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Deliverable D05.8

Ship integration cost and environmental assessment

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Abstract

This report presents the life cycle cost (LCC) and environmental assessment results addressed to the developments within the LASH FIRE project.

The economic feasibility study of Risk Control Measures (RCMs) and Risk Control Options (RCOs) was conducted by LCC methodology where all related costs are included, from investment/production to operation/maintenance and until the end of the life span. A selection of solutions provided by specific developments was assessed where the LCC assessment was performed for integration on selected three generic ro-ro ship types, considering both new buildings and existing ships. Finally, more than 40 RCMs and 16 RCOs were assessed, resulting in more than 200 LCC assessments.

The LCC assessment results are used as input for the cost-effectiveness assessment of a selection of solutions, to be performed within WP04 in line with IMO formal safety assessment (FSA).

Further, environmental assessment using Life Cycle Assessment (LCA) methodology was performed for manual firefighting of a vehicle fire on the car deck of a ro-pax ship and two fixed fire protection systems (autonomous and remotely operated) on the weather deck of a ro-ro cargo ship. The LCA models include smoke emitted to the atmosphere, fire water run-off into surface water, replacing damaged vehicles and/or traction batteries (for manual firefighting), and replacing cargo (for weather deck fire protection). The manufacturing, use, and end-of-life phases of the devices and equipment developed for each of the new fire protection solutions were compared with reference cases in which a fire occurs but there is no new fire protection solution available to respond to it.

For manual firefighting of a vehicle fire, the results show that the ability to arrive at the fire quickly and use handheld fire extinguishers and/or a fire blanket reduces the overall impact of a fire considerably when compared with manual firefighting operations after the fire has developed or in the reference case. All three handheld fire extinguishers and the fire blanket had similar results, assuming the CAF extinguisher uses fluorine free foam.

There are very few fires on ro-ro cargo weather decks. For this reason, the impacts associated with manufacturing, use and end-of-life of the two fixed fire protection systems are higher than the impacts of fire, given the low probability of a fire occurring during the ship's lifetime. The autonomous system has more components, e.g., fire detectors and cabling, therefore its lifecycle impacts are higher than the remotely operated system. The autonomous system also has a faster activation time than the remotely operated system, which results in slightly lower smoke and fire water run-off impacts than the remotely operated system; however, the difference is very small due to the low probability of a fire occurring on the weather deck.

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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. For a selection of solutions, a Life Cycle Cost (LCC) and environmental assessments using life cycle assessment (LCA) were carried out.

It is crucial that ship designers and operators are involved in the assessment to provide reliable input, considering the design, production and operational processes.

The main challenges for the LCC assessment were to address all the application areas targeted by developed solutions, and to provide a clear picture of the relevant cost items.

Typically, the cost of the system is balanced against the cost of losses incurred if there is no system. The LCAs made it possible to include environmental consequences in the decision-making process together with other design factors such as cost, manufacturing processes, material availability, etc., during the development of fire protection systems in the LASH FIRE project.

1.2 Technical approach

To address the described problems and challenges above, LCC and LCA assessments were performed by WP05 Ship Integration, and input was provided to the development teams for the developed solutions separately.

Further, all types of ro-ro ships as well as new buildings and existing ships were considered where appropriate.

It is important to highlight that the assessments were performed during the development process in order to obtain the highest possible impact on the developments from relevant maritime stakeholders included. The LCC assessment process is illustrated on Figure 1, and the LCA process is similar. The LCC assessment results were exchanged with the LASH FIRE development teams and provided for the LASH FIRE WP04 Formal Safety Assessment (FSA), as illustrated in Figure 2. The LCA studies were developed in close coordination with LASH FIRE WP06 and WP10 partners.

