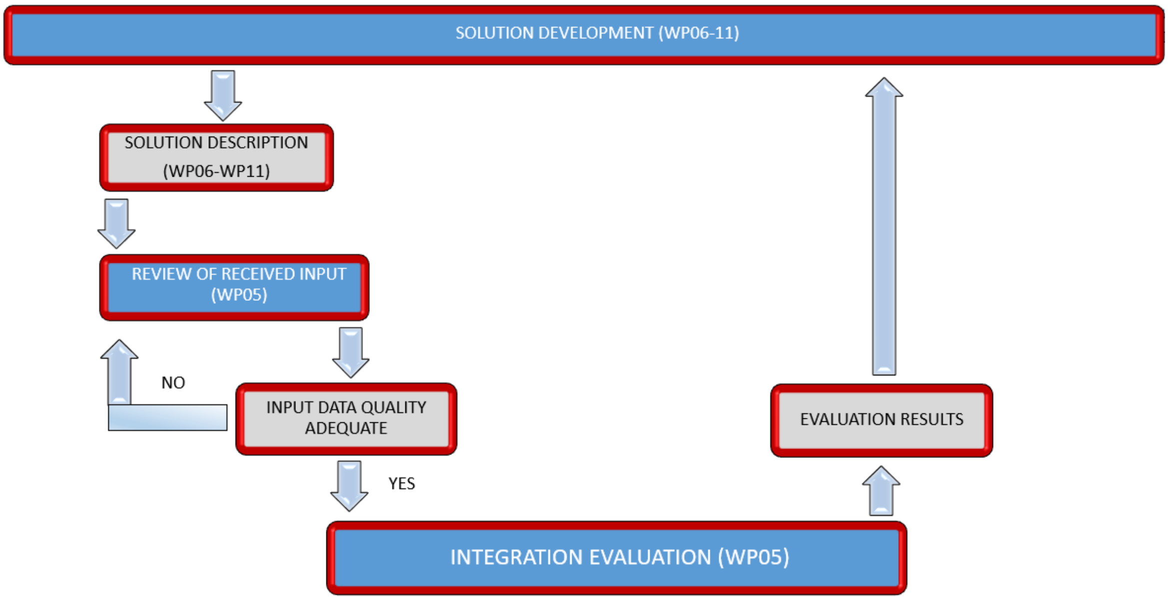

Figure 1. Integration evaluation process

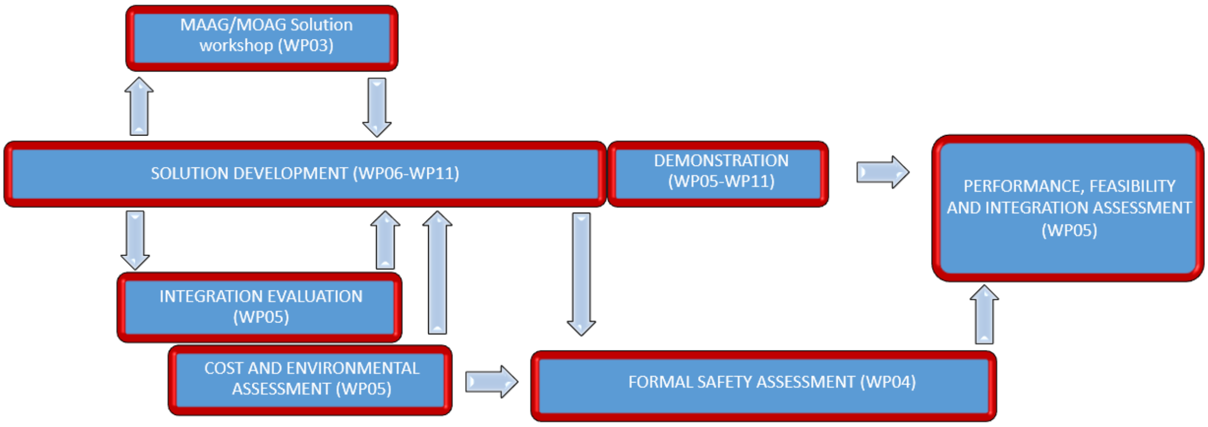

Figure 2. Ship integration assessment process

1.3 Results and achievements

This report presents a compilation of the ship integration evaluation results addressed to all the specific developments within the LASHFIRE project at this intermediate stage of the project, including design, production, operational and environmental aspects as well as proposals for the developments.

1.4 Contribution to LASH FIRE objectives

One of the main LASH FIRE objectives (Objective 2) is addressed by the ship integration work package (WP05):

> *LASH FIRE will evaluate and demonstrate ship integration feasibility and cost of developed operational and design risk control measures for all types of ro-ro ships and all types of ro-ro spaces.*

This report will further contribute to the development processes, demonstration of integration feasibility and final feasibility assessment for all the developed solutions within the LASH FIRE project and beyond.

1.5 Exploitation and implementation

The results were used within LASH FIRE as input for the D&D WPs to refine the ongoing developments, conduct the validation and the demonstration of solutions.

The report can be further used as input for the different assessments carried out by WP03 (MAAG/MOAG), WP04 (FSA) and WP05 (cost assessment, and final feasibility assessment).

The report can be used by external parties as it provides a description of technical and operational aspects related to innovative solutions. Further, it provides information on the expected or desired improvements and future developments.

This information can be useful for any stakeholder in the maritime industry.

2 List of symbols and abbreviations

AB	Able Seaman
ADR	Accord européen relatif au transport international des marchandises Dangereuses par Route (European Agreement Concerning the International Carriage of Dangerous Goods by Road)
AGV	Automatic Guided Vehicle
AHJ	Authority Having Jurisdiction
AI	Artificial intelligence
AIS	Automatic Identification System; Satellite transmitted positions of vessels.
APV	Alternative Powered Vehicle
BEV	Battery Electric Vehicles
CAFS	Compressed air foam system
CAF	Compressed Air Foam
CCR	Cargo control room
CCTV	Closed-Circuit Television
CFD	Computational Fluid Dynamics
CLIA	Cruise Lines International Association
CNG	Compressed natural gas
DECT	Digital Enhanced Cordless Telephone
DG	Dangerous goods
D&D WPs	Development and demonstration work packages
ECDIS	Electronic Chart Display and Information System; Electronic map and navigation tool
ECR	Engine Control Room
EEBD	Emergency Escape Breathing Device
EV	Electric vehicle
FDS	Fire Dynamics Simulator
FF	Fire fighting
FRMC	Firefighting Resource Management Centre
FSS	IMO International Code for Fire Safety Systems
FTP	International Code for the Application of Fire Test Procedures

FWBLAFFS	Fixed Water-Based Local Application Fire-Fighting Systems
GAP	General Arrangement Plan
GNSS	Global Navigation Satellite System
HCD	Human Centred Design
HD	High Definition
HGV	Heavy Goods Vehicle
HMI	Human-Machine Interface
HRR	Heat release rate
IACS	International Association of Classification Societies
IAMCS	Integrated Alarm Monitoring Control System – equipment
ICE	Internal Combustion Engine
IEC	International Electrotechnical Commission
IMDG	The International Maritime Dangerous Goods code
IMO	International Maritime Organization
IR	Infrared
ISM	International Safety Management
ISPS	International Ship and Port Facility Security Code
IR	Infrared Light
IT	Information technology
LCA	Life Cycle Assessment
LAN	Local Area Network
LLL	Low Location Lighting
LiDAR	Light Detection and Ranging
LNG	Liquefied natural gas
LPG	Liquefied Petroleum Gas
LSA	Life Saving Appliance
MAAG	Maritime Authorities Advisory Group
MOAG	Maritime Operators Advisory Group
MES	Marine Evacuation System
MFAG	Medical First Aid Guide for Use in Accidents Involving Dangerous Goods
MSC	Maritime Safety Committee

MVZ	Main Vertical Zone
NB	Nota bene, a Latin phrase meaning "note well"
NFPA	National Fire Protection Association
OOW	Officer Of the Watch
OPITO	Oil Petroleum Industry Training Organization
PC	Personal computer
PLC	Programmable Logic Controller
PTT	Press to talk
RCM	Risk control measure
RCO	Risk control option
SLAM	Simultaneous Localization and Mapping
SMAS	SMart Alert System
SCS	Safety control station, normally located on the bridge
SOLAS	International Convention for the Safety Of Life At Sea
SRtP	Safe Return to Port
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
SW	Software
TCP/IP	Transmission Control Protocol/Internet Protocol
TR	Thermal runaway
TUGMASTER	The small vehicle that drives the trailers on/off board
UHF	Ultra Hight Frequency; Short wave radio, shorter reach than VHF
UV	Ultra Violet light
UWB	Ultra-wideband
VFD	Video Flame Detection
VGM	Verified Gross Mass
VHD	Vehicle Hotspot Detection
VHF	Very High Frequency; Short wave radio
VSD	Video Smoke Detection
WAN	Wide Area Network

3 Introduction

Main author of the chapter: Vito Radolovic, FLOW

One of the main LASH FIRE objectives (Objective 2) is to evaluate and demonstrate ship integration feasibility and cost of developed operational and design risk control measures for all types of ro-ro ships and all types of ro-ro spaces.

Technical ship integration evaluation has been performed considering the design, production, operational and environmental aspects. Further, input has been given to the cost assessment, formal safety assessment and demonstration on board. This report presents the ship integration evaluation results addressed to all the developments within the LASHFIRE project. The evaluation results have been exchanged with the development teams to further improve and refine the developed solutions and to ensure a feasible and integrable solution to be assessed through the life cycle cost, formal safety assessment and final demonstration of the most promising solutions.

Six Development and Demonstration Work Packages (D&D WPs) will address a total of twenty challenges, also called actions, in all stages of fire scenario originating in ro-ro spaces (Figure 3).

WP06	**Effective Manual Operations**
6-A	Manual screening of cargo fire hazards and effective fire patrols
6-B	Quick manual fire confirmation and localization
6-C	Efficient first response
6-D	Effective and efficient manual firefighting
WP07	**Inherently Safe Design**
7-A	Improved fire detection system interface design
7-B	Efficient extinguishing system activation and inherently safe design
7-C	Firefighting resource management centre
WP08	**Ignition Prevention**
8-A	Automatic screening and management of cargo fire hazards
8-B	Guidelines and solutions for safe electrical connections
8-C	Fire requirements for new ro-ro space materials
WP09	**Detection**
9-A	Detection on weather deck
9-B	Detection in closed and open ro-ro spaces
9-C	Technologies for visual fire confirmation and localization
WP10	**Extinguishment**
10-A	Local application fire-extinguishing systems
10-B	Weather deck fixed fire-extinguishing systems
10-C	Updated performance of alternative fixed fire-fighting systems
WP11	**Containment**
11-A	Division of ro-ro spaces
11-B	Ensuring safe evacuation
11-C	Safe design with ro-ro space openings
11-D	Ro-ro space ventilation and smoke extraction

Figure 3. LASH FIRE 20 challenges (or actions).

Several solutions, also called Risk Control Measures (RCMs), will be developed, validated, and demonstrated to address those challenges. Based on the preliminary list of selected solutions and from the inputs provided by the D&D WPs (Ref. Deliverable D04.9, [1]), this report presents an intermediate compilation of the ship integration evaluation conducted by Work Package 5 Ship Integration (WP05) addressed to each specific development. The document shall not be understood or used as a final outcome of the LASH FIRE project. Rather, it provides a summary of aspects by WP05 to the developments, including design, production, operational and environmental aspects, as well as proposals for improvements, of the developments for all proposed solutions. The actual Risk Controll Measures (RCMs) are only specified by title in this report, where a more detailed description is found in D04.9 “Preliminary impact of solutions and related testing and demonstrations plan” [1].

4 Manual screening of cargo hazards and effective fire patrols - Action 6-A

Main author of the chapter: Martin Carlsson, STL

This chapter gives an overview of the ship integration evaluation for Action 6-A, i.e., manual screening of cargo hazards and effective fire patrols. Two RCMs are proposed by WP06 and assessed within this report:

- RCM Op1 - Improved fire patrol procedures and new assisting equipment for a more effective screening of fire hazards
- RCM Op2 - Manual screening of cargo at port before the loading operations

For the description of the solutions please refer to Deliverable D04.9 [1].

4.1 Operational aspects

4.1.1 RCM Op1 - Improved fire patrol procedures and new assisting equipment for a more effective screening of fire hazards

There is good value in establishing a minimum list of equipment for a fire patrol, for example torchlight should be on such list.

A guideline can include:

- Instructions what to look for
- Minimum equipment and clothes standards
- Training and skills requirements
- Radio coverage requirements

4.1.2 RCM Op2 - Manual screening of cargo at port before the loading operations

Details of additional manual screening shall be described, including the following aspects:

- What to look for
- How much time to spend
- When to act
- What decisions to take
- Impact on loading operations etc

It should be well specified who, when and where the manual screening shall be performed. Different options are suggested and described in

Table 1.

Table 1. Manual screening evaluation matrix

RCM Alternative		Location	Start-up cost	Running cost	Operation impact	Effectiveness	Total RCM efficiency
A	Today screening	Ramp, cargo deck	0	0	0	May be improved	0
B	Refocused existing resources, cargo screening to take place in parallel with cargo operations, by loading officers and crew	Ramp, cargo deck	# Training	# No extra resources # Extra training	# Consequences on other deck crew activities if screening get more attention # Less attention to traffic (increased safety risk) # Challenge to get unit out if a problem is discovered already onboard.	# Attention split between many task - less concentration on fire hazards	Very high
C	**Added resource from ship, separate screening activity in terminal and just before ramp**	**Terminal area**	**# Training**	**# Extra workhours - more crew or maintenance activities # 30-60 min extra activity per departure (estimation) # Extra training**	**# Scanning of vehicles to be performed in terminal area while unloading in case of fast turnaround # Risk of stress if late arrival or full load**	**# Full attention to fire hazards # Ship crew motivated to secure the ship safety**	**High**
D	Added resource from shore, screening in terminal	Terminal area	# Training # Startup/ Recruitement	# 60 min screening per departure (estimation)	# Will be a challenge to get external resources to perform screening, unless compensated for it	# Full attention to fire hazards # Less motive force by shore crew potentially # Varying conditions in ports # Out of Master/IMO jurisdiction	Low

According to

Table 1, alternative C is selected by WP06 as preferrable. Alternative B is probably more cost efficient but less effective.

If there is a risk of delayed departure of the vessel, masters shall make the decision on how to handle fire safety screening (a trade-off between enhanced fire safety and possible delay of the vessel).

Port and terminal design needs to take into account relevant conditions for automatic and manual screening as well as locations for singling out identified units for inspection. Such inspection must take place in a fire safe location.

For the cost assessment and risk reduction impact it is important to establish how much screening time should be spent on each cargo unit and how exactly to attempt to detect each hazard.

4.2 Recommendations for the lifecycle cost assessment

4.2.1 RCM Op1 - Improved fire patrol procedures and new assisting equipment for a more effective screening of fire hazards

The following cost items shall be considered:

Investment cost:

- Additional equipment

Operation cost:

- Cost of training (crew/vessel);
- Cost of operational limitations
    - additional working time (if any)

4.2.2 RCM Op2 - Manual screening of cargo at port before the loading operations

Implementation cost will vary considerably between vessels, due to crew situation and schedule.

The following cost items shall be considered:

Investment cost:

- Additional equipment

Operation cost:

- Cost of training (crew/vessel);
    - Startup crew/staff/training cost per vessel/terminal
- Cost of maintenance of equipment
- Cost of operational limitations
    - additional working time (if any)
    - Screening time to be spent per cargo unit/vehicle
    - impact on loading schedules
    - Cost of consequences from identification of a hazardous unit, by means of handling, inspection, administration, and customer, especially related to units identified that are later concluded to not pose a fire hazards.

4.3 Environmental aspects

The location in the terminal for the inspection of a vehicle with identified fire risk needs to be chosen, taking into account the environmental risk of leaks and fire, including a considerable amount of associated fire suppression media.

4.4 Proposal for improvements

4.4.1 RCM Op1 - Improved fire patrol procedures and new assisting equipment for a more effective screening of fire hazards

STCW code to be updated with proper competence and training requirements.

Radio shadows should be limited to acceptable disturbance. Each deck must be radio covered to a large degree and in no case the range to reach radio signal should be more than 10 m walking distance (valid for fully loaded conditions).

4.4.2 RCM Op2 - Manual screening of cargo at port before the loading operations

The interaction between automatic (Action 8A) and manual cargo screening must be fully established, as it makes no sense for double scanning (both manually and automatically) for the same hazards. Care must be taken that in the likely case when automatic cargo screening will be arranged at the entry of the terminal, no manual screening can take place before or at the same time and location.

As a proposal, the interrelation between the different screening options may be mapped as in Table 2.

Table 2. Screening options matrix

	Hazard	How to detect in practice	Where			
			Automatic screening at terminal	Manual screening at terminal	Manual screening at Ramp/Loading	Fire Patrol
1	The status of reefer units.	Strange smell/noise	YES. Heat screen	YES. Identification of cracks	NO	YES. Identification of cracks
2	Substandard electrical connections.	Socket inspection	NO	YES. Identification of corrosion	NO	YES. Identification of corrosion
3	Suspicious noise or smell.	Walk close and hear/smell	NO	YES. Senses	YES. Noise	YES. Senses
4	Heat radiations.	IR camera	YES. Heat screen	NO. No time for each unit	NO	YES. Heat screen
5	Fuel leakage (solid, gas)	Visual under vehicle	NO	YES. Visual Identification	YES. Only the obvious	YES. Visual Identification
6	Portable fuel containers or added fuel tanks	Visual inspection	NO	YES. Visual Identification	NO. Very difficult	YES. Visual Identification
7	Handmade installations on RVs	Visual inspection inside	NO	YES. Visual Identification	NO. Very difficult	YES. Visual Identification
8	Stowaways activities	Damaged covers, visible people	YES. Heat screen	YES. Visual Identification	NO	YES. Visual Identification
9	Presence of ignition sources	IR camera	YES. Heat screen	NO. No time for each unit	NO	YES. Heat screen
10	Thermal runaway on Li-ion batteries of EVs	Look for visual gases, Heat	YES. Heat screen	YES. Visual Identification	YES. Visual Identification	YES. Visual Identification
11	Self-reactions with IMDG	Look for visual smoke, scan for heat	YES. Heat screen	YES. Visual Identification	YES. Visual Identification	YES. Visual Identification
12	Lashing arrangements failure	Visual inspection	NO	NO. No lashing	YES. Visual Identification	YES. Visual Identification
13	Other obvious fire hazards (smoke, sparkles)	Visual inspection	YES. Heat screen	YES. Visual Identification	YES. Visual Identification	YES. Visual Identification

Intended time to be spent on each vehicle/cargo unit must be established, indicating the target level of attention.

Since time will always be limited, guidelines on different focus depending on first-glance conditions should be established (for example to spend more time on aged vehicles, late arriving vehicles, reefers, and less time on apparent new units, open trailers or from known very serious forwarders).

Routines on how to handle a unit with increased fire risk in port must be established.

Proposed regulatory text related to Op2 cargo screening is listed below:

1. *At booking or time of arrival to port and check in, drivers should be informed in writing on what rules apply related to fire hazards of their vehicle, conditions for carriage and the Masters' right to refuse carriage.*
2. *Fire safety screening of vehicles and cargo to be loaded shall be performed before the departure of the vessel. Consideration should be taken to fire risks that may appear during parking in the terminal area.*
3. *Screening may be executed manually by trained personnel or automatically by a fixed screening system, or both.*
4. *Screening should consider, as a minimum, the following items:*
   - *Status of reefer units*
   - *Electrical connection sockets*
   - *Suspicious noise/smell/smoke*
   - *Abnormal heat radiation*
   - *Fuel leakages*
   - *Portable fuel containers or added fuel tanks*
   - *Handmade electrical installations*
   - *Manipulated/rebuild vehicles*
   - *Fire hazards caused by stowaways' activities*
5. *If a fixed automatic screening system is arranged it should alert terminal staff if the screening parameter is outside the acceptable range.*
6. *Handheld IR camera and flash light to be carried and used as appropriate by the screening personnel.*
7. *On the suspicion of increased risk, a vehicle should be singled out for deeper inspection. If the increased risk cannot be contained, the vehicle should not be transported or it should be subjected to additional safety measures during voyage. The decision on carriage is taken by Master.*

STCW code to be updated with proper competence and training requirements.

As the result of this RCM, a guideline shall be issued for the final evaluation of the operational impact and cost assessment.

4.5 Conclusion

The solutions Op1 and Op2 can be integrated into ships operational procedures if improvement proposals are duly considered.

Both Op1 and Op2 guidelines shall be further considered by ship's crew and operations and preferably by terminal staff and operations.

5 Quick manual fire confirmation, localization, and assessment – Action 6-B

Main author of the chapter: Martin Carlsson, STL

This chapter gives an overview of the ship integration evaluation for Action 6-B, i.e., quick manual fire confirmation, localization, and assessment. Two RCMs are proposed by WP06 and assessed within this report:

- RCM Op3 - The improvement of current signage and marking standards/conditions to support effective wayfinding and localization
- RCM Op4 - Guidelines for the standardization and formalization of manual fire confirmation and localization

For the description of the solutions please refer to Deliverable D04.9 [1].

5.1 Operational aspects

5.1.1 RCM Op3 - The improvement of current signage and marking standards/conditions to support effective wayfinding and localization

It is critical to ensure that communication and location references are clear and doubtless in stressed cases of emergency. Reality has proven that disasters may evolve from shortcomings in this regard. Possible root causes for the issues are the lack of coordination between the systems already existing in the new building design or those added during the operational lifetime of the ship as part of system replacements or configuration changes in the ship. For example, a printed copy of the General Arrangement (GA) plan or that of the drencher zone plan are easy to forget to update.

It is essential to clearly establish the proposed designations, font, colours, material, and locations of any signage, with proper examples, to allow the full evaluation of the added fire safety value. Systems shall be stipulated in such a way considering appropriate format, dimensions, distances etc. before they can be applied.

In order to enable the proper evaluation of how the synchronization of systems must be done, the relations between all linked systems should be outlined regarding the following items:

- Painted markings on deck/bulkhead
- Alarm panel
- CCTV
- Drencher station valves/pipes
- Any remote operation of any system
- Integrated fire management system (if any)
- Any printed instructions
- Fire plan
- Verbal terminology
- And similar items of importance to the particular system in question

5.1.2 RCM Op4 - Guidelines for the standardization and formalization of manual fire confirmation and localization

The common opinion is that, in addition to ship familiarization, it is of great importance to introduce the crew to the possible scenarios which may be encountered during fire confirmation: typical signs of an incident, typical personal safety risks and default actions depending on the spotted situation.

5.2 Design and construction aspects

5.2.1 RCM Op3 - The improvement of current signage and marking standards/conditions to support effective wayfinding and localization

Font, colours, material, and locations of any physical signage should be established to enable a full technical evaluation. The requirements shall be stipulated with dimensions, distances etc. that can be applied on any vessel as best as possible.

Both painted markings and prefabricated signs should be permitted.

Paintwork on deck is more complicated from the perspective of surface preparation and from the perspective of long term visibility and maintenance. Deck surfaces tend to get dirty rather fast, and any paint work is quickly obscured. Also, the wear/tear on deck is extensive due to the frequent traffic of vehicles.

Any changes to onboard systems (other than deck markings) need to be established.

If numbers/designations of any kind are changed on board, it is of great importance that all references to old information in printed or electronic material are deleted and replaced with new designations.

Regarding drencher station pipe markings, duplicating references to functions or locations such as colour coding in addition to numbering should be carefully evaluated due to the risk of confusion and potentially contradictory information.

5.3 Recommendations for the lifecycle cost assessment

An adequate cost assessment shall be performed for the two selected solutions:

- Op3: The improvement of current signage and marking standards/conditions to support effective wayfinding and localization
- Op4: Guidelines for the standardization and formalization of manual fire confirmation and localization

5.3.1 RCM Op3 - The improvement of current signage and marking standards/conditions to support effective wayfinding and localization.

For existing ships, it is a relatively low cost (only for material and work) to update/establish painted markings on bulkheads/web frames. Paint work at certain heights above deck adds complexity and cost, but this is only a one-time cost.

As for new buildings, the implementation cost of this RCM is close to zero for painted markings, including certain low additional expenses for prefabricated signage, although the maintenance cost remains the same.

The following cost items shall be considered:

Investment cost:

- Establish company procedures
- Ship specific investigations and drawings
- Painted or premanufactured signage
- Work by crew or contractors (including removing existing markings on existing ships)
- Reconfiguring the fire alarm system
- Approval cost

Operational cost:

- Paint and signage maintenance

5.3.2 RCM Op4 - Guidelines for the standardization and formalization of manual fire confirmation and localization

The following cost items shall be considered:

Investment cost:

- Company procedures
- Ship specific investigation
- UHF radio system
- UHF repeater purchase
- Repeater installation & integration cost
- Initial training

Operational cost:

- Continuous training
- Maintenance/replacement

5.4 Proposal for improvements

5.4.1 RCM Op3 - The improvement of current signage and marking standards/conditions to support effective wayfinding and localization

It is suggested to develop practical guidelines to serve as a starting point for each ship.

It is proposed that signs and markings painted on the vessel should be illuminated in the darkness

Examples of markings on board existing ships are illustrated in the following figures.

Figure 4. Drencher zone and frame markings on Stena Saga, realized with prefabricated "paint patterns" from the supplier.

On Stena Saga there is one set of markings on the high level for visibility in CCTV system and on the low level 0,5 m above deck for best visibility for the patrol of fire team. Low level markings need to be visible below trailers but also above cars.

Figure 5. Drencher zone markings on Stena Scandica

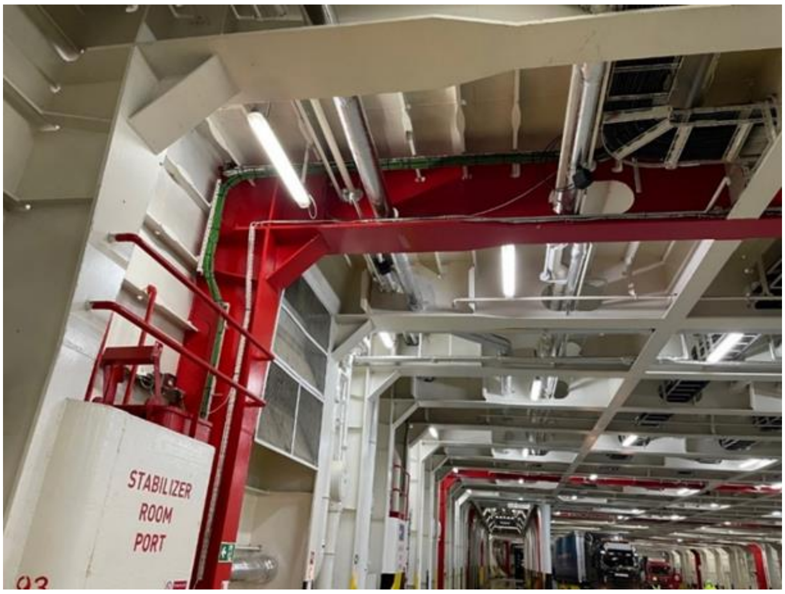

Figure 6. Drencher zone boundaries on Stena Scandica.

According to some sources **Bold Sans Serif** is the most readable font for signage such as in this case.

Figure 7. Example of Bold Sans Serif drencher zone marking

It is recommended to establish a signage standard with a practical example. Below are displayed some examples of various items requiring improvements.

Current mismatches between marking and signage in drencher systems and ro-ro spaces are illustrated in Figure 8.

Figure 8. Current mismatches between marking and signage.

Figure 9 illustrates the need to ‘translate’ information provided by the alarm system into sensors and positions.

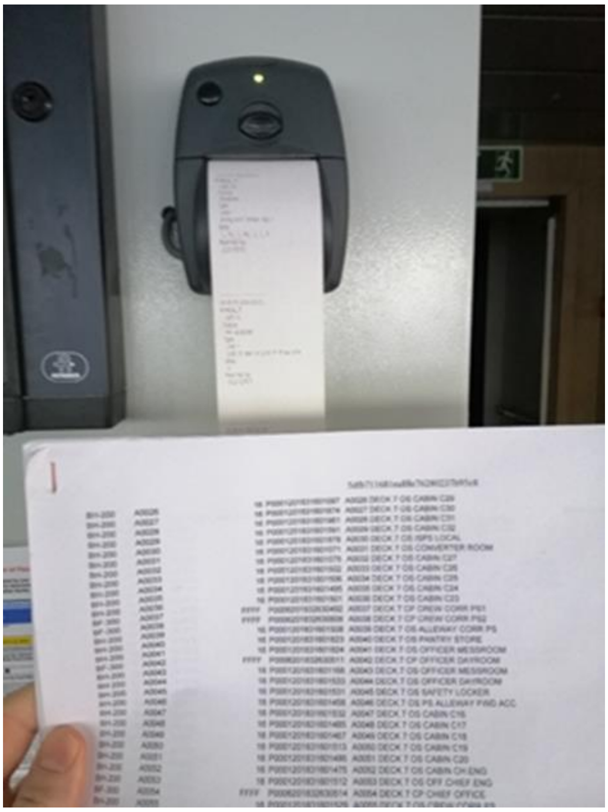

Figure 9. Information from alarm system.

Figure 10 illustrates the current size of markings as well as its poor maintenance.

Figure 10. Current size and conditions of the markings.

5.4.2 RCM Op4 - Guidelines for the standardization and formalization of manual fire confirmation and localization

These guidelines should be aligned with EMSA Guidance on Carriage of AFVs in Ro-Ro Spaces.

5.5 Conclusion

The solutions Op3 and Op4 can be integrated into ships systems and operational procedures for both new buildings and existing ships.

Regarding the RCM Op3, the opinion is that it is critical to ensure that communication and location references are clear and doubtless in stressed cases of emergency. Further, in order to fully evaluate the added fire safety value of the integration, it is needed to clearly establish the proposed designations, font, colours, material, and locations of any signage, with proper examples. It is proposed to develop practical guidelines to serve as a starting point for each ship.

The common opinion for the integration of the RCM Op4 is that, in addition to ship familiarization, it is of great importance to introduce the crew to the possible scenarios which may be encountered during fire confirmation. It is proposed that the developed guidelines shall be aligned with EMSA Guidance on Carriage of AFVs in Ro-Ro Spaces.

6 Efficient first response - Action 6-C

Main author of the chapter: Martin Carlsson, STL

This chapter gives an overview of the ship integration evaluation for Action 6-C, i.e., efficient first response. Two RCMs are proposed by WP06 and assessed within this report:

- RCM Op5 - First response guidelines and new equipment to put out the fire in the initial stage
- RCM Op6 - Technology for localization of first responders through digital information processed via network

For the description of the solutions please refer to Deliverable D04.9, [1].

6.1 Operational aspects

6.1.1 RCM Op5 - First response guidelines

Well usage of first minutes after the fire is detected is usually of critical importance. Therefore, definition of designated first response concept is of greatest value.

The content of this RCM is not fully established yet at this point. For the sake of this evaluation, the content is assumed to be the following:

- Establish **First Response** concept and the role of **Designated First Responder** in the most efficient way, and issue a standard role description

- Develop standard communication terminology protocol to ensure prompt understanding

The mutual understanding of intentions is very important since terminology may vary between different operators and other stakeholders.

Another important aspect is the risk of a “designated first responder” which is based on the traditional use of a fire extinguisher or any useful equipment. On the other hand, the establishment of a designated first responder should not prevent the urgent engagement of any crewmember in the early phase of a fire.

The operational implications of this RCM are changed procedures, enhanced training and, in some cases, investment in fire safe work clothes for crewmembers.

From the operational point of view, the target should be to establish the guidance as similar as possible, regardless of vehicle fuel type such as petrol, diesel, battery, CNG, or LNG. This is to avoid complexity and the need for the responder to know fuel type in an early-stage fire situation.

6.1.2 RCM Op6 -Technology for localization of first responders

The content of this RCM is assumed to be as follows:

- Localization system based on image recognition technology
- Master unit for overview on the bridge or another location
- User devices provided to fire patrol and fire teams
- System to be functional in all ro-ro cargo spaces and car decks
- System to be operational for weather decks, open ro-ro decks and closed ro-ro decks

Potential operational benefits of this system are:

- Support for determining the position of a user, in cases this is not manually established, supportive to crew if someone not fully familiar with the vessel or under influence of stress or in poor visibility conditions
- (Graphical) overview of resources and their positions
- Logging of movement paths, useful in search and evacuation situations
- Sharing of thermal images and other data from the user to the command centre

The trial of the system prototype was conducted on Stena Flavia Aug 17-18th 2022 with interactions with the crew. Some of the findings are listed below:

- Some of pre-scanned object was not recognized in the positioning stage
- System seems sensitive to light conditions, must be same as the time of scanning
- System is not using visible location references like cabin numbers, etc.
- Not likely that the exact location would be determined inside a loaded cargo space, i.e., without additional aids.
- Wi-Fi, mobile network or similar is needed for full functioning and information sharing.
- Radio communications should be made available in the system in order to replace existing systems.
- Scanning procedure must be made less sensitive, using wide-angle cameras, allowing short distance scanning
- System may be improved by combining existing different localization concepts and algorithms
- One-time single button activation when starting patrol or leaving fire station
- Natural learning/improvements of system during operation should be provided
- Signs or letters are easier recognized with a square around or in a square with a different color than the background

See also D06.6, chapter 7.3.4 Localization drill [5].

After the onboard trials, it was clear that the system is currently far from being mature enough for implementation, in terms of basic functions, hardware, and adaptions to specific marine and ro-ro requirements and conditions.

6.2 Design and construction aspects

6.2.1 RCM Op6 -Technology for localization of first responders

The image localization technology is dependent on the recognition of objects in the vicinity of a assigned crew member. Further, the visibility of most objects is different for every cargo loading condition. This limits the number of available objects for localization.

Should such objects not be sufficient for a stable positioning, other technologies may be needed to add special unique objects/signs along the most important paths.

However, such combinations of technologies increase the complexity and cost, and a balance needs to be found (in terms of a compromise with accuracy rate).

6.3 Recommendations for the lifecycle cost assessment

6.3.1 RCM Op5 - First response guidelines

Cost will vary depending on the different ro-ro ship type, where the following cost items shall be considered:

Investment cost:

- New equipment (if applicable)
- Training of corporate safety management
- Company procedure updates
- Establish procedures per vessel
- Crew training

Operational cost:

- Crew training with yearly updates

6.3.2 RCM Op6 -Technology for localization of first responders

Cost will vary depending on the ro-ro ship type, where the following cost items shall be considered:

Investment cost:

- Server cost
- Software rental
- Network
- IR smartphones
- Fixed screens at bridge and ECR
- Investigation onboard
- Integration onboard
- Training of safety management
- Company procedure updates
- Ship procedure update
- Crew training

6.4 Proposal for improvements

6.4.1 RCM Op6 -Technology for localization of first responders

In its final state, the hardware of this technology must be integrated into the gear of the user in order to avoid manual handling of extra devices. Also, the system should support the communication basis so that the current UHF system may be replaced.