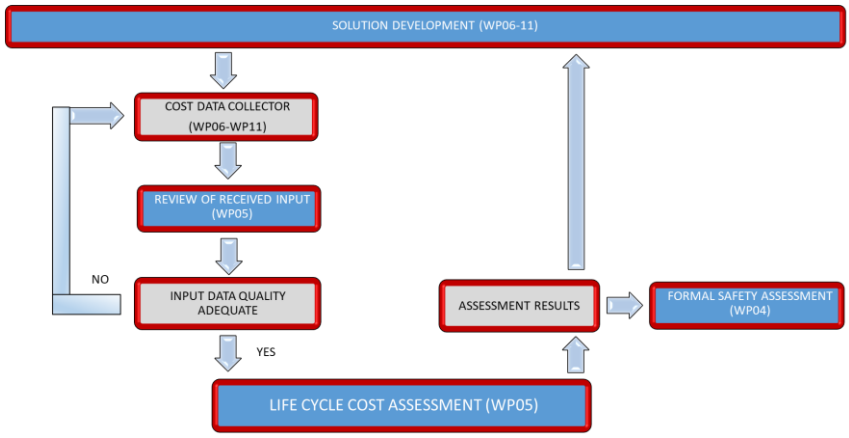

Figure 1. Life Cycle Cost (LCC) assessment process

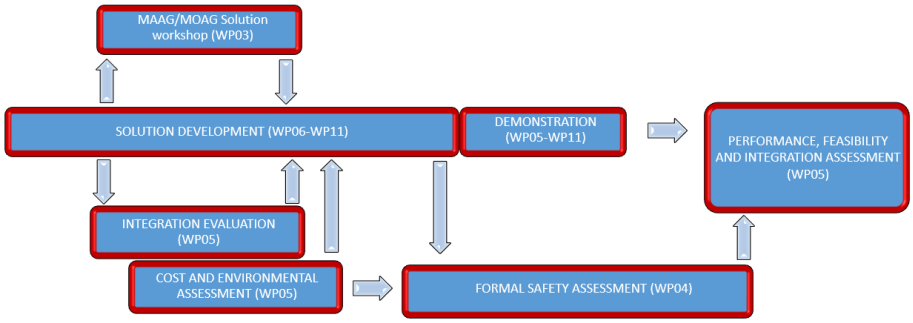

Figure 2. Ship integration assessment process

1.3 Results and achievements

This report presents a compilation of the Life Cycle Cost and environmental assessment (LCA) results addressed to a selection of solutions provided by specific developments within the LASH FIRE project.

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, cost effectiveness assessment and final feasibility assessment for all 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 and conduct the validation of solutions. Further, the results were used as input for the cost effectiveness assessment which will be performed in line with IMO formal safety assessment (FSA) in WP04.

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

The report can be used by external parties as it provides a comprehensive description of the integration of innovative solutions and related cost.

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

2 List of symbols and abbreviations

3F	Fluorine Free Foam
APV	Alternative Powered Vehicle (IMO terminology)
CAF	Compressed Air Foam
CAFS	Compressed Air Foam Systems
CCTV	Closed-circuit television for video surveillance
CEU	Cargo equivalent unit
CNG	Compressed natural gas
CO_2	Carbon dioxide
DNV	Det Norske Veritas
DTS	Distributed temperature sensing (acquisition system)
ECR	Engine Control Room
EV	Electric vehicle
FSA	Formal safety assessment
HDD	Hard disk drive
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LCPA	Life Cycle Performance Assessment
GDP	Gross Domestic Product
KPI	Key Performance Indicator
NVR	Network video recorder (switch unit)
PoE	Power over Ethernet (switch unit)
PPE	Personal Protective Equipment
PTT	Press to talk
RCM	Risk control measure
RCO	Risk control option
REF	Reference case
RHO	Radiant Heat Output (kW)
SCU	Sensor control unit
SFP	Small form-factor pluggable (network module)

SSE	Sub-Committee on Ship Systems and Equipment at IMO
UTP	Unshielded Twisted Pair (cable)
VFD	Video flame detection
VSD	Video smoke detection
WSA	Work system analysis

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.

This report presents the life cycle cost (LCC) and environmental assessment (LCA) results addressed to the developments within the LASH FIRE project. The assessment results have been exchanged with the development teams to further improve the developed solution as well as to provide an input for the cost effectiveness assessment which was performed in line with IMO formal safety assessment (FSA).

Six Development and Demonstration Work Packages (D&D WPs) addressed a total of twenty challenges, also called Actions, in all stages of a 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).

The economic feasibility study of Risk Control Measures (RCMs) and Risk Control Options (RCOs) was conducted by LCC methodology where all related costs are included, from investment/production to operation/maintenance and until the end of the life span.

More than 40 RCMs and 16 RCOs were assessed, applied (when relevant) to the three selected generic ro-ro ships of types ro-ro passenger ship, ro-ro cargo ship and vehicle carrier (Ref D05.1 “Definition of generic ships” [4]), including new buildings and existing vessels. For the assessments, a LCC tool developed within LASH FIRE was used. A comprehensive description of the LCC tool and LCC process is presented in deliverable D05.2 “Cost assessment tool” [5] and D05.3 “Development of cost assessment tool” [6], respectively.

LCA studies were conducted for the manual firefighting solutions (Action 6-D) and weather deck extinguishment solutions (Action 10-B). The LCAs were conducted on a selection of handheld fire extinguishers, a fire blanket, and several types of water application devices for Action 6-D and on two

fixed fire protection systems (autonomous and remotely operated) for Action 10-B. These solutions were compared with reference cases specific to each action, in which a fire occurs but the developed solutions were unavailable to use. Sensitivity and uncertainty analyses were conducted to identify weaknesses in the LCA models and framework construction. Much of the inventory data used to create the LCA models came from LASH FIRE partners and from fire suppression testing performed in WP06 and WP10.

The LCA analysis is partly based on results provided by an LCA screening tool documented in deliverable D05.4 "Environmental assessment tool" [7] and D05.5 "Development of environmental assessment tool" [8]. Additional information came from sources such as LCA databases, literature, and the internet. Care was taken to ensure that the LCA models were consistent with the LCC and FSA models.

A summary of the assessed RCM's and selected RCO's including the applicability vs ro-ro ship types and ro-ro spaces is presented within Table 2 and Table 3.

For the description of the RCM's, reference is made to deliverable D04.9 "Preliminary impact of solutions and related testing and demonstrations plan", [1]. For the description of the RCOs and the selection process please refer to deliverable D04.6 "Cost effectiveness assessment report" [2].

Table 2 (taken from deliverable D04.9 [1]) summarizes the RCMs initially proposed by the D&D WPs, before the selection and definition of the RCOs.

Table 3 (taken from deliverable D04.6 [2]) summarizes the selected RCOs.

3.1.1 Assessment assumptions

The expected lifetimes for the different types of ships was considered according to WP04 input (Ref. D04.6, [2]) summarized in Table 1.

Table 1. Expected lifetime (in years) for the different types of ships studied.

	Ro-ro passenger ships	Ro-ro cargo ships	Vehicle carriers
New buildings	43	40	29
Existing ships	23	23	17

Net Present Value (NPV) was used: a discount rate of 3.5% was applied for the first 30 years, and then was lowered to 3.0% for the following years.

Table 2. Summary of the RCMs proposed by the D&D WPs.

WP	Action	ID	Title of solution	Ship types[1]	Ro-ro spaces types[2]	NB, Ex[3]	TRL	Attribute(s) Category A[4]	Attribute(s) Category B[4]
06	6-A	Op1	Improved fire patrol procedures and minimum assisting equipment for a more effective screening of fire hazards	Ro-Pax, Ro-Ro	CRS, ORS, WD	NB + Ex	6, 7	Preventive, Mitigating	Engineering, Procedural
		Op2	Manual screening of cargo at port before the loading operations	Ro-Pax, Ro-Ro	CRS, ORS, WD	NB + Ex	6, 7	Preventive	Engineering, Procedural
	6-B	Op3	Improvement of current signage and markings standards/conditions to support effective wayfinding and localization	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex	6, 7	Mitigating	Inherent
		Op4	Guidelines for the standardization and formalization of manual fire confirmation and localization	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex	6, 7	Mitigating	Engineering, Procedural
	6-C	Op5	First response guidelines and new equipment to put out the fire in the initial stage	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex	5, 6	Mitigating	Engineering, Procedural
		Op6	Technology for localization of first responders through digital information processed via network	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex	4, 5, 6, 7	Mitigating	Engineering
	6-D	Op7	Training, new equipment and procedures to suppress fires in Alternatively Powered Vehicles with special focus on Li-ion batteries fires	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex	5, 6	Mitigating	Engineering, Procedural

WP	Action	ID	Title of solution	Ship types[1]	Ro-ro spaces types[2]	NB, Ex[3]	TRL	Attribute(s) Category A[4]	Attribute(s) Category B[4]
07	7-A	Des1	User friendly alarm system interface design guidelines	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex		Mitigating	Engineering, Inherent
		Des2	Alarm system interface prototype	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex	5	Mitigating	Engineering, Inherent
	7-B	Des3	Procedures and design for efficient extinguishment system activation	Ro-Pax, Ro-Ro, VC	CRS, ORS, (WD)	NB + Ex	6	Mitigating	Procedural
		Des4	Training module for activation of extinguishment systems	Ro-Pax, Ro-Ro, VC	CRS, ORS	NB + Ex	5	Mitigating	Procedural
	7-C	Des5	Integrated solutions for fire resource management, combining relevant sources of information, including drone and camera monitoring system	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex	6	Mitigating	Engineering, Inherent
		Des6	Guidelines for organizing the response in case of a fire emergency	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex	6	Mitigating	Procedural
08	8-A	Pre1a	Cargo scanning and identification and tracking system by the means of a called Vehicle Hot Spot Detector system	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex	5	Preventive	Engineering
		Pre1b	Automatic screening and management of cargo fire hazards by means of Automated Guided Vehicles	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex	5	Preventive, Mitigating	Engineering
		Pre2	Stowage planning tool with optimization algorithm for cargo distribution	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex	5	Preventive, Mitigating	Engineering, Inherent
	8-B	Pre3	Develop guidelines for safe electrical power connections in ro-ro spaces for reefer units	Ro-Pax, Ro-Ro	CRS, ORS, WD	NB + Ex	6, 7	Preventive	Engineering
		Pre4	Develop guidelines for safe electrical power connections in ro-ro spaces for charging of electric vehicles	Ro-Pax	CRS, ORS, WD	NB + Ex	6, 7	Preventive	Engineering
	8-C	Pre5	Proposal for requirements of surface materials in ro-ro spaces, with reference to suitable test method and material property performance criteria	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex	6, 7	Mitigating	Engineering, Inherent