Focus should be placed on the ro-ro cargo spaces. For the moment, the performance is not satisfactory in a loaded cargo space, and several technologies may need to be combined to give sufficient accuracy.

The targeted accuracy must be defined first and then the existing image concept may be investigated accordingly. If proved to be insufficient, the additional steps should be foreseen in order to reach the targeted performance.

The potential use of such a system requires the following items:

- Cabin search follow up
- Fire patrol location
- Fire team location
- Crew assembly prior to C02 release
- Replace fire patrol check point scanning

6.5 Conclusion

The good usage of first minutes after fire detection is usually of critical importance. Therefore, at RCM Op5, the definition of designated first response concept is of greatest value. Further, the mutual understanding of intentions is very important since terminology may vary between different operators and other stakeholders.

The considered technology and suggested system in RCM Op6 is very interesting for implementation on board ro-ro ships. However, after the onboard trials, it was clear that the system is currently far from being mature enough for implementation, in terms of basic functions, hardware, and adaptions to specific marine and ro-ro requirements and conditions. It is proposed to focus on the ro-ro cargo spaces. For the moment, the performance is not satisfactory in a loaded cargo space, and several technologies may need to be combined to give sufficient accuracy.

7 Effective and efficient manual firefighting- Action 6-D

Main author of the chapter: Martin Carlsson, STL

This chapter gives an overview of the ship integration evaluation for Action 6-D, i.e., effective and efficient manual firefighting. The RCM proposed by WP06 and assessed within this report is:

- RCM Op7 -Training, new equipment, and procedures to suppress APV fires with special focus on Li-Ion batteries fires

For the description of the solutions, refer to Deliverable D04.9 [1].

7.1 Operational aspects

7.1.1 RCM Op7 - Training, new equipment and procedures to suppress APV fires

This RCM is not fully defined yet at this point, but for the sake of this evaluation is assumed to contain the following:

- Recommended manual fire-fighting methodology for:
  - Electric cars
  - LNG cars
  - CNG cars
- List of recommended equipment to support methodology
- Recommendations for PPE and fire suits
- Method for post treatment of gear and crew

Operational value is undoubtedly positive, as it could increase the knowledge and competence to handle these situations. The operational cost is very low, limited to the extra cost for content to be included in the external training, if needed.

7.2 Design and construction aspects

7.2.1 RCM Op7 Training, new equipment and procedures to suppress APV fires

At this moment, water monitors on weather decks are not a requirement. However, this is an important prerequisite for handling a fire incident, especially for APVs with gas tanks and electric cars.

7.3 Recommendations for the lifecycle cost assessment

7.3.1 Op7 Training, new equipment and procedures to suppress APV fires

Cost will vary depending on the ro-ro ship type, where the following cost items shall be considered:

<u>Investment cost:</u>

- Additional equipment
- Cooling devices
- Fire blanket
- Fognails
- Push talk button
- Fire suits EN 469 Level 2 Wheel

- Hood
- Spare second layer
- Post mission treatment kit
- Company procedures development
- Ship procedures development
- Training cost (Advanced firefighting)

7.4 Environmental aspects

7.4.1 RCM Op7 Training, new equipment, and procedures to suppress APV fires

During the extinguishing of a fire, large quantities of extinguishing media mixed with fire by-products are released into the environment.

A detailed assessment will be performed for the developed solution and the existing state of the art so that the environmental impacts of different systems can be compared.

7.5 Proposal for improvements

7.5.1 RCM Op7 Training, new equipment, and procedures to suppress APV fires

The content of this RCM should be more clearly defined.

Recommendation should best relate to and be in line with the recent issues identified in the *EMSA Guidance for safe transport of APVs.*

Experience from performed tests in parallel with other projects results, such as DBI Elbas project, should be considered in Op7 recommendations.

A proposal for the updates of the STCW code should be recommended by LASH FIRE to explicitly cover car deck fires and APVs, based on the outcome of Op7. Crew training on board and at training centres.

Due to vague and undetermined definitions related to potential crew safety aspects, it is important to distinguish between unprotected first response and regular fully equipped firefighting.

Recommendations on fire blankets and/or water cooling devices would be highly valuable to support investment decisions for operators.

The performance of traditional/existing equipment for APV fires should be established to serve as a reference for any additional measures proposed.

The size of the electric cars/batteries used in the WP6 tests and training modules should be set in relation to other larger cars and batteries. Methods and equipment proposed to crew should work safely on all available car types on the market.

7.6 Conclusion

All stakeholders, from IMO and Flag states to crewmembers are positively awaiting guidance in this area, so the value of RCM Op7 shall not be overestimated.

It is of outmost importance to communicate clear instructions on how to practically deal with APV's, especially electric car fires, with assigned crew in order to clear any doubts and hesitations.

8 Improved bridge alarm panel design - Action 7-A

Main author of the chapter: Michael Stig, DFDS

This chapter gives an overview of the ship integration evaluation for the Action 7--A i.e. Improved bridge alarm panel design. The RCMs proposed by WP07 and assessed within this report are:

- RCM Des1: User friendly alarm system interface design guidelines
- RCM Des2: Alarm system interface prototype

For the description of the solutions please refer to Deliverable D04.9, [1].

8.1 Operational aspects

A design guideline for the industry for bridge alarm panel design is highly welcomed and needed, as great differences are visible in the alarm designs currently fitted on board many ships, ranging from quite user-friendly and intuitive systems to rather basic systems that provide very little guidance (or perhaps even provide misguidance) to the crew/operator.

Current challenges include:

- An overload of information/alarms including non-essential alarms to the crew/operator. All information needs to be processed by the crew with the risk of causing work overload.
- Many audible alarms (too many) that cause stress and confusion to the crew/operator.
- A “mute it all” function is needed, as currently one person could be needed just to mute alarms, though current legislations do not allow for such a setup.
- Unclear presentation of the various alarms to the operator.
- One common system display for all alarms, currently on some ships alarms are scattered around on many different displays/panels.
- Different terminology and risk of mismatch if several systems refer to the same information

8.2 Design and construction aspects

Main author of the chapter: Ivan Vidic, FLOW

The proposed design guideline is welcome to improve practices in ship design, specifically to adopt a new view in system design considering human interaction and organizational practices. It is understood that the guideline was developed focusing on organizational solutions, where integration of the solution into ship systems was not in the focus and found not to be mature for a full integration evaluation.

Furthermore, the integration of the solutions will largely depend on the designer and ship operator as well as selected systems that are, or required to be, installed on board, and its manufacturer, communication possibilities, etc.

The main alarm system interface integration issue foreseen could be a collision of controls and commands with other systems. Some examples are listed below:

- Fire dampers contacts are often used for ventilation starters, these contacts need to be duplicated to be able to use them within the proposed solution. This will include modification in starter cabinets and cabling.

- Ventilation is controlled by the vessel alarm system, and in case of fire control shall be taken from the vessel alarm system. This needs to be communicated with the supplier of the alarm system because it will cause modifications on that system as well.

- All additional signals, which are not gathered over communication while needed in the proposed solution system, will be hardwired, so complete solution should have I/O cabinet to get all the signals which are needed.

Regarding the abovementioned issues, the integration to existing vessels will vary significantly, depending on the installed equipment, and this is difficult to evaluate. Further, relevant adjustments and approval may be challenging and depending on the ship, and possibly not integrable. The conclusion is that the solution development shall focus on new buildings only.

For the new buildings, the solution is integrable, considering all above-mentioned issues, and it is largely dependent on the ship system providers (and their willingness to adjust their products to the proposed solution requirements).

A potential approach could be to integrate the improved bridge alarm panel design as part of the alarm and control system. In that case, only the fire alarm system should be connected to the alarm system to get all the relevant data. However, collaboration with the system suppliers is necessary.

Potential issues that could be foreseen are related to class approval, as all these systems (fire system, and alarm system) are subject to class approval. Modifications on these systems are not allowed without appropriate class exemption.

Integration examples (on generic ships in LASH FIRE project) are necessary to fully evaluate the integration feasibility and to perform the cost assessment.

8.3 Recommendations for the lifecycle cost assessment

Main author of the chapter: Vito Radolovic, FLOW

An installation cost assessment shall be performed for the two selected solutions:

- Des1: User friendly alarm system interface design guidelines
- Des2: Alarm system interface prototype

The following cost items shall be considered:

<u>Investment cost:</u>

- Cost of the systems per components
- Cost of integration with other ship systems
- Cost of software and licenses (if applicable)
- Cost of engineering, documentation and administration;
- Cost of installation and commissioning;
- Cost of classification/certification;

Operation cost:

- Cost of crew training,
- Cost of consultation (if applicable)
- Cost of maintenance;
- Cost of auditing/survey;

8.4 Proposal for improvements

Main author of the chapter: Ivan Vidic, FLOW

For the alarm system interface development it is proposed to focus on software development and guidance for software development towards suppliers of alarm and control systems. If accepted by suppliers of these systems, integration will be much easier as no additional system would then be added. Instead, system which is already used will be improved and expanded to fulfil the required functionalities.

8.5 Conclusion

Main author of the chapter: Vito Radolovic, FLOW

A design guideline for the industry is highly welcomed and needed for a harmonisation of the alarm designs, as currently various system designs may be found on board ships, ranging from quite user-friendly and intuitive systems to systems that provide very little guidance or perhaps even provide misguidance to the crew/operator. The proposed guideline is focusing on organizational solutions where the integration of the solution into ship systems was not in focus and found not to be mature for a full integration evaluation.

Integration of the solutions into ship systems will largely depend on the designer and ship operator as well as systems that are, or required to be, installed on board. Further, relevant adjustments and approvals are found to be challenging, specifically for existing ships. The integration to existing ships is found to be very difficult to evaluate and the conclusion is that the solution development shall focus on new buildings. For the new buildings, the solution may be easily integrable, considering that a complete solution according to the proposed system requirements is available on the market, i.e., from the ship system providers.

For the alarm system interface development, it is proposed to focus on software development and guidance for software development towards suppliers of alarm and control systems.

9 Efficient extinguishing system activation and inherently safe design - Action 7-B

Main author of the chapter: Michael Stig, DFDS

This chapter gives an overview of the ship integration evaluation for the Action 7-B, i.e., firefighting resource management centre. The RCMs proposed by WP07 and assessed within this report are:

- RCM Des3: Procedures and design for efficient extinguishment system activation
- RCM Des4: Training module for activation of extinguishing systems

For the description of the solutions please refer to Deliverable D04.9 [1].

9.1 Operational aspects

9.1.1 Des3 Procedures for efficient extinguishment system activation

The impacts of implementing the procedures and design for efficient extinguishment system activation may significantly vary depending on the ship, crew, etc. To improve the communication, the conclusion is that radio communication shall be carried out in the defined working language of the vessel, not necessarily in English.

For the reflection, evaluation and change process, it is proposed to further describe facilitators training/skillset.

Regarding the integration example referring to a minor impact, it is found to be a fairly simple and easy solution to implement on board, with a low impact on the current operations on board. Further, as a number of similar drills are already being conducted, this could be implemented into one of these mandatory drills. Regarding the integration example referring to a major impact, about remote activation of the drencher system, it would most likely have a significant impact as many existing ro-ro ships do not have the possibility for remote activation of drencher systems. However, for new vessels could be beneficial to have remote activation points. In terms of a minor integration impact, no significant difference would be imposed, as it can be integrated into existing drills on board to a large extent. In terms of a major integration impact, it would obviously have a significant effect for those vessels currently not fitted with remote activation points.

Regarding CO_2 activation procedures, the systems are quite complicated and many steps need to be followed in sequence, and it is crucial that all steps are considered and well described. Generally, in a fleet with many vessels and different crews for each vessel, it is most likely valuable to have harmonized company standards. If different crews are allowed to change the procedures, they might deviate a lot between different vessels in the end. The decision of changing routines should be made by an authorized party in the company.

The outcomes of the training session within WP7 will provide valuable output.

9.2 Des4 Training module for activation of extinguishing systems

The advantage of the training module for the activation of extinguishing systems should be a significantly faster release of the firefighting system, especially in the case of drencher systems. For CO_2 systems, a 100% accurate head count of the crew is still needed for obvious safety reasons, where a conclusion is that the related shall be done on board, not ashore at a training facility. Further, enhanced and frequent drills could also lead to a faster head count.

Specifically for CO_2 systems, there are many different manufacturers and the hands-on experience is important for each system. It should be considered how this problem of variety can be taken care of in a single training centre. It is proposed to further consider this aspect as well as potential training sessions at the facilities of the system manufacturer.

Regarding drencher system activation, the general view is that onboard training would add more value compared to onshore training.

It is proposed to specifically mention the existing courses used as starting point for the development.

Finally, outcomes of the training sessions within LASH FIRE will provide valuable output in this area.

9.3 Design and construction aspects

Main author of the chapter: Vito Radolovic, FLOW

9.3.1 Des3 Procedures for efficient extinguishment system activation

Generally, the complexity of the vessel increases and additional space may be required when a new system is introduced or modifications are made in the existing systems. The integration impact of Des3 solution is expected to be manageable for new buildings where the equipment and system adjustments could be integrated in the design at an early stage. For existing ships, the integration impact can vary significantly, and shall be assessed on a case-by-case basis. Further, the arrangement of additional system equipment within existing service and cargo spaces may be challenging for a designer, particularly due to the fact that exact design drawings for all adjacent structural elements and equipment may not exist. Much of the design would need to be adapted to the actual as-built construction onboard.

Therefore, the proposed solution Des3 implementation impact shall be assessed using the generic ships Magnolia Seaways (ro-ro cargo), Stena Flavia (ro-pax) and Torrens (vehicle carrier) and considered for the cost assessment.

9.4 Recommendations for the lifecycle cost assessment

Main author of the chapter: Vito Radolovic, FLOW

An installation cost assessment shall be performed for the two selected solutions:

- Des3: Procedures and design for efficient extinguishment system activation
- Des4: Training module for activation of extinguishment systems

The following cost items shall be considered:

<u>Investment cost:</u>

- Cost of the additional systems components (if applicable)
- Cost of engineering, documentation, and administration
- Cost of installation and commissioning
- Cost of classification/certification

<u>Operation cost:</u>

- Cost of training
- Cost of maintenance

9.5 Conclusion

Main author of the chapter: Vito Radolovic, FLOW

The implementation of the procedures and design for efficient extinguishment system activation (Des3) is found to be feasible for new buildings with no significant impact on the cost whereas for existing ships it may significantly vary depending on the ship, crew, etc.

Training for the activation of extinguishing systems (Des4) is deemed to significantly improve the release procedures of the firefighting systems, thereby enabling a faster response. Regarding drencher system activation, the conclusion is that onboard training would add more value compared to onshore training.

10 Firefighting resource management centre - Action 7-C

Main author of the chapter: Michael Stig, DFDS

This chapter gives an overview of the ship integration evaluation for the Action 7-C i.e. firefighting resource management centre. The RCMs proposed by WP07 and assessed within this report are :

- RCM Des5: Integrated solutions for fire resource management, combining relevant sources of information, including drone and camera monitoring system
- RCM Des6: Guidelines for organizing the response in case of a fire emergency

For the description of the solutions please refer to Deliverable D04.9, [1]

10.1 Operational aspects

10.1.1 Des5 - Integrated solutions for fire resource management, combining relevant sources of information, including drone and camera monitoring system

Presentation of all information needed and available in an integrated and attractive way would be very valuable for operators.

For new builds, it is important that the Firefighting Resource Management Centre (FMRC) replaces existing interfaces to avoid extra cost, to reduce equipment in safety centre, and to avoid having multiple sources of information.

During routine fire patrolling, there are areas of a fully loaded cargo deck that are virtually inaccessible to a human since the cargo is often stowed very tightly. The introduction of dynamic machine fire patrolling is deemed to provide a significant improvement towards early detection and hence the general fire safety on board.

With the enhanced data that drones and their moveable sensors can provide, it is expected that decision making during firefighting becomes easier, faster, and more reliable.

This new stream of data provides intelligence that would not be available through stationary sensor equipment or by human intelligence due to potential unacceptable risks to human life in a fire scenario.
Weather conditions may have significant impacts on the functionality of outside drones.

10.1.2 Des6 - Guidelines for organizing the response in case of a fire emergency

Debriefing sessions are already common after drills, which are sometimes organized with all the participants, and sometimes only with the officers. Guidance on how to hold debriefing sessions in the best way could be highly valuable, as it would ensure a stable learning process for individual and organizational learning.

Outcomes of the training sessions and workshops within LASH FIRE will provide valuable output.

10.2 Design and construction aspects

Main author of the chapter: Ivan Vidic, FLOW

Design and integration aspects of the proposed solution Des5 are considered as an additional functionality of the solution Des2 (Ref. Chapter 8), including exterior flying drones, crawling drones, CCTV etc. Further, it is assumed that proposed equipment (drones) is available on the market.

The integration impact of solution Des2 is considered to be manageable for new buildings, where the equipment and system adjustments could be integrated in the design at an early stage. For existing ships, the integration impact can vary significantly, and shall be assessed on a case-by-case basis. Further, the arrangement of additional system equipment and/or functionalities within existing service and cargo spaces as well as relevant ship systems may be challenging for a designer, particularly because exact design drawings and descriptions may not exist. Much of the design would need to be adapted to the actual situation onboard. Additional aspects are discussed in Chapter 8.