WP	Action	ID	Title of solution	Ship types[1]	Ro-ro spaces types[2]	NB, Ex[3]	TRL	Attribute(s) Category A[4]	Attribute(s) Category B[4]
09	9-A	Det1	Flame wavelength detectors	Ro-Pax, Ro-Ro, (VC)	WD, (CRS), (ORS)	NB + Ex	7	Mitigating	Engineering
		Det8	Thermal imaging (infrared) cameras	Ro-Pax, Ro-Ro, (VC)	WD, (CRS), (ORS)	NB + Ex	7	Mitigating	Engineering
		Det2	Deck mounted linear heat detection by fibre optic cables	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex	6	Mitigating	Engineering
	9-B	Det3	Video detection	Ro-Pax, Ro-Ro, VC	CRS	NB + Ex	7	Mitigating	Engineering
		Det4	Adaptive detection threshold settings	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex	6	Mitigating	Engineering
		Det7	Fibre optic linear heat detection	Ro-Pax, Ro-Ro, VC	CRS, ORS	NB + Ex	7	Mitigating	Engineering
	9-C	Det5	Video detection	Ro-Pax, Ro-Ro, VC	CRS	NB + Ex	7	Mitigating	Engineering
		Det6	Thermal imaging (infrared) cameras	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex	7	Mitigating	Engineering
10	10-A	Ext1a	Dry pipe sprinkler system for ro-ro spaces on vehicle carriers	VC	CRS	NB + Ex	5	Mitigating	Engineering
		Ext1b	Automatic deluge water spray for ro-ro spaces system on vehicle carriers	VC	CRS	NB + Ex	5	Mitigating	Engineering
	10-B	Ext3	Autonomous fire monitor (water only) system for the protection of weather decks	Ro-Pax, Ro-Ro	WD	NB + Ex	6	Mitigating	Engineering
		Ext4	Remotely-controlled Compressed Air Foam fire monitor system for the protection of weather deck	Ro-Pax, Ro-Ro	WD	NB + Ex	6	Mitigating	Engineering
	10-C	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	Ro-Pax, Ro-Ro	CRS, ORS	NB	6	Mitigating	Engineering
11	11-A	Cont1b1	A-30 fire integrity	Ro-Pax, Ro-Ro, VC	CRS, ORS	NB	9	Mitigating	Engineering, Inherent
		Cont1b2	Extinguishing system simultaneously activated above and below sub-dividing deck	Ro-Pax, Ro-Ro, VC	CRS, ORS	NB	9	Mitigating	Engineering
		Cont3a	Solid curtain, horizontal mounting, fully rolled down	Ro-Pax, Ro-Ro	CRS, ORS	NB	5	Mitigating	Engineering

WP	Action	ID	Title of solution	Ship types[1]	Ro-ro spaces types[2]	NB, Ex[3]	TRL	Attribute(s) Category A[4]	Attribute(s) Category B[4]
		Cont3b	Solid curtain, vertical mounting, fully rolled down	Ro-Pax, Ro-Ro	CRS, ORS	NB	5	Mitigating	Engineering
		Cont3c	Solid curtain, vertical mounting, partly rolled down	Ro-Pax, Ro-Ro	CRS, ORS	NB	5	Mitigating	Engineering
		Cont3d	Solid stripped curtain, vertical mounting, fully/partly rolled down	Ro-Pax, Ro-Ro	CRS, ORS	NB	5	Mitigating	Engineering
	11-B	Cont5	Alternative disembarkation path through “dedicated side door”	Ro-Pax, Ro-Ro, VC?	CRS, ORS, WD	NB	5	Mitigating	Engineering
	11-C	Cont9	Ship manoeuvring/operation to limit the effect of fire at least in critical areas	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex	5	Mitigating	Procedural
		Cont10	Safety distances between side and end openings and critical areas	Ro-Pax, Ro-Ro	ORS	NB + Ex	5	Mitigating	Inherent
	11-D	Cont11	Guidance on calculation of side openings in ro-ro spaces	Ro-Pax, Ro-Ro	CRS, ORS	NB	5	Mitigating	Inherent
		Cont12	Configuration of side openings in ro-ro spaces	Ro-Pax, Ro-Ro	CRS, ORS	NB	5	Mitigating	Inherent
		Cont13	Tactical guidelines for manual interventions	Ro-Pax, Ro-Ro	CRS	NB + Ex	5	Mitigating	Procedural?
		Cont14	SOLAS requirement of reversible fans	Ro-Pax, Ro-Ro	CRS	NB	5	Mitigating	Engineering, Procedural

[1] Ro-Pax = Ro-ro passenger ships, Ro-Ro = Ro-ro cargo ships, VC = Vehicle carriers.

[2] CRS = Closed ro-ro spaces, ORS = Open ro-ro spaces, WD = Weather decks.

[3] NB = New ships, Ex = Existing ships.

[4] Attributes as defined in MSC-MEPC.2/Circ.12/Rev.2 **[1]**.

Table 3. Detailed list of the 16 selected RCOs.