The impact of proposed solution Des5 shall be further assessed based on concrete examples, using the generic ships Magnolia Seaways (ro-ro cargo), Stena Flavia (ro-pax) and Torrens (vehicle carrier) and further considered for the cost assessment.

10.3 Recommendations for the lifecycle cost assessment

Main author of the chapter: Vito Radolovic, FLOW

An installation cost assessment shall be performed for the two selected solutions:

- Des5: Integrated solutions for fire resource management, combining relevant sources of information, including drone and camera monitoring system
- Des6: Guidelines for organizing the response in case of a fire emergency

10.3.1 Des5 - Integrated solutions for fire resource management, combining relevant sources of information, including drone and camera monitoring system

Des5 is considered as an add-on to Des2 (Ref. Chapter 8). The cost related to the process part of Des5 are included in Des2. This cost assessment shall only include the drone system for monitoring the open decks and the cost of system add-ons required by deploying a drone on the ship. As the Des2 assessment is only for new builds, Des5 is assessed as an add-on to Des2 in the same way.

The following cost items shall be considered:

<u>Investment cost:</u>

- Cost of the systems per components
- Cost of integration with other ship systems (if applicable)
- Cost of software and licenses (if applicable)
- Cost of engineering, documentation, and administration
- Cost of installation and commissioning (if applicable)
- Cost of classification/certification

Operation cost:

- Cost of crew training
- Cost of consultation (if applicable)
- Cost of maintenance
- Cost of auditing/survey

10.3.2 Des6. Guidelines for organizing the response in case of a fire emergency

The following cost items shall be considered:

Investment cost:

- Cost of the systems per components

Operation cost:

- Cost of crew training
- Cost of maintenance

10.4 Conclusion

Main author of the chapter: Vito Radolovic, FLOW

The proposed integrated solutions for fire resource management (Des5) are found to be very valuable to the ship operator as they include integrated sources of information and additional equipment that finally lead to significant improvements towards early detection, easier and faster decision making and hence increased fire safety on board. Accordingly, the impact of the proposed solution shall be further assessed based on concrete examples and further considered for the cost assessment.

Guidelines for organizing the response in case of a fire emergency (Des6) would ensure a stable learning process for individual and organizational learning.

11 Automatic screening and management of cargo hazards- Action 8-A

Main author of the chapter: Martin Carlsson, STL

This chapter gives an overview of the ship integration evaluation for the Action 8-A i.e. automatic screening and management of cargo hazards. The RCMs proposed by WP08 and assessed within this report are :

- RCM Pre1a: Cargo scanning and identification and tracking system
- RCM Pre1b: Automatic screening with rolling drone
- RCM Pre2: Stowage planning tool with optimization algorithm for cargo distribution

For the description of the solutions please refer to Deliverable D04.9, [1].

11.1 Operational, design and construction aspects

This chapter reflects the integration evaluation aspects from the perspective of ship operators, and it summarizes the results of discussions with the development team about relevant proposed solutions.

11.1.1 RCM Pre1a: Cargo scanning and identification and tracking system

The solution will contribute to identifying and avoiding fire risks on board and highlighting units with increased fire risk for extra attention during voyage. Information from scanning will enable fact-based decision making and resource prioritization.

It is not yet clarified in what way the terminal staff or crew should act upon the identification of a hazardous unit. Routines must be established/suggested so that operational consequences may be evaluated.

The location of the screening equipment is not predefined. Nevertheless, it is essential to define the optimal location and timing of an automatic screening function to enable its full evaluation from the operational perspective. Accordingly, the equipment is assumed to be located either at the terminal gate, at the ramp of the ship, or at another suitable location inside the terminal area.

Guidelines for the space requirement and geometric configuration of the automatic screening system need to be defined (distances, heights, driving areas entry and exit etc.) to fully evaluate the integration of the solution.

11.1.2 RCM Pre1b: Automatic screening with rolling drone

The idea with a moving screening device is interesting since large number of cargo units/vehicles can be covered with less equipment.

To move across the deck safely and autonomously, following items need to be considered:

- Lashing pots, elephant feet, illustrated on Figure 11
- Fishbone anti slip patterns, 6x6 mm bars welded to deck, illustrated on Figure 11
- Weld seems, gaps at hatches
- Movable ramps

- Lashing equipment, with loose ends on deck, illustrated on Figure 12, Figure 13and Figure 14
- Cables
- Rubber wedges at random positions
- Other equipment, located especially in the perimeter of cargo space
- Ship structure and other fixed objects
- Water pools on deck
- Vehicle tyres
- Trailer trestles
- Manholes
- Working equipment on deck such as water and pneumatical hoses

Figure 11. Fishbone pattern and lashing pot of elephant foot type on a ro-pax vessel.

Figure 12. Cargo lashings on a ro-pax vessel.

Figure 13. Cargo lashings, wheel rubber wedges, rubber mats, trailer trestles, manhole lids, other foreign objects on ro-pax vessel.

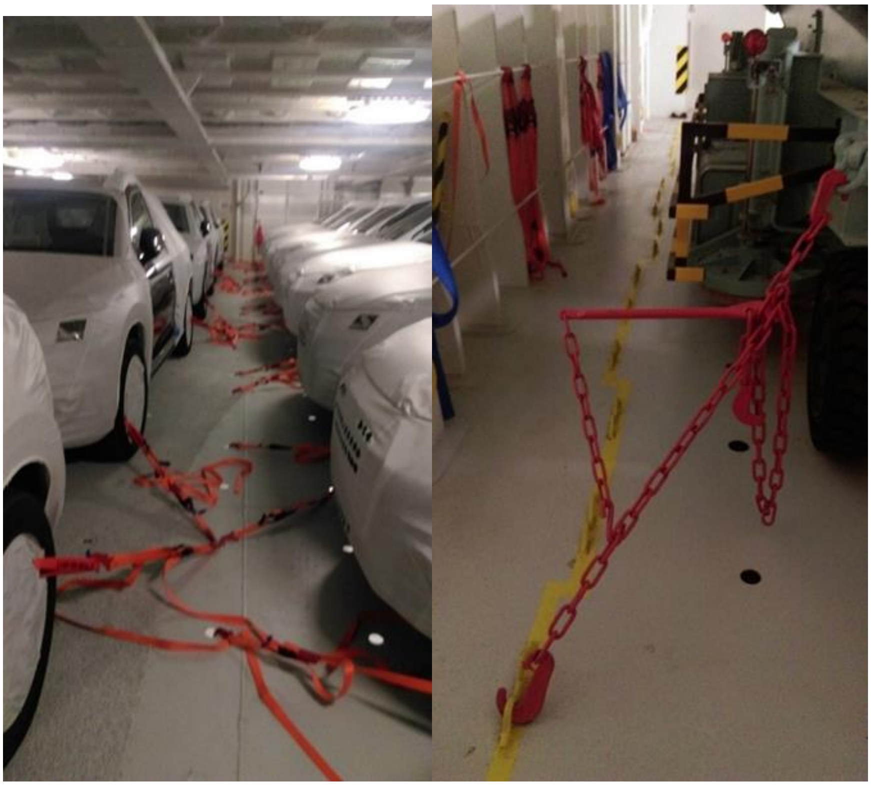

Figure 14. Car lashings and cargo lashings on a vehicle carrier.

In order to cover the maximum number of vehicles, wayfinding algorithms must be developed considering "ideal" regular lane parking, transitions from for example 6-7 lanes, random pattern parking and mix of vehicle types in the same area, especially in the forward and aft part of cargo deck.

The drone-to-ship communication infrastructure should be determined, considering low availability of wi-fi on cargo decks on ro-pax today, although a client demand may trigger further development of such systems in the future on this type of vessel. For ro-ro cargo ships and vehicle carriers, there is no foreseen establishment of communication network in cargo spaces.

Effective routes regarding loading condition and parking pattern for each departure shall be considered.

Operation on hoistable car decks shall be also considered, as large number of cars can be placed on such decks.

Charging stations arrangement for drone as well as related infrastructure need be defined.

Implementation example on at least one generic ship is necessary for further evaluation. Number of AGVs per ship and/or per deck shall be defined/suggested, scanning strategy to be defined and frequencies estimated.

11.1.3 RCM Pre2: Stowage planning tool with optimization algorithm for cargo distribution

Gathered information from the proposed system will provide more transparent overview to the actual fire safety situation onboard as well as provide decision support for increase of fire safety level on each voyage. It may also lead to continuous crew learning to improve localization of fire dangerous units in relation to vessel conditions and other units. Also, on a statistical level, operator may gain knowledge of dangerous concentration of fire risks in operations.

A list of potential users and portable equipment shall be described to fully evaluate the solution.

Information foreseen to be transferred to different stakeholders (first officer, loading officer, AB on deck, stevedores, tugmaster drivers) via system shall be described as well as different actions foreseen by stakeholders upon the received information.

Regarding tool output accuracy perspective, it is important that the tool is continuously updated with respect to the fire safety database, learning from events and evolving knowledge.

11.2 Recommendations for the lifecycle cost assessment

An installation cost assessment shall be performed for the two selected solutions:

- Pre1a: Cargo scanning and identification and tracking system
- Pre1b: Automatic screening with rolling drone
- Pre2: Stowage planning tool with optimization algorithm for cargo distribution

Open items as well as suggestions for improvement described in Chapter 11.5 shall be assessed for the cost assessment.

11.2.1 RCM Pre1a: Cargo scanning and identification and tracking system

The following cost items shall be considered:

Investment cost

- Cost of the systems per components
  - Foundations ground works
  - Portal building/protection shed
  - Brackets frame for sensor system
  - Sensor system
  - Other required equipment
- Cost of integration with operators/terminal IT system
- Cost of software and licenses
- Cost of engineering, documentation and administration
- Cost of installation and commissioning
- Cost of classification/certification

Operation cost

- Cost of staff/crew training and manning
- Procedures development
- Cost of inspection
- Cost of maintenance
- Cost of auditing/survey (if applicable)
- Cost of operational limitations (if applicable)
  - More time required for loading operation (if applicable)
  - Arrangement of parking space for identified unit with increased fire risk
  - Reactions based on identification of increased fire risk including false alarms
- Cost of insurance (cargo damage in case of system malfunction)

11.2.2 RCM Pre1b: Automatic screening with rolling drone

The following cost items shall be considered:

Investment cost

- Cost of the systems per components
  - Drone
  - Charging stations
  - Other required equipment
- Cost of integration with ships systems
  - Electrical system
  - Wi-fi or equivalent
  - Connection to ship safety management system
  - other
- Cost of software and licenses
- Cost of engineering, documentation and administration
- Cost of installation and commissioning
- Cost of classification/certification

Operation cost

- Cost of staff/crew training and manning (if applicable)
- Cost of maintenance
- Cost of auditing/survey (if applicable)
- Cost of operational limitations (if applicable)
- Cost of insurance (cargo damage in case of system malfunction)

11.3 Pre2: Stowage planning tool with optimization algorithm for cargo distribution

The following cost items shall be considered:

Investment cost

- Cost of the systems per components
    - Software, hardware
- Cost of software and licenses
- Cost of engineering, documentation and administration
- Cost of installation and commissioning
- Cost of classification/certification (if applicable)

Operation cost

- Cost of crew training and manning (additional working time)
- Procedures development
- Cost of maintenance (software/hardware updates)
- Cost of auditing/survey (if applicable)
- Cost of operational limitations (if applicable)
    - Extra turnaround time due to influence on decisions and rearranging stowage plan

11.4 Environmental aspects

No direct environmental impact of significance is foreseen.

11.5 Proposal for improvements

11.5.1 RCM Pre1a: Cargo scanning and identification and tracking system

Acceptance criteria and operational routines need to be developed.

Optimal location of portal needs to be evaluated, close to ship or at gate or in between.

Interaction with the manual screening may be evaluated with respect to fire hazard identification i.e. which solution is intended to identify specific fire hazards.

11.5.2 RCM Pre1b: Automatic screening with rolling drone

Scope of screening is to be further evaluated.

11.5.3 RCM Pre2: Stowage planning tool with optimization algorithm for cargo distribution

Interface to existing stowage planning software needs to be developed, probably the best approach would be to make an interface test with one of the common stowage plan solutions.

Output format needs to be established.

Operational consequences by using the tool shall be assessed as may have considerable impact on stowage time and cost. Further, procedures shall be established for different scenarios such as late arrival of cargo units etc.

The risk index algorithm to be evaluated and calibrated according to operational stowage scenarios.

The solution output can also be further used on a higher level to draw attention to the fire safety level and enable follow up, in statistical terms, on fire risks is taken by an operator/ship/route/client etc. This could help optimizing fire safety resources.

The location vs cargo type risk contribution matrix could be used to evaluate different ship designs in terms of fire safety.

11.6 Conclusion

A potential fire safety issue should be discovered as earlier as possible in order to be able to increase level of fire safety. Therefore, all considered solutions are of high interest from WP5 perspective, and it is strongly recommended to assess open items as much as possible in order to increase their impacts.

12 Guidelines and solutions for safe electrical connections - Action 8-B

Main author of the chapter: Martin Carlsson, STL

This chapter gives an overview of the ship integration evaluation for the Action 8-B i.e. guidelines and solutions for safe electrical connections. The RCMs proposed by WP08 and assessed within this report are :

- RCM Pre3 - Develop guidelines for safe electrical power connections in ro-ro spaces for reefer units
- RCM Pre4 - Develop guidelines for safe electrical power connections in ro-ro spaces for charging of EVs

For the description of the solutions please refer to Deliverable D04.9, [1].

12.1 Operational aspects

12.1.1 RCM Pre3 - Develop guidelines for safe electrical power connections in ro-ro spaces for reefer units

Implementing this solution, it is expected that more risk situations will be detected but, as a consequence, more false alarms might be generated. This issue should be further tested and evaluated during onboard demonstration. Time from first alarm to confirmed risk will be shorter if reaction on alarm from monitoring system is treated with more sense of urgency compared to current operational practice. Refusing/terminating electrical connection will definitely lead to objections from client/driver and this may also lead to bad compromises such as running reefer units with truck engines, either continuously or intermittently. The worst-case scenario might be loss of cargo due to no cooling operations at all. Therefore, crew must be quite sure there is an actual or possible fire situation before taking such decisions to disconnect loads from ship's electrical network. Knowledge of status (audio & visual alarm on cargo deck) instantly after electrical connection would be of great value since crew may then have the opportunity to relocate unit onboard where, for example, running on diesel is permitted or other cable connections are available, depending on actual problem. Anyhow, all clients should be timely informed that electrical connections may be refused in certain risky conditions.

12.1.2 RCM Pre4 - Develop guidelines for safe electrical power connections in ro-ro spaces for charging of EVs

Some EV charging systems include monitoring of charging session and vehicle, while less advanced ones therefore require external monitoring such as proposed. It is certainly a great advantage to have access to a "black box" monitoring system, as this gives flexibility for different charging solutions.

False alarms have to be eliminated to avoid poorly based interruption in charging service to client.

12.2 Design and construction aspects

The proposed solution for monitoring the reefer units and EV charging is considered manageable for both new buildings and existing ships.

For new buildings, the equipment could be integrated in the design at an early stage while for existing ships, minor modifications and addition of necessary cabinets and other supporting infrastructure should make it feasible.

For existing ships, the equipment can be integrated with negligible impact on the ship arrangement and cargo area. However, the arrangement of additional system equipment within existing service spaces and cargo area together with existing structural elements would be demanding for a designer. This is particularly so since exact design drawings for all relevant equipment and systems may not exist. The complexity of the vessel will increase when introducing a new system and additional space will be required and hence much of the design would need to be adapted to the actual as-built construction onboard. It is deemed manageable to carry out the installations and testing within a normal docking time frame of 2 weeks.

12.3 Recommendations for the lifecycle cost assessment

An installation cost assessment shall be performed for the two selected RCMs:

- RCM Pre3: Develop guidelines for safe electrical power connections in ro-ro spaces for reefer units
- RCM Pre4: Develop guidelines for safe electrical power connections in ro-ro spaces for charging of EVs

The following cost items shall be considered:

<u>Investment cost:</u>

- Cost of the systems per components
    - larger and/or extra cabinets, etc.
    - cables
    - Other Electrical Equipment, control panels, etc. (if applicable)
    - Other required equipment
- Cost of integration with other ship systems
- Cost of software and licenses (monitoring system)
- Cost of engineering, documentation and administration
- Cost of installation and commissioning
- Cost of classification/certification

<u>Operation cost:</u>

- Cost of training
- Cost of inspection
- Cost of maintenance
- Cost of auditing/survey
- Cost of operational limitations
    - Refusing/terminating electric connection may lead to objections from client/driver
- Cost of operational benefits
    - EV charging
- Cost of insurance (cargo damage in case of system malfunction)
- Cost of handling high risk suspected cases, communication to drivers, hauliers etc.

12.4 Proposal for improvements

12.4.1 RCM Pre3 - Develop guidelines for safe electrical power connections in ro-ro spaces for reefer units

Elaboration of the integration of system into Magnolia Seaways is needed for the life cycle cost assessment.

12.4.2 RCM Pre4 - Develop guidelines for safe electrical power connections in ro-ro spaces for charging of EVs

No improvements identified

12.5 Conclusion

With these solutions in place, there would be a clear added value providing more precise analysis of reefers and EV's in terms of status and location of a problematic units. The crew gets a better insight of fire risk assessment and will have the possibility to act with higher attention. Therefore, response times and investigation effort will be shorter.

However, the complexity of the vessel will increase due to implementation of a new system.

13 Fire requirements for new deck materials - Action 8-C

Main author of the chapter: Vito Radolovic, FLOW

This chapter gives an overview of the ship integration evaluation for the Action 8-C i.e. fire requirements for new deck materials. The RCM proposed by WP08 and assessed within this report is:

- RCM Pre5: Proposal for requirements of surface materials in ro-ro spaces, with reference to suitable test method and material property performance criteria

For the description of the solutions please refer to Deliverable D04.9, [1].

13.1 Operational, design and construction aspects

Main author of the chapter: Urban Lishajko, WAL

The main issues related to the usage of non-regulated materials on commercial ships are extensive, time consuming and costly design and approval process. This usually discourage both the shipyards and ship operators at the very beginning which finally leads to usage of materials regulated by relevant Classification Societies and Authorities. By determining the requirements, specifically for reaction to fire properties of non-regulated materials, it may lead to a reduced lead time and cost of the design and approval process and may generally increase the application of such materials on ro-ro ship. Further, it will reduce uncertainties during the design and approval process as well as during operation in case of a fire scenario. It may further help the crew in fire management operations.

Composite materials are of high interest due to their known lightweight properties, which leads to a reduction of fuel consumption and CO2 emissions. Application of composite materials may also reduce the production process lead time and cost production as well as maintenance cost reductions. Structural application of composite materials on ro-ro decks would cover a significant part (area) of the ro-ro space and potentially have significant influence within a fire scenario. Similar influence may also have other material systems such as insulation and coating systems.

Intumescent coating systems could be of particular interest for cargo decks and bulkheads separating vehicle spaces on vehicle carriers. Normally the cargo space is divided horizontally into several vehicle spaces. Since 2014, these spaces must be separated by A-30 class decks and bulkheads. The ordinary fire insulation with pins, washers and cloth constitutes a considerable weight of these three decks which could probably be reduced if intumescent systems would be used instead. Further, insulation in between ventilation trunks serving different spaces, if required, could be replaced by intumescent systems, which would enable more freedom in the ventilation arrangement design. Ordinary insulation in ventilation ducts must normally be avoided since the environment is harsh and maintenance is difficult. Damaged insulation could be difficult to inspect and could cause cargo damage or contamination.

13.2 Environmental aspects

Knowledge on reaction to fire properties of materials will increase the knowledge on potential impact to the environment.

13.3 Conclusion

Having available the knowledge of the material requirements, specifically for reaction to fire properties, it may lead to a reduced lead time and cost of the design and approval process by reducing uncertainties and may generally increase the application of such materials on ro-ro ship. Further, it may have positive impact during fire management operations.

Most interest is found in composite materials and intumescent coating systems.

14 Means for detection on weather deck - Action 9-A

Main author of the chapter: Sif Lundsfig, DFDS

This chapter gives an overview of the ship integration evaluation for the Action 9-A i.e. Means for detection on weather deck. The RCMs proposed by WP09 and assessed within this report are:

- RCM Det1 - Flame wavelength detectors
- RCM Det8 - Thermal imaging (infrared) cameras

For the description of the solutions please refer to Deliverable D04.9, [1].

14.1 Operational aspects

From ship operators' point of view, there is a concern on how to handle the practical part of mounting/sensor threshold adjustment on both mentioned solutions. This is a manageable task, but might require more frequent cleaning and maintenance on sensors and this should be reflected in the cost assessment evaluation. Also, further input from ongoing tests on board Hollandia Seaways both on false alarms and cleaning of detectors would be a valuable input on evaluating the solution.

A detection system requires regular and periodical inspections, testing and maintenance as well as training that require time, competence, and planning. Maintenance and inspection may be difficult if such equipment is installed on superstructures with limited access as well as on standalone supports.

14.2 Design and construction aspects

The design is using the generic ships Magnolia Seaways (ro-ro cargo) and Stena Flavia (ro-pax) as a baseline. The onboard tests are conducted on Hollandia Seaways, for practical reasons (still ongoing at the time of writing this report).

The complexity of the vessel will increase due to the implementation of a new system and additional space will be required. Both systems are considered to be manageable for new buildings where the equipment could be integrated in the design at an early stage. For existing ships, the equipment could be integrated with a minor impact on the ship arrangement and cargo area. Further, the arrangement of additional system equipment within existing service and cargo spaces may be challenging for the designers, particularly due to the fact that exact design drawings for all adjacent structural elements and equipment may not exist. Much of the design would need to be adapted to the actual as-built construction on board.

Equipment supports shall be carefully arranged to minimize the impact on the cargo area, passageways, etc. and shall be designed to withstand the design loads (equipment loads, weather loads, etc.) and to avoid vibrations (for example, tensioners may be arranged).

The impacts of the additional weight on the stability and fuel consumption of ships can be disregarded.

14.3 Recommendations for the lifecycle cost assessment

Main author of the chapter: Vito Radolovic, FLOW

An installation cost assessment shall be performed for the two selected solutions:

- Det1: Flame detectors
- Det8: thermal imaging (infrared) cameras.

The following cost items shall be considered:

Investment cost:

- Purchasing cost:
    - Cost of the systems per components
    - Cabling
    - Supports, hangers, mounting brackets etc.
    - Electrical Equipment, control panels, etc. (if applicable)
    - Other required equipment
- Cost of software and licenses (if applicable)
- Cost of engineering, documentation, and administration
- Cost of installation and commissioning
- Cost of classification/certification

Operation cost:

- Cost of training and manning
- Cost of inspection
- Cost of maintenance
- Cost of auditing/survey
- Cost of insurance (cargo damage in case of system malfunction)

14.4 Proposal for improvements

Recommendations for fire sensors' installations and settings, such as height, range, sensitivity etc. shall be provided.

14.5 Conclusion

The two solutions proposed have potential to increase the possibility of detecting fires on weather decks. Since the detectors will be placed on existing superstructures, it should be possible to place sensors such that cleaning and maintenance are feasible without requiring a lot of auxiliary equipment on board. Further instructions on how to adjust sensor sensitivity settings for the entire length of the weather deck will be needed and it should be expected to have a certain trade-off between early detection and false alarms occurrence.

Further information on false alarm frequencies as well as cleaning and maintenance requirements are expected after the operational evaluations and testing on board DFDS vessel Hollandia Seaways.

15 New means for fire detection in closed and open ro-ro spaces - Action 9-B

Main author of the chapter: Michael Stig, DFDS

This chapter gives an overview of the ship integration evaluation for the Action 9-B i.e. new means for fire detection in closed and open ro-ro spaces. The RCMs proposed by WP09 and assessed within this report are:

- RCM Det3 - Video detection
- RCM Det4 - Adaptive detection threshold settings
- RCM Det7 - Fibre optic linear heat detection

For the description of the solutions please refer to Deliverable D04.9, [1].

15.1 Operational aspects

The limitation of linear heat detection is straightforward as only heat can be detected and not smoke particles. However, given the continuous measurements along the sensor cable, it is understood that the sensitivity of the system is generally higher than a system consisting of several point heat detectors. Further, compared to combined heat and smoke detectors, the linear heat detection system requires a separate system for the detection of smoke particles. Ideally, the systems may be connected to the same user interface.

A big advantage provided by the linear systems is that they require very minimal maintenance from the crew side. In contrast to traditional point detectors which require cleaning and inspection for each individual unit, the sensor cable of a linear heat detection system is quite heavy-duty and the system constantly monitors any faults along the cable in a systematic way, which can be brought to the attention of the crew along with the temperature information that is provided as a heat map of the protected area.

Another advantage is the improved coverage with the continuous measurements along the sensor cable as well as the short distances between the cable routes in the linear system compared to traditional spacing sensors as per the FSS code [3].

VFD & VSD systems offer some potential as many ro-ro operators already have CCTV installed on ro-ro cargo decks. Most modern cameras are easily compatible with VFD and VSD, but older ships may have CCTVs with varied coverage and picture quality, and thus it is possible that some CCTV systems are not suited/detailed for VFD & VSD. Hence, new installations or upgrades might be needed in some cases.

VSD systems on closed cargo decks are reliant on the ambient light conditions. This may have significant effect on their reliability for the detection of smoke as, with current focus on environmental footprint, many shipping companies swich off all lights in closed cargo decks whilst at sea. Lights are also switched off due to “light pollution” in terms of night vision for the bridge team during night-time navigation.

The VSD & VFD use of CCTV installed in open environments such as weather decks and open ro-ro decks may need frequent maintenance from the crew side in terms of cleaning camera lenses for unwanted smear.

15.2 Design and construction aspects

Main author of the chapter: Vito Radolovic, FLOW

The design is assessed based on the generic ships Magnolia Seaways (ro-ro cargo), Stena Flavia (ro-pax) and Torrens (vehicle carrier) as a baseline. The on-board tests for the linear heat detection and video fire detection systems are conducted on Hollandia Seaways as part of operational evaluations (ongoing at the time of writing this report).

The complexity of the vessel will increase when introducing a new system, and additional space may be required. All systems are considered to be manageable for new buildings where the equipment and system adjustments could be integrated in the design at an early stage. For existing ships, the equipment could be integrated with a minor impact on the ship arrangement and cargo area. However, specific detection system software adjustments are needed, especially regarding the adaptive threshold settings for detection where existing systems may not support relevant adjustments. Furthermore, the accurate cost estimation of the relevant adjustments and approval related to the adaptive threshold settings for detection may be challenging, but the costs are assumed to be too high to be acceptable for the ship operator. It is expected that this solution shall be considered for new buildings only, where no additional cost is expected, compared to the currently used detection systems.

The arrangement of additional system equipment within existing service and cargo spaces may be challenging for a designer, particularly due to the fact that exact design drawings for all existing structural elements and equipment may not exist. Much of the design drawings would need to be adapted on the spot onboard to the actual as-built construction and this would be a time-consuming task.

Equipment supports shall be carefully arranged to minimize the impact on the cargo area, passageways etc. and shall be designed to withstand the design loads (equipment loads, weather loads, etc.) and avoid vibrations (for example, tensioners may be arranged). Specifically, installation of supports for the fibreoptic linear heat detection may be challenging.

The impacts of the additional weight on the stability and fuel consumption of ships can be disregarded.

15.3 Recommendations for the lifecycle cost assessment

Main author of the chapter: Vito Radolovic, FLOW

An installation cost assessment shall be performed for the two selected solutions:

- Det3: Video fire detection
- Det7: Linear heat detection.

The following cost items shall be considered:

Investment cost:

- Purchasing cost
    - Cost of the systems per components
    - Cabling
    - Supports, hangers, mounting brackets etc.

    - Electrical Equipment, control panels, etc if applicable.
    - Other required equipment
- Cost of software and licenses (if applicable)
- Cost of engineering, documentation, and administration;
- Cost of installation and commissioning;
- Cost of classification/certification;

Operation cost:

- Cost of training and manning;
- Cost of inspection,
- Cost of maintenance;
- Cost of auditing/survey;

15.4 Conclusion

Main author of the chapter: Vito Radolovic, FLOW

Both proposed solutions have a potential for increasing the possibility of detecting fires in closed and open ro-ro spaces.

Several advantages are found using linear heat detection compared to the traditional detection system, such as minimal maintenance requirements and improved coverage.

The VFD & VSD systems do seem to have a good potential as CCTV systems are already being used on ro-ro cargo decks, despite the fact that the coverage, picture quality and maintenance may pose a challenge. Moreover, early detection on open ro-ro decks is still an issue and not fully addressed by the proposed solutions, although the linear system is expected to offer earlier detection compared to the conventional point smoke/heat detectors.

The solution of adaptive threshold settings for detection is expected to be only integrable for new buildings due to potential difficulties with system software adjustments and approval issues. The integration potential for existing ships highly depends on the systems installed on board, and in general it is found costly and not acceptable for the ship operators.

Further information on false alarm frequencies as well as cleaning and maintenance requirements are expected after the operational evaluations and testing on board DFDS vessel Hollandia Seaways.

16 Means for automatic fire confirmation, localization and assessment - Action 9-C

Main author of the chapter: Michael Stig, DFDS

This chapter gives an overview of the ship integration evaluation for the Action 9-C i.e. means for automatic fire confirmation, localization and assessment. The RCMs proposed by WP09 and assessed within this report are:

- RCM Det5 - Video detection
- RCM Det6 - Thermal imaging (infrared) cameras

For the description of the solutions please refer to Deliverable D04.9, [1].

16.1 Operational aspects

The provided description of RCMs is same as for relevant RCMs within Action 9A and 9B evaluated within Chapter 14 and Chapter 15, respectively. It is proposed to clearly describe the differences of proposed Action 9C RCMs compared to RCMs proposed within Actions 9A and 9B. Further, it is assumed that the RCMs proposed within Actions 9A and 9B already have integrated identical features as proposed within RCMs at Action 9C, where the use of such solutions may be different. Through Action 9C, it is assumed that the focus is on the visual confirmation regarding the location of the fire identified by the detector.

Infrared thermal imaging cameras do offer a big advantage compared to VSD & VFD as potential heat sources can be detected, enabling a visual confirmation of the location from a concealed fire without a direct line of sight, such that a secondary surface affected by the concealed primary heat source may be detected. Such cameras are also mostly unaffected by ambient light conditions.

Fewer thermal infrared cameras are likely needed to give sufficient coverage of a weather deck compared to VFD & VSD, which results in less maintenance/cleaning of the cameras.

VFD & VSD systems also offer some potential, as many ro-ro operators already have CCTV installed on ro-ro cargo decks. Most modern cameras are easily compatible with VFD and VSD, but older ships may have CCTVs with varied coverage and picture quality, and thus it is possible that some CCTV systems are not suited/detailed for VFD & VSD. Hence, new installations or upgrades might be needed in some cases.

VSD systems on closed cargo decks are reliant on the ambient light conditions. This may have significant effect on their reliability for the detection of smoke as, with current focus on environmental footprint, many shipping companies swich off all lights in closed cargo decks whilst at sea. Lights are also switched off due to “light pollution” in terms of night vision for the bridge team during night-time navigation.

Maintenance of CCTV for VSD & VFD, especially installed in open environments such as weather decks and open ro-ro decks, would need a lot of maintenance from crew side in terms of cleaning camera lenses for unwanted smear.

It appears that early detection on weather decks and open ro-ro decks is still an issue and not fully addressed here. However, thermal infrared imaging cameras may be a contributor to early detection of (concealed) fires on weather decks and open ro-ro decks.

For more aspects, please also refer to Chapter 14 for Thermal imaging cameras and Chapter 15, for Video detection system.

16.2 Design and construction aspects

For design and construction aspects, please also refer to Chapter 14 for Thermal imaging cameras and Chapter 15, for Video detection system.

16.3 Recommendations for the lifecycle cost assessment

For recommendations, please also refer to Chapter 14 for Thermal imaging cameras and Chapter 15, for Video detection system.

16.4 Conclusion

Thermal infrared imaging cameras have advantages over other systems (VSD & VFD) due to the ability to detect heat sources without direct line of sight to flames or smoke. Moreover, fewer cameras may be needed to give full coverage of a weather deck. Such cameras will work independently of ambient light conditions. Finally, thermal infrared imaging cameras may be a contributor to early detection of (concealed) fires on weather decks.

The VFD & VSD systems do seem to have potential as CCTV systems are already being used on ro-ro cargo decks. However, the coverage, picture quality and maintenance may cause challenges.

Further information on false alarm frequencies as well as cleaning and maintenance requirements are expected after the operational evaluations and testing on board DFDS vessel Hollandia Seaways.

17 Local application fire-extinguishing systems - Action 10-A

Main author of the chapter: Urban Lishajko, WAL

This chapter gives an overview of the ship integration evaluation for the Action 10-A i.e. local application fire-extinguishing systems. The RCMs proposed by WP10 and assessed within this report are:

- RCM Ext1a - A dry pipe sprinkler system. Note: This is per definition an automatic system
- RCM Ext1b - Ext1b: An automatic deluge water spray system utilizing open nozzles

For the description of the solutions please refer to Deliverables D04.9, [1] and D10.1, [2].

17.1 Operational aspects

The proposed RCMs are defined as a complement to the main fixed firefighting system and the system is intended as an add-on to the vessels firefighting equipment.

Technically the system itself will not affect the fixed firefighting system (i.e. CO2) or other systems.

The system with its pumps and valves is automatically activated upon the detection of fire and therefore the system would not require any regular daily operation from the crew. On the other hand, the system, which shall cover the complete cargo space, will require training, regular checks and maintenance which takes time from the crew. Service engineers from the system maker are required to come onboard in regular periods which also requires time from the crew.

Flexible hose connections to movable car decks will require special attention during decks' operation. This operations increase a risk of potential system malfunction as well as wear and tear of the hoses.

Wet pipe systems will pose risk for leakage from nozzles and joints and even the smallest contamination of cargo must be avoided by all means when transporting new cars. Thus, the necessary monitoring of potential leakage from such system would affect the crew workload. If a leakage occurs in an area loaded with cars, the access to the damaged part is often difficult or even impossible. If a leakage happens in the top part of the hold, the water would drip down through the lashing holes on all lower decks in the hold contaminating vehicles below.

17.2 Design and construction aspects

The complexity of the vessel will increase due to implementation of a new system and additional space will be required. The following areas should be mentioned:

- Main supply piping throughout the cargo hold
- Local piping and nozzles which shall be integrated with structure, cabling, lighting fixtures and fire detectors for the cargo decks
- Flexible hoses for movable decks which shall work together with flexible joints for electrical cables
- Space for pump stations for the required sections
- EX-class for electrical equipment inside the cargo hold
- Electrical load balance
- Control and monitoring of pumps and valves in Fire Control Station, Engine Control Room or Wheelhouse

- Water supply (Technical fresh water, sea water connection)
- Bilge system (for all vehicle spaces)
- Impact of the additional weight on ships stability and fuel consumption

The above items are considered to be manageable for new buildings where the equipment could be integrated in the design at an early stage.