ID	RCM(s) of origin	Title of Risk Control Option (RCO)	Ship types	Ro-ro space types	NB + Ex?
		WP06			
RCO1	Op1, Op4	Fire patrol. Fire confirmation & localization	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex
RCO2	Op3	Signage and markings for effective wayfinding and localization	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex
RCO3	Op5	Efficient first response	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex
RCO4	Op7	Manual firefighting for Alternatively Powered Vehicles	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex
		WP07			
RCO5	Des2	Alarm system interface prototype	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB
RCO6	Des3	Process for development of procedures and design for efficient activation of extinguishing system	Ro-Pax, Ro-Ro, VC	CRS, ORS	NB + Ex
RCO7	Des4	Training module for efficient activation of extinguishing system	Ro-Pax, Ro-Ro, VC	CRS, ORS	NB + Ex
		WP08			
RCO8	Pre3	Safe electrical connection for reefers	Ro-Pax, Ro-Ro	CRS, ORS, WD	NB + Ex
RCO9	Pre4, Pre3	Safe electrical connection of reefers and electric vehicles (EVs)	Ro-Pax	CRS, ORS, WD	NB + Ex
		WP09			
RCO10	Ex: Det1, Det8	Fire detection on weather decks	Ro-Pax, Ro-Ro	WD	NB + Ex
RCO11	Det7	Fire detection in closed ro-ro spaces & open ro-ro spaces	Ro-Pax, Ro-Ro, VC	CRS, ORS	NB
RCO12	Ex: Det5, Det6, Det8	Visual system for fire confirmation and localization	Ro-Pax, Ro-Ro, VC	CRS, ORS, WD	NB + Ex
		WP10			
RCO13	Ext1a	Dry-pipe sprinkler system for vehicle carriers	VC	CRS	NB
RCO14	Ext3a	Fixed remotely-controlled fire monitor system using water for weather decks	Ro-Pax, Ro-Ro	WD	NB + Ex
RCO15	Ext3	Fixed autonomous fire monitor system using water for weather decks	Ro-Pax, Ro-Ro	WD	NB + Ex
		WP11			
RCO16	Cont13, Cont14	Guideline for fire ventilation in closed ro-ro space	Ro-Pax, Ro-Ro	CRS	NB + Ex

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.

CRS = closed ro-ro spaces, ORS = open ro-ro spaces, WD = weather decks.

NB = newbuildings, Ex = existing ships.

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

Main author of the chapter: Martin Carlsson, STL

This chapter presents an overview of the life cycle cost assessment for the solutions proposed by Action 6-A i.e. Manual screening of cargo hazards and effective fire patrols. For this Action two RCMs are assessed:

- 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 "Preliminary impact of solutions and related testing and demonstrations plan" [1].

Commented [MH1]: Please add also title

4.1 Life cycle cost assessment

An installation cost assessment for two different system solutions was made:

- **System#01** - Improved fire patrol procedures and minimum assisting equipment for a more effective screening of fire hazards (RCM Op1)
- **System#02** - Manual screening of cargo at port before the loading operations (RCM Op2)

The cost assessment was made for the generic ships selected by the project with respect to the applicability of the solutions proposed; Magnolia Seaways the generic ro-ro cargo ship (System #01,#02) operated by DFDS Seaways, and Stena Flavia, the generic ro-pax ship (System #01,#02). The cost assessment was made for new buildings and existing ships.

4.1.1 Life cycle cost model

Main author of the chapter: Martin Carlsson, STL

4.1.1.1 Cost items description and assumptions

For each of the systems and ship types the following costs were considered:

- Investment cost,
- operation cost,
- inspections, testing, and maintenance costs, and
- end of life cost.

Commented [MH2]: Usually I like the format of the bullet point lists to be consistent throughout the report. However, I think it is OK as you have done here, (in the list of costs end each bullet point with comma or "and" and only capital letter at the first bullet point) and for the other lists starting each bullet point with a capital letter and end without punctuation mark. Make sure you follow these two formats in all action sections.

It was assumed that all system solutions will be serviceable during the entire time if properly maintained.

4.1.1.1.1 System#01: Improved fire patrol procedures and minimum assisting equipment for a more effective screening of fire hazards (Op1)

4.1.1.1.1.1 Investment cost

The following items are considered:

- Added equipment:
  - Safety torch,

    - check point reader,
    - push to talk button, and
    - hand held IR camera.
- establish procedures in company,
- establish procedures per vessel, and
- training per vessel

The purchasing costs of equipment was estimated based on figures from system component suppliers. Cost for establishing procedures and crew training on board was estimated based on Stena best practice experience.

4.1.1.1.1.2 Operation cost

No operational cost considered.

4.1.1.1.1.3 Maintenance cost

Maintenance cost estimation was based on necessary renewal of equipment according to Stena best practice experience.

4.1.1.1.1.4 End of life cost

No end of life cost considered.

4.1.1.1.2 System#02: Manual screening of cargo at port before the loading operations (Op2)

4.1.1.1.2.1 Investment cost

The following items are considered:

- Added equipment:
    - hand held IR camera, and
    - safety torch.
- establish procedures in company,
- establish procedures onboard, and
- training of screening personal.

The purchasing costs of equipment was estimated based on figures from system component suppliers. Cost for establishing procedures and crew training on board was estimated based on Stena best practice experience.

4.1.1.1.2.2 Operation cost

The following items are considered:

- Training of screening personal,
- screening operations,
- cost of handling suspected units,
- cost of handling identified decided units, and
- cost of handling false alarm with freight owner.

4.1.1.1.2.3 Maintenance cost

Maintenance cost estimation was based on necessary renewal of equipment according to Stena best practice experience.

4.1.1.1.2.4 End of life cost

No end of life cost considered.

4.1.1.2 Life cycle cost component for ro-pax newbuilding

4.1.1.2.1 Investment cost

The estimated cost for the installation of the system solutions, respectively, on a ro-pax new building is summarized in Table 4.

Table 4 Action 6A- The estimated cost for the installation of the four system solutions, respectively, on a ro-pax new building

System Number		System#01	System#02
System Name		Op1: Improved fire	Op2: Manual screen
Investment cost			
Purchasing cost	EUR	1 060.00	1 760.00
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	-	-
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	-	-
Comissioning cost	EUR	-	-
Document, certification and other administration costs	EUR	1 440.00	3 000.00
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	2 880.00	3 120.00
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	5 380.00	7 880.00

4.1.1.2.2 Operation cost

The operational cost for the installation of the two systems, respectively, on a ro-ro cargo new building was considered and summarized in Table 5.

Table 5. Action 6A- The estimated operation cost for the installation of the four system solutions, respectively, on a ro-pax new building

System Number		System#01	System#02
System Name		Op1: Improved fire	Op2: Manual screen
Operation cost			
Additional Energy consumption	kWh/year	-	-
Additional Fuel Consumption	t/year	-	-
Reduce Fuel Consumption	t/year	-	-
Operator cost	EUR/year	-	24 000.00
Insurance, taxes, and other fees cost	EUR/year	-	-
Loss of cargo/loss revenue	EUR/year	-	17 000.00
Additional of cargo/profit revenue	EUR/year	-	-
Other operation cost	EUR/year	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total operation cost exc. Energy cost	EUR/year	-	41 000.00

4.1.1.2.3 Maintenance cost

The estimated cost for inspections, testing, and maintenance for the four system solutions on a ro-pax new building is summarized in Table 6.

Table 6. Action 6A- The estimated cost for the inspection, testing and maintenance of the four system solutions for a ro-pax newbuilding

System Number		System#01	System#02
System Name		Op1: Improved fire	Op2: Manual screen
Maintenance cost			
Annual maintenance			
Annual system maintenance cost	EUR/year	576.00	624.00
Loss due to vessel downtime during maintenance	EUR/year	-	-
Other annual maintenance cost	EUR/year	-	-
		-	-
Total annual maintenance cost	EUR/year	576.00	624.00

4.1.1.2.4 End of life cost

No end of life cost considered.

4.1.1.3 Life cycle cost component for ro-pax existing ship

4.1.1.3.1 Investment cost

The estimated cost for the installation of the system solutions, respectively, on a ro-pax new building is summarized in Table 7

Table 7 Action 6A- The estimated cost for the installation of the four system solutions, respectively, on a ro-pax existing ship

System Number		System#01	System#02
System Name		Op1: Improved fire	Op2: Manual screen
Investment cost			
Purchasing cost	EUR	1 060.00	1 760.00
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	-	-
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	-	-
Comissioning cost	EUR	-	-
Document, certification and other administration costs	EUR	1 440.00	3 000.00
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	2 880.00	3 120.00
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	5 380.00	7 880.00

4.1.1.3.2 Operation cost

The operational cost for the installation of the two systems, respectively, on a ro-ro cargo new building was considered and summarized in Table 8.

Table 8. Action 6A- The estimated operation cost for the installation of the four system solutions, respectively, on a ro-pax new building

System Number		System#01	System#02
System Name		Op1: Improved fire	Op2: Manual screen
Operation cost			
Additional Energy consumption	kWh/year	-	-
Additional Fuel Consumption	t/year	-	-
Reduce Fuel Consumption	t/year	-	-
Operator cost	EUR/year	-	24 000.00
Insurance, taxes, and other fees cost	EUR/year	-	-
Loss of cargo/loss revenue	EUR/year	-	17 000.00
Additional of cargo/profit revenue	EUR/year	-	-
Other operation cost	EUR/year	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total operation cost exc. Energy cost	EUR/year	-	41 000.00

4.1.1.3.3 Maintenance cost

The estimated cost for inspections, testing, and maintenance for the four system solutions on a ro-ro cargo new building is summarized in Table 9.

Table 9. Action 6A- The estimated cost for the inspection, testing and maintenance of the four system solutions for a ro-pax newbuilding

System Number		System#01	System#02
System Name		Op1: Improved fire	Op2: Manual screen
Maintenance cost			
Annual maintenance			
Annual system maintenance cost	EUR/year	576.00	624.00
Loss due to vessel downtime during maintenance	EUR/year	-	-
Other annual maintenance cost	EUR/year	-	-
		-	-
Total annual maintenance cost	EUR/year	576.00	624.00

4.1.1.3.4 End of life cost

No end of life cost considered.

4.1.1.4 Life cycle cost component for ro-ro cargo newbuilding

4.1.1.4.1 Investment cost

The estimated cost for the installation of the two system solutions, respectively, on a ro-ro cargo new building is summarized in Table 10.

Table 10 Action 6A- The estimated cost for the installation of the two system solutions, respectively, on a ro-ro cargo new building

System Number		System#01	System#02
System Name		Op1: Improved fire	Op2: Manual screen
Investment cost			
Purchasing cost	EUR	1 060.00	1 760.00
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	-	-
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	-	-
Comissioning cost	EUR	-	-
Document, certification and other administration costs	EUR	1 440.00	3 000.00
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	1 440.00	3 120.00
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	3 940.00	7 880.00

4.1.1.4.2 Operation cost

The operational cost for the installation of the two systems, respectively, on a ro-ro cargo new building was considered and summarized in Table 11.