Further, minor impact of the additional system weight (estimated 110 t) on ship stability (additional 30 t of water ballast in double bottom tanks estimated to reach same stability parameters as without the system) and fuel consumption (fuel consumption increased by 0.3 t/day of heavy fuel oil estimated for same loading conditions).

For existing vessels, the extensive pipe work within existing structures would be particularly demanding for a designer, partially due to the sheer size of the cargo decks and partially due to the fact that exact design drawings for all adjacent fittings and cabling may not exist. Much of the design would need to be adapted to the actual as-built construction onboard.

From a construction point of view on new buildings, the system and its piping could be integrated and built-in during block construction and outfitting.

The construction and installation on an existing vessel would have to be done in connection with a regular dry docking and to be prepared very carefully. The additional time required is difficult to assess and it comes down to the capacity of the repair yard and the price paid, but it is deemed challenging to carry out the installations and testing within a normal docking time frame of 2 weeks.

17.3 Recommendations for the lifecycle cost assessment

The following cost items shall be considered:

Investment cost:

- Cost of the systems (firefighting, detection, drainage, if applicable) per components
    - Pumps, valves, nozzles, sprinklers, detectors, etc.
    - El. Equipment, control panels, etc.
    - Piping, couplings, flexible hoses, hangers
    - Thermal insulation and heat tracing
    - Bilge and scuppers arrangement
    - other
- Cost of engineering, documentation and administration
- Cost of installation and commissioning
- Cost of classification/certification

Operational cost:

- Cost of training and manning
- Cost of inspection
- Cost of maintenance
- Cost of auditing/survey
- Cost of operational limitations

    - increased fuel oil consumption due to added weight
    - effect on ship stability due to added weight (additional ballast water weight)
- Cost of insurance (cargo damage in case of system malfunction)

17.4 Proposal for improvements

Main author of the chapter: Vito Radolovic, FLOW

Proposals for development are listed below:

- Increase the allowable channel length, required per proposed guidelines, to facilitate the design and installation of the system. Increased value would simplify the installation on typical Panamax Vehicle carriers with two rows of pillar structural arrangement, where the channel length is typically abt. Ship breadth/3=32.26 m/3=10.75 m)
- Increase the allowable maximum horizontal spacing between nozzles, required per proposed guidelines. Increasing the max spacing to 3.6 m, which is typical (average) transverse beams spacing, would increase the installation flexibility.

17.5 Conclusion

Main author of the chapter: Vito Radolovic, FLOW

Both RCM's are considered to be manageable for both new buildings and existing ships and increasing the level of fire safety. For new buildings the equipment could be integrated in the design at an early stage where for existing ships extensive and demanding work is expected. However, the complexity of the vessel as well as crew training, regular checks and maintenance will increase.

18 Weather deck fixed fire-extinguishing systems - Action 10-B

Main author of the chapter: Vito Radolovic, FLOW

This chapter gives an overview of the ship integration evaluation for the Action 10-B i.e. weather deck fixed fire-extinguishing systems. Three optional types of system controls are assessed and are suggested in the design and installation guidelines developed in WP10:

- Remotely controlled by operator
- Semi-autonomous (record and play function)
- Autonomous (with operator override)

It should be noted that only two RCMs were selected for the ship integration evaluation within LASH FIRE, as follows:

- RCM Ext3 - An autonomous fire monitor system (water only).
- RCM Ext4 - A remote-controlled fire monitor system using CAF

For the description of the solutions please refer to Deliverables D04.9, [1].

18.1 Operational aspects

It is presumed that the use of an autonomous or remote-controlled fire monitors for firefighting purposes are both more effective and considerably safer than manual firefighting involving crew members fighting a fire from deck level by means of fire hoses and similar equipment, especially as any manual operation of fire monitors shall be remote-controlled from a safe position.

A fire monitor system will, however, require regular and periodical inspections, testing, and maintenance as well as training that require time, competence, and planning.

Maintenance and inspection may be difficult if fire monitors are installed on superstructures with limited access as well as on standalone supports.

A fully autonomous system minimizes the crew involvement and further contributes to the ships autonomous operation.

Ultimately, a current requirement by Rules and Regulation for a safe location of a fire monitor can be reconsidered as no crew involvement is necessary at the monitor location. This will increase the design flexibility with respect to the system arrangement.

18.2 Design and construction aspects

The complexity of the vessel will increase due to the introduction of a new system and additional space will be required. The following areas for both proposed solutions are considered as follows:

- Main supply piping from the engine room to the weather deck, throughout the cargo hold (below the weather deck)
- Local piping cabling, fire monitor supports which shall be integrated with the structure, deck equipment avoiding interference with the cargo area, ships visibility, etc.
- Space for pumps, CAFS components and foam agent tank(s)
- Electrical load balance
- Control and monitoring of pumps and valves, fire monitors to Fire Control Station, Engine Control Room or Wheelhouse

- Water supply (Technical fresh water, sea water connection)
- Drainage system
- Fire detection system

The above items are considered to be manageable for new buildings where the equipment could be integrated in the design at an early stage.

For existing ships, the equipment could be integrated with a minor impact on the ship arrangement and cargo area. Further, the arrangement of additional system equipment (pump, CAF system, foam agent tank(s)) within existing service spaces or new spaces at superstructure decks, installation of fire monitor supports as well as pipe work within existing structural elements would be challenging for a designer. Particularly due to the fact that exact design drawings for all adjacent structures and equipment may not exist. Much of the design would need to be adapted to the actual as-built construction onboard.

From a construction point of view on new buildings, the system and its piping could be integrated and built-in during block construction and outfitting, with exception of the fire monitor stand-alone supports, if arranged, and fire monitors. Those shall be installed in the subsequent outfitting stage.

The construction and installation on an existing vessel would have to be done in connection with a regular dry docking and to be prepared very carefully. The additional time required is difficult to assess and to a large extent, it depends on the capacity of the repair yard and the price paid. However, it is considered challenging to carry out the installations and testing within a normal docking time frame of 2 weeks.

Fire monitors supports shall be carefully arranged to minimise the impact on the cargo area and shall be designed to withstand the design loads (equipment loads, weather loads, etc.) and avoid vibrations (for example, tensioners may be arranged).

The Impacts of the additional weight on ships stability and fuel consumption can be disregarded.

The system integration made for a reference ship, Magnolia Seaways, considers parts of the deck that are not arranged according to the guidelines which prescribes that a minimum of two fire monitors are installed in opposing angles. At the reference ship integration, parts of the deck area (B, C, D and E as illustrated on Figure 15) are not covered by two monitors. The system equipment would considerably differ for a full coverage compared to the proposed arrangement where additional fire monitors would be required. Although the fire monitor system arrangement is found to be acceptable, it is not clear how such arrangement will affect the prescribed system requirements and/or affect the system performance. In addition, a considerable deck coverage with two monitors is obtained, and found acceptable.

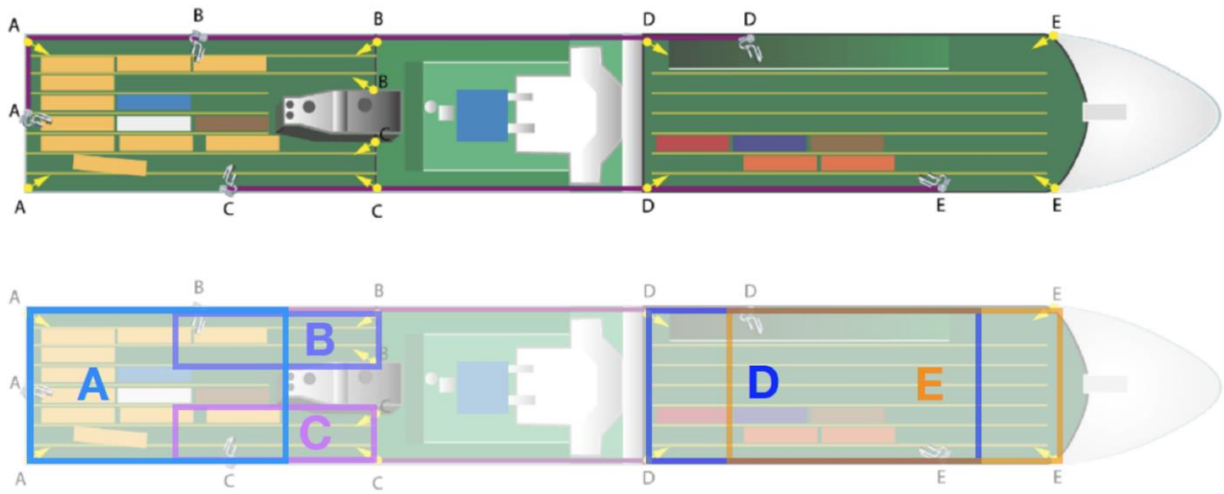

Figure 15. The layout of an autonomous fire monitor systems on the weather deck on Magnolia Seaways, with the positions of the monitors and the fire detectors.

Impact of the cargo area is found negligible. Further, the design of the fire monitor supports shall be carefully designed to avoid interference with the deck cargo area and passageways.

No major effect on the drainage system is expected according to the current rules and regulation requirements. Further, freeing ports area arranged along the weather deck enable a rapid discharge of the green loads (rain, snow, sea water/waves) from the weather deck and will serve for the drainage of the extinguishing media from the fire monitors as well. Although, case by case consideration about arrangement and dimensions of the freeing ports openings and drainage system is suggested.

Fire detection system is considered as an integrated part of an autonomous fire monitor system to both detect a fire and provide the exact location and as a recommendation, for a remote-controlled fire monitor system using CAF.

It is suggested to consider relevant rules and regulation whether the detection system used for the fire monitor system can be considered as part of the general fire detection system used on board.

18.3 Recommendations for the lifecycle cost assessment

An installation cost assessment shall be performed for the two selected solutions:

- Ext3: An autonomous fire monitor system (water only)
- Ext4: A remote-controlled fire monitor system using CAF

The following cost items shall be considered:

Investment cost:

- Purchasing cost
    - Cost of the systems per components
    - Pumps, valves, nozzles, etc.
    - CAFS system equipment and tanks
    - Piping, couplings, hangers
    - Fire monitors and control equipment
    - Supports for fire monitors
    - Electrical Equipment, control panels, etc. (if applicable)
    - Other required equipment
- Cost of software and licenses (for autonomous system)
- Cost of engineering, documentation, and administration
- Cost of installation and commissioning
- Cost of classification/certification

Operation cost:

- Cost of training and manning
- Cost of inspection
- Cost of maintenance
- Cost of auditing/survey
- Cost for foam agent testing and foam agent replacement (if needed)
- Cost of operational limitations
    - increased fuel oil consumption due to added weight
    - effect on ship stability due to added weight (additional ballast water weight)
- Cost of insurance (cargo damage in case of system malfunction)

18.4 Environmental aspects

Main author of the chapter: Francine Amon, RISE

During the extinguishing of a fire on a weather deck, large quantities of extinguishing media mixed with fire by-products gets released into the environment.

Detailed assessment will be performed for both the developed solutions and the existing state of the art so that the environmental impacts of different systems can be compared.

The information required for the life cycle analysis (LCA) considers production parameters including the materials, energy, transport, waste, and any known emissions to air, soil and water during the entire production chain. In addition to this, information about the installation, inspections, energy needed by the system during its service life, recharging of the systems, maintenance and length of service life is required. Finally, information related to the decommissioning and end of life of the systems is needed.

18.5 Proposal for improvements

Both RCM's are considered to be manageable for both new buildings and existing ships and increasing the level of fire safety. The use of an autonomous or remote-controlled fire monitors for firefighting purposes are both more effective and considerably safer than manual firefighting involving crew members, especially as any manual operation of fire monitors shall be remote-controlled from a safe position. A fully autonomous system minimizes the crew involvement and further contributes to the ships autonomous operation. Ultimately, a current requirement by Rules and Regulation for a safe location of a fire monitor can be reconsidered as no crew involvement is necessary at the monitor location. Deck coverage against system arrangement and performance may be further clarified for a more feasible integration requirement definition.

The complexity of the vessel as well as crew training, regular checks and maintenance will increase. Further, during the extinguishing of a fire on a weather deck, impact to the environment may be considerable.

. Generally, the guideline prescribes a minimum of two fire monitors coverage along the deck to minimize the effect of weather conditions (wind). Parts of the deck area "shielded" by deckhouses or superstructures can be found, which seems reasonable not to be protected with pair of water monitors, as suggested for the integration on the generic ship. It should be clearly described how such arrangement may affect the system definition according to the prescribed requirements by the guidelines focusing on performance against coverage.

18.6 Conclusion

Both RCM's are considered to be manageable for both new buildings and existing ships and increasing the level of fire safety. The use of an autonomous or remote-controlled fire monitors for firefighting purposes are both more effective and considerably safer than manual firefighting involving crew members, especially as any manual operation of fire monitors shall be remote-controlled from a safe position. A fully autonomous system minimizes the crew involvement and further contributes to the ships autonomous operation. Ultimately, a current requirement by Rules and Regulation for a safe location of a fire monitor can be reconsidered as no crew involvement is necessary at the monitor location. Deck coverage against system arrangement and performance may be further clarified for a more feasible integration requirement definition.

The complexity of the vessel as well as crew training, regular checks and maintenance will increase. Further, during the extinguishing of a fire on a weather deck, impact to the environment may be considerable.

19 Updated performance of alternative fixed fire-fighting systems - Action10-C

Main author of the chapter: Obrad Kuzmanovic, FLOW

This chapter gives an overview of the ship integration evaluation for the Action 10-C i.e. updated performance of alternative fixed fire-fighting systems. The RCM proposed by WP10 and assessed within this report is:

- RCM Ext5 - Development of a relevant fire test standard for alternative fixed water-based fire-fighting systems intended for ro-ro spaces and special category spaces

For the description of the solutions please refer to Deliverables D04.9, [1].

19.1 Operational, Design and Construction aspects

The development of the relevant fire test procedures for performance-based systems in more realistic and relevant manner will equalize the safety levels for prescriptive- and performance-based systems. The ultimate goal is that alternative systems can achieve similar or better performance properties as prescriptive-based system, with no additional costs regarding operational, maintenance and installation aspects.

The equalization of requirements for both types of fire-fighting systems should include equal ceiling height definition as well as taking into consideration typical deep deck beams in vehicle spaces. Additionally, the report suggests that the fire test procedures to be developed shall also consider alternative structural arrangement such as use of composite materials for ro-ro deck application, which is found a step forward to the facilitation of alternative materials implementation. The impact of the activation time to the performance of the fire suppression system should also be investigated or at least considered. As a starting point, a realistic activation time considering fire detection, confirmation and decision making should be applied. Further, impact of a temporary stopping of the drencher system to allow crew entering the space shall be considered.

The short horizontal clearances between parked vehicles which acts as shield preventing direct application of water from overhead sprinklers or nozzles should be also considered in development of new fire test procedures. Moreover, with growing EV market, a compilation of fire tests data from fires in electrical vehicles and the development of a passenger car mock-up that provides a heat release rate significant for a modern car, should also be used as input for the work.

To conclude, it is assumed that the routines for inspections, testing, and maintenance are judged similar for performance-based and prescriptive-based systems. The use of performance-based system is considered not resulting in additional operational costs.

19.2 Recommendations for the lifecycle cost assessment

It is impossible to accurately calculate lifecycle costs at the moment as it is not possible to describe in detail how the performance-based systems will completely be designed and installed. The objective of Action 10-C is not to literally develop any performance-based systems, instead it is to establish a harmonized performance level for performance-based systems that is similar to that of prescriptive-based systems.

19.3 Conclusion

The development of the relevant fire test procedures for performance-based systems in more realistic and relevant manner will equalize the safety levels for prescriptive- and performance-based systems. The ultimate goal is that alternative systems can achieve similar or better performance properties as prescriptive-based system, with no additional costs regarding operational, maintenance and installation aspects.

20 Division of ro-ro spaces - Action 11-A

Main author of the chapter: Vito Radolovic, FLOW

This chapter gives an overview of the ship integration evaluation for the Action 11-A i.e., division of ro-ro spaces. The RCMs proposed by WP11 and assessed within this report are:

Horizontal subdivision of ro-ro spaces:

- RCM Cont1b1 - A-30 fire insulation at decks separating ro-ro spaces
- RCM Cont1b2 - Extinguishing system simultaneously activated above and below sub-dividing deck

Vertical subdivision of ro-ro spaces:

- RCM Cont3b - Solid curtain, transversal mounting, fully rolled down
- RCM Cont3d - Solid striped curtain, transversal mounting, fully/partly rolled down

For the description of the solutions please refer to Deliverables D04.9, [1].

20.1 Operational aspects

20.1.1 Horizontal subdivision of ro-ro spaces

20.1.1.1 RCM Cont1b1: Fire insulation at decks separating ro-ro spaces

The proposed RCO will improve the safety level of the ship. However, the impact of the new installation may affect the cargo handling and stowage limitation, as described further in chapter 20.2.1.1.1. Further, maintenance will be more complicated compared to the current arrangement with no insulation applied, leading to increased maintenance cost.

20.1.1.2 RCM Cont1b2: Extinguishing system simultaneously activated above and below sub-dividing deck

The proposed solution will improve the safety level of the ship. The operation of the system might be slightly more complex than currently used extinguishing systems in way of ro-ro space deck area of activation. Maintenance and inspection activities are found to be same as for currently used system arrangement.

20.1.2 Vertical subdivision of ro-ro spaces

20.1.2.1 RCM Cont3b: Solid curtain, transversal mounting, fully rolled down

Need for a discontinuation in cargo stowage on deck will significantly influence cargo handling operations and cargo loading flexibility. Further, cargo capacity on the deck will be reduced which will have significant impact on the cost (loss of revenue). Results of the FIRESAFE II project showed that the arrangement of such stowage discontinuation on cargo decks will lead to a cost ineffective solution (assessment performed for Stena Flavia).

Use of curtain system on movable decks will increase the complexity of cargo loading/unloading operations. For more detailed description see Chapter 20.2.2.1.

From operational perspective, the gravity fail safe option may lead to unexpected injuries to crew and passengers as well as to damage of cargo.

It is recommended that the control of the curtain should be performed from a remote location such as fire control station or similar.

Additional crew training will be necessary.

20.1.2.2 RCM Cont3d: Solid striped curtain, transversal mounting, fully/partly rolled down

The operational aspects are similar as for Cont3b. Additional aspects are described below.

As the discontinuation of the cargo stowage on the deck is not required, there will be no or minor impact on cargo handling and cargo capacity. However, Installation of a striped curtain within ro-ro spaces with movable decks is questionable and may increase the complexity of the deck arrangement as well as cargo loading/unloading operation still leading to discontinuations of cargo stowage. For more detailed description see Chapter 20.2.2.2.

20.2 Design and construction aspects

20.2.1 Horizontal subdivision of ro-ro spaces

20.2.1.1 RCM Cont1b1: Fire insulation at decks separating ro-ro spaces

The proposed solutions consider additional installation of a fire class A60 or A30(Cont1b1) thermal insulation (based on stone wool) on decks not forming a boundary of a special category space. **These solutions refer to fixed decks only**. Fire class insulation shall be applied, and no structural fire integrity "A class" division shall be reached[1].

The proposed solutions are considered for ro-pax new buildings only.

Fire insulation in ro-ro spaces on ro-pax ships is mandatory for special category spaces boundaries and design and installation of such in a ro-ro space is very well known.

However, the complexity of the vessel will increase when introducing a new system affecting ship specific parameters. The most relevant technical aspects are described below.

20.2.1.1.1 Impact on ships main particulars and operational limitations

Depending on the deck structural arrangement and insulation requirements, the impact on the ship (deadweight, stability, fuel consumption, clear height) may vary. The insulation shall be arranged over the beam flange and impact on the clear height. Such structural arrangement is typical for both fixed and movable internal decks within a ro-ro space on ro-pax ships.

By keeping the designed clear height for cargo, the additional insulation thickness of 50-70 mm leads to increased distance between decks. Due to this, either the ship height shall be increased or deck structure height reduced. Both lead to increased weight and costs and have impact on the ship's payload and/or fuel consumption and stability requirements. The other option would be to reduce the design clear height which will have minor impact on the ship's parameters but potentially major impact on the ship operation by reducing the flexibility with respect to the cargo stowage. Increased

[1] according to the structural fire integrity definition at SOLAS (FTP Code, Part 3) the "A class" divisions shall "be capable to prevent the passage of smoke and flame to the end of the one-hour standard fire test".

weight of the new installed A60 insulation has minor impact (insulation specific weight 2.5-3.3 kg/m2).

20.2.1.1.2 Gas tightness requirement

From the solution description, the insulation shall only be applied where the full gas tightness is not required. A common definition usually used in rules and regulations, specify similar requirement as ”reasonably gas-tightness”, which is not fully clear. It can be assumed that SOLAS definitions are considered in such interpretations as well.

The required gas tightness of the internal decks, where openings in deck are usually arranged, as well as effect of openings on the deck fire integrity shall be better described. Openings arrangement and size can vary depending on the deck layout.

Further, arrangement of insulation below deck at openings, without closing the openings, is not acceptable from operational point of view as water may penetrate the insulation (for example, during a fire drill with activation of a water based extinguishing system). It is recommended to execute such openings watertight. Such closures would lead to an improved fire integrity at the deck area where the insulation is applied.

Assumptions related to typical openings arrangement on internal decks and solution implementation are listed below:

- access to decks (openings for cargo loading/unloading from rampway, escape routes) → no permanent closure i.e. no insulation applied
- openings in decks for passage of piping, cables, structure etc. with no permanent closure arranged (penetrations, lugs, etc) → closures and insulation to be applied only where applicable, otherwise arrangement is to be adjusted to avoid contact of insulation and water
- Openings in ventilation → same ventilation ducts may be used for internal cargo decks separating ro-ro spaces within individual special category space → no closure appliances and no insulation applied

20.2.1.1.3 Installation aspects

From a construction point of view, the insulation system on new buildings could be integrated in the typical construction and outfitting process.

20.2.1.2 RCM Cont1b2: Extinguishing system simultaneously activated above and below sub-dividing deck

The complexity of the vessel will increase when introducing a more stringent requirement and additional space might be required. The following areas are considered as follows:

- Main supply piping (increased diameter due to increased water flow requirement)
- Pumps (increased size/capacity due to increased water flow requirement)
- Electrical load balance

The above items are considered to be manageable for new buildings where the equipment could be integrated in the design at an early stage and integrated in the typical construction and outfitting process. The complexity of the proposed system arrangement may be considered similar as currently required system arrangement.

Impact of the additional weight on ships stability and fuel consumption can be disregarded.

20.2.1.3 Rules and regulation aspects

The development results showed that the hydrocarbon time-temperature curve better represented the heat exposure from realistic fire of particular cases.

In particular, the main result of the simulations was that only for the case of closed ro-ro space fully loaded with cars, the heat exposure is better modelled by the standard time-temperature curve (called cellulosic curve or ISO 834), which is a standard according to the FTP. But, for other cases i.e. ro-ro space fully loaded with trucks and open ro-ro space fully loaded with cars, the heat exposure is better represented by the hydrocarbon time-temperature curve which is more severe than the cellulosic time-temperature curve used to test and approve thermal insulation according to the FTP Code.

The above results and conclusions significantly affect current rules and regulations requirements and should be carefully presented to the stakeholders as it questions current standards. Such modifications shall have major impact on ship design and operational aspects.

Approach vs MCS/Circ.1615 (*Interim guidelines for minimizing the incidence and consequences of fires in ro-ro spaces and special category spaces of new and existing ro-ro passenger ships)* and Potential SOLAS2024 Amendments shall be considered as described below.

” The fire integrity of ro-ro decks separating ro-ro spaces should be at least A-30.”

[MSC.1/ Circ.1615/4.1]

Potential SOLAS 2024 Amendments related to Reg. 20.5 or Reg. 9.2 are considering the concept fire integrity of decks within a ro-ro spaces or special category space not forming part of the space boundaries where the fire integrity is also associated with an efficient fire-extinguishing system (Option 5.1, Option 5.2).

Option 5.1

SOLAS regulation Ch.II-2/9.6.2 is amended as follows:

6.4 *The fire integrity of decks within ro-ro spaces or special category space not forming part of the space boundaries shall be at least A-30*

Option 5.2

SOLAS regulation Ch.II-2/20.5 is amended as follows:

6.4 *Where a special category space or ro-ro space is sub-divided with internal decks, the fire rating of these decks shall be determined based on the capacity and arrangement of the fixed water based fire-fighting system. If the fixed water based fire-fighting system cannot simultaneously cover the applicable area above and below a given deck, this deck shall be of [tight steel] [A0] [A30] while any ramps and doors between decks shall be made of steel and of a design being as tight as practical. No fire rating is required if the fixed water based fire-fighting system can simultaneously cover the applicable area above and below a given internal deck.*

According to the above approach, the fire integrity of ro-ro decks separating ro-ro spaces should be at least A-30. However, the term fire integrity is not clearly described. Specifically, in way of gas tightness and closure of openings. Further, if A-30 fire integrity shall be reached, that would basically mean that a new ro-ro space would be created leading to no internal ro-ro decks within a ro-ro space. The proposed solution Cont1b1 may provide a clear requirement with respect to the fire integrity of ro-ro decks separating ro-ro spaces.

The solution Cont1b2 is found to support the ongoing work at IMO and potential SOLAS amendments which is well accepted.

20.2.2 Vertical subdivision of ro-ro spaces

The solutions Cont3b and Cont3d are considered for ro-pax and ro-ro cargo new buildings only.

The complexity of the vessel will increase when introducing a new system and additional space will be required. The following areas for both proposed solutions are considered as follows:

- arrangement requirements
- installation

20.2.2.1 RCM Cont3b: Solid curtain, transversal mounting, fully rolled down

From the installation aspect, the curtain system is considered to be manageable for new buildings where the equipment could be integrated in the design at an early stage, considering the following aspects and exceptions.

The most common structural arrangement within the vehicle spaces on ro-pax and ro-ro cargo ships includes a grillage consisting of long span transverse girders (side to side) and longitudinal girders, with no pillars. This leads to web heights of primary supporting structure (longitudinal and transversal beams) in the range 600 mm-1200 mm where beams are extending from side to side. Within the considered range, it is manageable to adjust both the structural and outfitting (piping, electrical cables, etc.) arrangements, with a minor influence on the ship design. However, in some cases the structural height may be too low for possible installation of the curtain casing without influence on ship height and/or clear height for cargo. Such structural arrangement is found on Deck2 of the generic ship Stena Flavia, where the Deck 2 structural height of 220 mm would not allow the installation of the curtain without a major impact on the Deck 1 or Deck 2 clear height. To keep the same clear heights, the overall ship height needs to be increased. Reducing the clear height will have impact on the operational cost, while increasing the overall ship height will have impact on the investment cost.

Installation within ro-ro spaces with movable decks is not described. It is assumed that could be manageable considering appropriate gaps between selected movable decks panels and appropriate deck lifting arrangements. As full width of the cargo space is to be arranged with a gap, special attention shall be given to movable deck supports. Cargo passage shall be possible over the gaps. If gaps size would not allow cargo passage, additional flaps may be arranged. Further, arrangement of the curtain without guides seems to be not appropriate in case of passage between the movable deck modules.

This would then increase the complexity of the deck arrangement as well as cargo loading/unloading operation.

As side guides are not applicable for most ro-ro and ro-pax ships (width of ro-ro space greater than 10 m), it is questionable how will the curtain perform in case of harsh weather (wind) when arranged in an open ro-ro space. This may have influence on the required length of the stowage discontinuation on deck, where no cargo stowage will be allowed.

Impact of the additional weight on ships stability and fuel consumption can be disregarded.

20.2.2.2 RCM Cont3d: Solid striped curtain, transversal mounting, fully/partly rolled down

The installation aspects are similar as for Cont3b. Additional aspects are described below.

Installation of a striped curtain within ro-ro spaces with movable decks is not described and found to be hardly manageable. As the curtain shall be rolled up to the cargo, it is not understandable how shall this be executed on the deck below the movable deck. An option could be to lower the curtain up to the cargo on the lowermost deck, leading to a discontinuation in the cargo stowage on the upper movable deck(s). This would then increase the complexity of the deck arrangement as well as cargo loading/unloading operation.

Another option could consider installation of a curtain below a movable deck but such configuration will have significant impact on the ship design and so found unacceptable.

It is found reasonable that the curtain stripe width is equal to the lane width, but it is to be noted that number of lanes may vary for the same deck. Lane width for trailers differs from the lane width for cars. Further, cargo height may vary. In case of a combined cargo stowage, gaps may be possible between lower cargo top edge and curtain lower edge.

The proposal is to investigate a curtain with more numerous stripes to increase the flexibility of the curtain and to reduce the probability of gaps.

20.3 Recommendations for the lifecycle cost assessment

20.3.1 Horizontal subdivision of ro-ro spaces

20.3.1.1 RCM Cont1b1: A30 Fire insulation at decks separating ro-ro spaces

The following items may be considered:

Investment cost:

- Material cost (insulation)
- Material cost (modified deck structure, increased ship height)
- Installation and commissioning cost

Operation cost

- Cost of operational limitations
  - increased fuel oil consumption due to added weight
  - Limitations due to reduced clear height (if applicable)
- Cost of maintenance

20.3.1.2 RCM Cont1b2: Extinguishing system simultaneously activated above and below sub-dividing

The following items may be considered:

Investment cost:

- Additional cost for increased pump capacity
- Additional material cost for increased water flow (increased supply piping diameter)

20.3.2 Vertical subdivision of ro-ro spaces (Cont3b, Cont3d)

The following items may be considered:

Investment cost

- Material cost (curtain system)
  - Curtain system
  - Cabling
  - Control panel
- Material cost (modified deck structure, increased ship height)
- Cost of engineering, documentation, and administration
- Installation and commissioning cost
- Cost of classification/certification

Operational cost

- Cost of training and manning
- Cost of inspection
- Cost of maintenance
- Cost of auditing/survey
- Cost of operational limitations
  - Limitations due to reduced brake in cargo stowage (if applicable)
  - Limitations due to reduced clear height (if applicable)
- Cost of insurance (cargo damage in case of system malfunction)

20.4 Proposal for improvements

20.4.1 Horizontal subdivision of ro-ro spaces (Cont1b1, Cont1b2)

The required gas tightness of the internal decks in way of insulation application, where openings in deck are usually arranged, as well as effect of openings on the deck fire protection shall be better specified. Openings arrangement and size can vary depending on the deck layout.

20.4.2 Vertical subdivision of ro-ro spaces (Cont3b, Cont3d)

For both Cont3b and Cont3d it is proposed that a functional requirement is set for definition of subdivision with curtains. For example, according to deck area, deck volume, cargo space length, etc.

Further, it is proposed that the curtain arrangement that follow the drencher zone is a requirement, rather than a recommendation.

Lowering the curtain on every voyage may be considered as well. This would avoid cargo damage by uncontrolled roll downs. However, this would certainly have negative effect on ventilation system and maintenance cost (as the curtain is not resistant for frequent operation).

20.5 Conclusion

The proposed horizontal subdivision considering fire insulation, is found integrable for new buildings where the installation may affect the cargo handling and stowage limitation and increase maintenance cost.

Rules and regulation requirements such as gas tightness and fire integrity shall be established and clearly presented. Further, currently presented assessment results and conclusions at proposed solution significantly affects current rules and regulations requirements and should be carefully presented to the stakeholders as it questions current standards.

Proposed Extinguishing system simultaneously activated above and below sub-dividing deck is found easily integrable and might be slightly more complex than currently used extinguishing systems in way of ro-ro space deck area of activation.

Vertical subdivision solutions are found to be manageable for new buildings. However, discontinuation in cargo stowage on deck shall be avoided as will significantly influence on cargo handling operations and cargo loading flexibility leading to significant increase of operational cost. Solutions description shell be further described including all design aspects, such as arrangement at movable decks, interference with surrounding structure, equipment cargo and crew passageways, etc.

Further, proposals for development are suggested including functional requirement and operational features.

21 Ensuring safe evacuation – Action 11-B

Main author of the chapter: Vito Radolovic, FLOW

This chapter gives an overview of the ship integration evaluation for the Action 11-B i.e., ensuring safe evacuation. The RCM proposed by WP11 and assessed within this report is:

- RCM Cont5 -Alternative disembarkation path based on slides

For the description of the solutions please refer to Deliverables D04.9, [1].

21.1 Operational aspects

Generally, the assembly process starts at early stages of an emergency development, in order to be ensured better support to passengers and to be prepared as much as possible for eventual evacuation. In some cases, the time frame between the assembly and evacuation stage is long.

It is assumed that the main reason for alternative evacuation in port is that all ordinary shore connections are unavailable.

It is presumed that the installation of additional LSA is both more effective and increase the possibilities for a safe evacuation. On the other side, the complexity of the evacuation procedure will increase, including potential risk of injuries and difficulties for children and old persons.

Additionally, the use of slides may be limited due to port limitation such as terminal or quay arrangement, etc.

Additional equipment would require regular and periodical inspections, testing, and maintenance as well as training that require time, competence, and planning.

21.2 Design and construction aspects

The assessment is performed for the solution Cont5, the alternative disembarkation paths based on slides.

The complexity of the vessel will increase when introducing a new system and additional space will be required on open deck for slides. More detailed technical specification of the slide system is required to fully assess the integration on board.

The above is considered to be manageable for new buildings where the equipment could be integrated in the design at an early stage.

For existing ships, the equipment (slides) could be integrated, but with an impact on the ship arrangement, mainly open deck, superstructure, ventilation and insulation arrangement below the installation. Impact on the cargo area may be considered negligible.

Further, the arrangement of additional system equipment (slides) within existing service spaces or open deck area within existing structures and equipment would be demanding for a designer. Particularly due to that deck area on the ship sides may not be available. Much of the design would need to be adapted having impact on the ship superstructures arrangement.

The construction and installation on an existing vessel would have to be done in connection with a regular dry docking and to be prepared very carefully. The additional time required comes down to the capacity of the repair yard and the price paid, but it is deemed manageable to carry out the installations and testing within a normal docking time frame of 2 weeks.

Impact of the additional weight on ships stability and fuel consumption can be disregarded.

21.3 Recommendations for the lifecycle cost assessment

An installation cost assessment shall be performed for the selected solution.

The following cost items shall be considered:

Investment cost

- Cost of the systems per components
  - Slides and related system
- Cost of engineering, documentation and administration
- Cost of installation and commissioning
- Cost of classification/certification

Running cost

- Cost of training and manning
- Cost of inspection
- Cost of maintenance
- Cost of auditing/survey
- Cost of operational limitations (if applicable)
- Cost of insurance (cargo damage in case of system malfunction)

21.4 Proposal for improvements

Disembarkation on one side only (to shore) should be considered for all people on board (passengers and crew) for the alternative disembarkation paths.