Table 11. Action 6A- The estimated operation cost for the installation of the two system solutions, respectively, on a ro-ro cargo new building

System Number		System#01	System#02
System Name		Op1: Improved fire	Op2: Manual screen
Operation cost			
Additional Energy consumption	kWh/year	-	-
Additional Fuel Consumption	t/year	-	-
Reduce Fuel Consumption	t/year	-	-
Operator cost	EUR/year	-	24 000.00
Insurance, taxes, and other fees cost	EUR/year	-	-
Loss of cargo/loss revenue	EUR/year	-	17 000.00
Additional of cargo/profit revenue	EUR/year	-	-
Other operation cost	EUR/year	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total operation cost exc. Energy cost	EUR/year	-	41 000.00

4.1.1.4.3 Maintenance cost

The estimated cost for the two system solutions on a ro-ro cargo new building is summarized in Table 12.

Table 12. Action 6A- The estimated cost for the inspection, testing and maintenance of the two system solutions for a ro-ro cargo newbuilding

System Number		System#01	System#02
System Name		Op1: Improved fire	Op2: Manual screen
Maintenance cost			
Annual maintenance			
Annual system maintenance cost	EUR/year	576.00	624.00
Loss due to vessel downtime during maintenance	EUR/year	-	-
Other annual maintenance cost	EUR/year	-	-
		-	-
Total annual maintenance cost	EUR/year	576.00	624.00

4.1.1.4.4 End of life cost

No end of life cost considered

4.1.1.5 Life cycle cost component for ro-ro cargo existing ship

4.1.1.5.1 Investment cost

The estimated cost for the installation of the two system solutions, respectively, on a ro-ro cargo existing ship is summarized inTable 13.

Table 13 Action 6A- The estimated cost for the installation of the two system solutions, respectively, on a ro-ro cargo existing ship

System Number		System#01	System#02
System Name		Op1: Improved fire	Op2: Manual screen
Investment cost			
Purchasing cost	EUR	1 060.00	1 760.00
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	-	-
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	-	-
Comissioning cost	EUR	-	-
Document, certification and other administration costs	EUR	1 440.00	3 000.00
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	1 440.00	3 120.00
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	3 940.00	7 880.00

4.1.1.5.2 Operation cost

The operational cost for the installation of the two systems, respectively, on a ro-ro cargo existing ship was considered and summarized inTable 14.

Table 14. Action 6A- The estimated operation cost for the installation of the two system solutions, respectively, on a ro-ro cargo existing ship

System Number		System#01	System#02
System Name		Op1: Improved fire	Op2: Manual screen
Operation cost			
Additional Energy consumption	kWh/year	-	-
Additional Fuel Consumption	t/year	-	-
Reduce Fuel Consumption	t/year	-	-
Operator cost	EUR/year	-	24 000.00
Insurance, taxes, and other fees cost	EUR/year	-	-
Loss of cargo/loss revenue	EUR/year	-	17 000.00
Additional of cargo/profit revenue	EUR/year	-	-
Other operation cost	EUR/year	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total operation cost exc. Energy cost	EUR/year	-	41 000.00

4.1.1.5.3 Maintenance cost

The estimated cost for the two system solutions on a ro-ro cargo existing ship is summarized inTable 15.

Table 15. Action 6A- The estimated cost for the inspection, testing and maintenance of the two system solutions for a ro-ro cargo existing ship

System Number		System#01	System#02
System Name		Op1: Improved fire p	Op2: Manual screen
Maintenance cost			
Annual maintenance			
Annual system maintenance cost	EUR/year	576.00	624.00
Loss due to vessel downtime during maintenance	EUR/year	-	-
Other annual maintenance cost	EUR/year	-	-
		-	-
Total annual maintenance cost	EUR/year	576.00	624.00

4.1.1.5.4 End of life cost

No end of life cost considered

4.1.2 LCC results

The LCC result for a ro-pax new building is shown in Table 16.

Table 16. Action 6A- The LCC results for a ro-pax new building

System Number		System#01	System#02
System Name		proved fire patrol proc	nual screening before de
Life cycle cost result			
Unit		**Per Ship**	
Total Investment cost	EUR	7 596.49 €	11 126.46 €
Total Operation cost	EUR	- €	965 495.54 €
Total Maintenance cost	EUR	13 564.03 €	14 694.37 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	21 160.52 €	991 316.36 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	3.45 €	5.06 €
Total Operation cost	EUR	- €	438.86 €
Total Maintenance cost	EUR	6.17 €	6.68 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	9.62 €	450.60 €

The LCC result for a ro-pax existing ship is shown in Table 17.

Table 17. Action 6A- The LCC results for a ro-pax existing ship

System Number		System#01	System#02
System Name		proved fire patrol proc	nual screening before de
Life cycle cost result			
Unit		**Per Ship**	
Total Investment cost	EUR	5 380.00 €	7 880.00 €
Total Operation cost	EUR	- €	662 852.12 €
Total Maintenance cost	EUR	9 312.26 €	10 088.29 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	14 692.26 €	680 820.40 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	2.45 €	3.58 €
Total Operation cost	EUR	- €	301.30 €
Total Maintenance cost	EUR	4.23 €	4.59 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	6.68 €	309.46 €

The LCC result for a ro-ro cargo new building is shown in Table 18.