As this is an alternative escape route, it is suggested to consider less stringent flux requirement vs optimal. The flux requirement is a slide design parameter, which may have considerable impact on vessels with high number of people on board.

A generic requirement may be proposed, for example, number of slides per people on board. It is suggested to separate the requirements according to the ship type, focusing on ro-pax vessels. For ro-ro cargo and vehicle carrier it can be assumed that one slide per side would fulfill the requirements.

The pilot door has been disregarded as considered that the location does not offer a safe walk-off abandonment in case of fire in the ro-ro space. However, in case of new buildings, the design can be adjusted according to the alternative disembarkation requirement. Design guidelines for new ship could be developed, so the pilot door and evacuation routes from assembly stations can be designed for alternative evacuation, including fire integrity, stairways, corridors, dedicated embarkation ramp, etc.

The arrival at foreign port after safe return to port and safe evacuation is a topic not very well covered by present regulations, especially for ro-pax vessels (the scenario when the fire blocks ro-ro and passenger loading ramps and gangways also cannot be used due to foreign port). Therefore, a procedure may be further suggested and described within this Action challenge.

21.5 Conclusion

The assessment is performed for the solution Cont5, the alternative disembarkation paths based on slides. Generally, the solution is integrable into ship systems and operations, but a more detailed technical specification of the slide system is required to fully assess the integration on board and its costs.

Discussions within the MAAG&MOAG workshops showed that ship operators are strongly opposed to the further development of this solution, as it can cause injuries and be intimidating for passengers, especially for old persons or children.

It has been also considered if the pilot door solution could have been further assessed for new buildings. Finally, proposals for improvements are suggested in chapter 21.4.

22 Safe design with ro-ro space openings - Action 11-C

Main author of the chapter: Martin Carlsson, STL

This chapter gives an overview of the ship integration evaluation for the Action 11-C i.e., safe design with ro-ro space openings. The RCMs proposed by WP11 and assessed within this report are:

- RCM Cont7 - Closure of side openings
- RCM Cont8 - Shutters for side openings
- RCM Cont9 - Ship maneuvering to limit the effects of fire in critical areas
- RCM Cont10 - Safety distances between side and end openings and critical areas

For the description of the solutions please refer to Deliverables D04.9, [1].

22.1 Operational aspects

22.1.1 RCM Cont7 - Closure of side openings

The Closure of side openings will result in operational restrictions in terms of cargo operations and limitations in carried types of goods, so this solution is discarded.

22.1.2 RCM Cont8 - Shutters for side openings

No viable technical solution is presented, therefore this solution is discarded.

22.1.3 RCM Cont9 - Ship maneuvering to limit the effects of fire in critical areas

The choice of heading is Master's decision considering fire situation, weather, navigational and traffic conditions, evacuation/airlift activities and location of closest safe port. Optimal heading may change during evolvement of a situation.

The need to protect an LSA unit from smoke/heat may contradict the need to protect same LSA from sway and wind.

Ship's decision support system may in some cases include a reminder or basic one-line instruction on this topic.

Crew are generally well aware of the need to select best possible heading in emergency, but it can certainly be of good value to publish a guideline further emphasizing this topic and suggest strategies.

Each operator has to interpret the generic guideline to the actual configuration of the individual ship and establish their specific instructions down to an appropriate detail level.

The proposed level of detail in the maneuvering recommendation is good, still some sketches for understanding, showing preferable combinations of location of heat and smoke sources, LSA equipment and ship heading etc. would be a useful addition.

Influence on air flow on weather decks well protected by vertical side and front structures side may need to be considered.

22.1.4 RCM Cont10 -Safety distances between side and end openings and critical areas

Restrictions on aft and forward openings located in the traffic flow will have significant impact on direct cargo operations.

Restrictions on side openings would reduce the ability to carry by the administration decided categories of dangerous goods (DG).

22.2 Design and construction aspects

22.2.1 RCM Cont10 - Safety distances between side and end openings and critical areas

The proposed solution will potentially imply significant redesign of new ro-pax vessels with same deck arrangement. Implementation of safety distances for side openings may lead to complete banning of the open ro-ro space due to the reason that the minimum required area of openings, according to the Authorities' requirements, might not be fulfilled. During and since SSE7, the IMO process has expressed non-approval of a direct ban of open ro-ro decks. If the intention or practical consequence of any proposal restricting positions or number of side openings is actually a ban of open ro-ro deck, this situation must be taken into consideration.

Weather deck and dangerous cargo capacity should be maintained, especially for those with large passenger capacity.

Ambition to limit open roro-spaces is in contradiction to promoting well ventilated spaces for alternatively fuelled vehicles.

As the work within LASHFIRE resulted in longer safety distances, it was concluded that the safety distances based on FIRESAFE II study results, currently under discussion at IMO for SOLAS 2024 amendments, shall be used. However, the LASH FIRE study results may be used for the development of a suitable alternative design method enabling a case-by-case assessment, which can be useful from a design point of view and as a proposal for IMO. Analytical formulas under development at LASH FIRE shall be further assessed within WP5 in the next stage of the technical evaluation, if applicable.

22.3 Recommendations for the lifecycle cost assessment

A cost assessment shall be performed for the two selected solutions:

- Cont9: Ship maneuvering to limit the effects of fire in critical areas
- Cont10: Safety distances between side and end openings and critical objects

22.3.1 RCM Cont9: Ship maneuvering to limit the effects of fire in critical areas

The following cost items shall be considered:

<u>Operation cost</u>

- Procedure establishment per operator
- Instructions development for each ship
- Training

22.3.2 RCM Cont10: Safety distances between side and end openings and critical areas

The following cost items shall be considered:

Investment cost

- Cost of engineering, documentation and administration
  - Vessel general arrangement re-development
- Cost of installation and commissioning
  - Added steel/system cost because of modified General Arrangement (GA)
  - Added steel/system to “close” openings
- Cost of classification/certification

Operation cost

- Procedure establishment per operator
- Lost cargo capacity: Lane meters, DG space
- Increased turnaround time (if applicable)
- Mechanical ventilation(if applicable): investment, fuel consumption, space, maintenance
- Increased fuel consumption due to added weight

22.4 Proposal for improvements

22.4.1 RCM Cont9: Ship maneuvering to limit the effects of fire in critical areas

Supporting graphics should be added to help understanding.

22.4.2 RCM Cont10: Safety distances between side and end openings and critical areas

Along with muster stations and LSA, it is proposed to identify other objects and areas, which are worthy to protect. Further, fire safety distance criteria should then be established as function of type of area.

22.5 Conclusion

Two proposed solutions were discarded during the development and evaluation process as resulting in operational restrictions in terms of cargo operations and limitations in carried types of goods (Cont7) or no viable technical solution was presented (Cont8).

Guidelines for ship maneuvering proposed at RCM Cont9 is found manageable within ship operation. And can certainly be of good value further emphasizing this topic and suggest strategies.

As the proposed RCM Con10 may potentially imply significant redesign of new ro-pax vessels with same deck arrangement it was concluded that the safety distances based on FIRESAFE II study results, currently under discussion at IMO for SOLAS 2024 amendments, shall be used. However, the LASH FIRE study results may be used for the development of a suitable alternative design method enabling a case-by-case assessment, which can be useful from a design point of view and as a proposal for IMO.

Finally, along with muster stations and LSA, it is proposed to identify other objects and areas, which are worthy to protect. Further, fire safety distance criteria should then be established as function of type of area.

23 Ro-ro space ventilation and smoke extraction – Action 11-D

Main author of the chapter: Obrad Kuzmanovic, FLOW

This chapter gives an overview of the ship integration evaluation for the Action 11-D i.e., ro-ro space ventilation and smoke extraction. The RCMs proposed by WP11 and assessed within this report are:

- RCM Cont11 – Guidance on calculation of side openings in ro-ro spaces
- RCM Cont12 – Configuration of side openings in ro-ro spaces
- RCM Cont13 – Tactical guidelines for manual intervention
- RCM Cont14 – SOLAS requirement of reversible fans

For the description of the solutions please refer to Deliverables D04.9, [1].

23.1 Operational, design and construction aspects

It is obvious that openings and ventilation configuration play an important role on fire and smoke spreading. It is also obvious that there are lack of procedures and requirements related to ventilation management in case of fire. Therefore, proposed solutions tend to solve that known issues. This chapter gives a review from operational, design and construction aspects.

23.1.1 RCM Cont11 - Guidance on calculation of side openings in ro-ro spaces

The lack of unambiguous procedure how to calculate side openings was often a problem in design practice. Therefore, the proposed guidance that the side should only consider the area of the long sides of ro-ro space is a good attempt in way of rules and design consolidation.

However, such consideration may lead to a reduced design flexibility where some arrangements will not fall into any ro-ro space definition. Specifically, the proposed definition where the side height of maximum 150 cm shall be allowed for the ship's long sides for a weather deck to still be considered exposed.

An example of a commonly used arrangement is a ro-ro deck exposed to the weather from above but with closed both sides (engine casing, etc.) and closed forward and/or aft (other ro-ro space, ramp). Examples are illustrated on the following figures.

Figure 16. ro-ro deck with closed sides (1)

Figure 17. ro-ro deck with closed sides (2)

23.1.2 RCM Cont12 – Configuration of side openings in ro-ro spaces

The proposed solution considers opening configuration, primarily in open ro-ro spaces in order to decrease the oxygen supply in case of fire, while maintaining same level of required ventilation. What is also not clear is a background of open ro-ro space definition regarding 10% of the total area of the space sides, whether it is derived from mathematical formula or from empirical evidence, and this fact also required checking with computer simulation. The results proved that the minimum openings area must be indeed 10% of the total area of open ro-ro space sides in order that required air changes per hour are obtained. What remained unclear whether the openness of the space sides in closed ro-ro spaces up to 10% should be completely banned, as it is almost as vulnerable as an open ro-ro space in case of fire incident (as concluded in RISE RO5 project, Ref. [4]).

As for openings configuration, it will be interesting to see the results, as the optimal configuration regarding the fire issues could considerably influence the general and structural arrangement. Moreover, reducing the height of the openings would require a larger number of openings along the ship, where in some cases the requirement of 10% might not be possible to obtain due to other requirements such as closures in way of LSA, engine casings, communication and ventilation ducts or other arrangements. This would lead to banning of open ro-ro space and considerable influence to the ship design and operation as well as increased cost.

The proposed configuration of openings is manageable at a certain level on both generic ro-pax (Stena Flavia) and ro-ro cargo (Magnolia Seaways) ships.

23.1.3 RCM Cont13 - Tactical guidelines for manual intervention

As the ventilation system is, in most cases, specially customized for each ship, it is very difficult to issue general guidelines how to operate it during fire incidents. Therefore, standard procedure for most of the operators nowadays is to turn off the fans and close the dampers for avoiding the supply of oxygen and preventing the spreading of smoke. However, in such cases, the conditions are extremely difficult for firefighting team due to low visibility and fire time is extended with clear risk of fire spreading on other vehicles. Thus, the formulation of new tactical guidelines would relate to the ventilation operation during small fires, enabling better visibility and conditions to the first response firefighting team and enhancing the odds that the fire can be extinguished fast. Such guidelines, with instructions when to start or shut down the forced ventilation system, which fans may be started, could be very useful from operational and design aspects.

Requirement for the equipment within ducts (fans and related cabling) shall be more clearly presented. The opinion is that no requirement is necessary as the intention is that the equipment within ducts shall be functional at early stages of a fire, during small fires.

To finalise the evaluation within WP05, guidelines shall be provided for review.

23.1.4 RCM Cont14 - SOLAS requirement of reversible fans

The installation of reversible fans shall be recommended for closed ro-ro spaces and their usage will be restricted for smaller fires only (restricted to one vehicle fire). Design wise, reversible fans are well known and widely used on board ships. Further, the ducts and other relevant equipment should be resistant to fire and ventilation outlets should be conveniently located that exhausted gases and smoke do not spread into accommodation, assembly stations nor disrupt working of crew. Such implementation will most probably increase the overall cost of the ship, but the probability for a quick suppression of small fire could be increased. Operationally, the crew must be familiarized and trained with usage of reversible fans and fire procedures (ref to Cont13).

23.2 Environmental aspects

Environmental aspects are not considered as no direct environmental impact of significance is foreseen.

23.3 Recommendations for the lifecycle cost assessment

23.3.1 RCM Cont11 - Guidance on calculation of side openings in ro-ro spaces

No additional cost compared to the current state.

23.3.2 RCM Cont12 – Configuration of side openings in ro-ro spaces

The following cost items shall be considered:

<u>Investment cost</u>

- design and drawings for specific ORS arrangements
- additional equipment cost in case opening requirement for ORS cannot be fulfilled, if applicable, to be verified on generic ships

<u>Operational cost</u>

- Reduced flexibility in cargo type in case opening requirement for ORS cannot be fulfilled, if applicable, to be verified on generic ships
- Increased fuel consumption due to additional required power for ventilation system, in case opening requirement for OCS cannot be fulfilled, if applicable, to be verified on generic ships

23.3.3 RCM Cont13 - Tactical guidelines for manual intervention

The following cost items shall be considered:

<u>Operational cost</u>

- Continuous training of the crew

23.3.4 RCM Cont14 - SOLAS requirement of reversible fans

The following cost items shall be considered:

<u>Investment cost</u>

- Additional cost for reversible fans
- Additional cost for ventilation systems components related to the requirement to withstand the conditions that can be expected of the gases from a fire (cabling, insulation, etc.)

<u>Operational cost</u>

- Continuous training of the crew
- Additional maintenance cost

23.4 Proposal for improvements

23.4.1 RCM Cont11 - Guidance on calculation of side openings in ro-ro spaces

The proposed definition where the side height of maximum 150 cm shall be allowed for the ship's long sides for a weather deck to still be considered exposed significantly defers from the current weather deck arrangement that can be found in the world fleet.

In order to publish an interpretation guidance such as this, consequence analysis need to be made to clearly show the structure of the limits etc. and relation to current interpretation possibilities.

Even the proposal shall be considered for new buildings only, results and conclusions should be carefully presented to the stakeholders as it questions current design standards, where deck arrangements with side height more than 150 cm are considered as weather decks, which would not be the case implementing the proposed solution.

23.4.2 RCM Cont13 - Tactical guidelines for manual intervention

It is proposed to consider toxic gases during a fire such as from EV's or other APV's, dangerous goods and other cargo.

Influence of ventilation operation in cargo spaces on smoke spread via staircases or other paths to public spaces may be considered, even such spaces are protected by self-closing gas tight doors. Over pressure in staircases should be established in case of fire.

Manoeuvring guidelines in case of fire are also considered at the solution Cont9. It is proposed to develop a Manoeuvring guideline considering also Cont9.

23.4.3 Cont14 - SOLAS requirement of reversible fans

It is proposed to consider the requirement of the reversible fans installation as a functional requirement rather than the requirement to install reversible fans at all ventilation ducts. The proposed requirement may consider distance between ducts with installed reversible fans, area/volume or similar.

23.5 Conclusion

A guideline on calculation of side openings in ro-ro spaces that clearly define the requirement is well accepted as an ambiguous procedure how to calculate side openings was often a problem in design practice. However, parts of the proposed guidelines considering the allowable side height at weather decks shall be further considered as significantly defers from the current weather deck arrangement that can be found in the world fleet. It Is proposed to make a consequence analysis to clearly show the structure of the limits etc. and relation to current interpretation possibilities.

Developments within the RCM Cont12 is well received the result may provide optimal size and configuration of openings in a open ro-ro space maintaining the required ventilation. Suggested configurations are found manageable for new buildings.

As the ventilation system is, in most cases, specially customized for each ship, it is very difficult to issue general guidelines, considered at RSM Cont13, how to operate it during fire incidents. Such guidelines, with instructions on how to operate with the ventilation system, during a small fire, could be very useful from operational and design point of view. However, to finalise the evaluation within WP05 a guideline shall be provided for review.

24 Conclusion

Main author of the chapter: Vito Radolovic, FLOW

This report presents the ship integration evaluation results addressed to all the developments within the LASHFIRE project. It reflects an intermediate stage of the project and shall not be understood or used as a final outcome of the LASH FIRE project. It is important to highlight that the assessments were performed during the development process in order to obtain as high as possible impact on the developments from relevant maritime stakeholders included. Design, production, operational and environmental aspects were considered for all 20 Actions, including several solutions, including applicable ro-ro spaces and ro-ro ship types. The evaluation process involved continuous exchange with the development teams to further improve the developed solution and to ensure a feasible solution to be assessed through the life cycle cost, formal safety assessment and finally demonstration of the most promising solutions.

Finally, this report contributes to the LASH FIRE specific Objective 2:

> *LASH FIRE will evaluate and demonstrate ship integration feasibility and cost of developed operational and design risk control measures for all types of ro-ro ships and all types of ro-ro spaces.*

25 References

[1] LASH FIRE, *Preliminary impact of solutions and related testing and demonstrations plan (D04.9), 2022.*

[2] LASH FIRE, *Description of the development of local application system solutions (D10.1), 2022.*

[3] IMO, 2019, FSS Code, Consolidated Edition, as amended.

[4] Olofsson, A. et al., 2020. RO5 ro-ro space fire ventilation Summary report. RISE.

[5] LASH FIRE, *Development of smart alert of nearby first responders (D06.6), 2022.*

26 Indexes

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26.2 Index of figures