Table 18. Action 6A- The LCC results for a ro-ro cargo new building

System Number		System#01	System#02
System Name		nproved fire patrol proc	nual screening before de
Life cycle cost result			
Unit		**Per Ship**	
Total Investment cost	EUR	5 563.23 €	11 126.46 €
Total Operation cost	EUR	- €	928 876.63 €
Total Maintenance cost	EUR	13 049.58 €	14 137.05 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	18 612.81 €	954 140.13 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	1.45 €	2.90 €
Total Operation cost	EUR	- €	242.46 €
Total Maintenance cost	EUR	3.41 €	3.69 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	4.86 €	249.06 €

The LCC result for a ro-ro cargo existing ship is shown inTable 19.

Table 19. Action 6A- The LCC results for a ro-ro cargo existing ship

System Number		System#01	System#02
System Name		nproved fire patrol proc	nual screening before de
Life cycle cost result			
Unit		**Per Ship**	
Total Investment cost	EUR	3 940.00 €	7 880.00 €
Total Operation cost	EUR	- €	662 852.12 €
Total Maintenance cost	EUR	9 312.26 €	10 088.29 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	13 252.26 €	680 820.40 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	1.03 €	2.06 €
Total Operation cost	EUR	- €	173.02 €
Total Maintenance cost	EUR	2.43 €	2.63 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	3.46 €	177.71 €

Results summary is shown in Table 20.

Table 20. Action 6A - Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-pax		ro-ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Op1	Improved fire patrol procedures and minimum assisting equipment for a more effective screening of fire hazards	Investment	7 596.49 €	5 380.00 €	5 563.23 €	3 940.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	13 564.03 €	9 312.26 €	13 049.58 €	9 312.26 €	N/A	N/A
		TOTAL	**21 160.52 €**	**14 692.26 €**	**18 612.81 €**	**13 252.26 €**	**N/A**	**N/A**
Op2	Manual screening of cargo at port before the loading operations	Investment	11 126.46 €	7 880.00 €	11 126.46 €	7 880.00 €	N/A	N/A
		Operation	965 495.54 €	662 852.12 €	928 876.63 €	662 852.12 €	N/A	N/A
		Maintance	14 694.37 €	10 088.29 €	14 137.05 €	10 088.29 €	N/A	N/A
		TOTAL	**991 316.37 €**	**680 820.41 €**	**954 140.14 €**	**680 820.40 €**	**N/A**	**N/A**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed

4.2 Conclusion

An assessment of the lifecycle cost for the solutions proposed by Action 6-A was performed. Further, the assessment was performed for two ship types, the selected generic ro-ro cargo, and ro-pax, ships, that were used for integration and LCC assessment.

The here considered solutions are independent of the arrangement of the vessel, instead cargo volumes and crew size are dominant parameters.

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

Main author of the chapter: Martin Carlsson, STL

This chapter presents an overview of the life cycle cost assessment for the solutions proposed by Action 6-B i.e. Quick manual fire confirmation, localization and assessment. Two RCMs were proposed by WP06 and two RCO's selected (Ref. D04.6 "Cost-effectiveness assessment report" [2]) and assessed within this report:

- RCM Op3 - Improvement of current signage and markings standards/conditions to support effective wayfinding and localization
- RCM Op4 - Guidelines for the standardization and formalization of manual fire confirmation and localization
- RCO1 - Fire patrol. Fire confirmation & localization
- RCO2 - Signage and markings for effective wayfinding and localization

For the description of the RCM's please refer to Deliverable D04.9 "Preliminary impact of solutions and related testing and demonstrations plan", [1], for the description of the RCO's please refer to Deliverable D04.6, [2].

5.1 Life cycle cost assessment

An installation cost assessment for selected system solutions was made:

- **System#01** - Improvement of current signage and markings standards/conditions to support effective wayfinding and localization (RCM Op3)
- **System#02** - Guidelines for the standardization and formalization of manual fire confirmation and localization (RCM Op4)
- **System#03**- Fire patrol. Fire confirmation & localization (RCO1)

Cost assessment for the RCO2 was found to be same as for System#1, RCM Op3.

The cost assessment was made for reference ships selected by the project with respect to the applicability of the solutions proposed; Magnolia Seaways the generic ro-ro cargo ship operated by DFDS Seaways, Stena Flavia, the generic ro-pax ship and Torrent the generic car carrier. The cost assessment was made for new buildings and existing ships.

5.1.1 Life cycle cost model

5.1.1.1 Cost items description and assumptions

Independent of the system and ship type the following costs were considered:

- Investment cost,
- operation cost,
- inspections, testing, and maintenance, and
- end of life cost.

It was assumed that all system solutions will be serviceable during the entire time if properly maintained.

5.1.1.1.1 System#01: Improvement of current signage and markings standards/conditions to support effective wayfinding and localization (Op3)

5.1.1.1.1.1 Investment cost

The following items are considered:

- Establish procedures in company,
- investigation and assessment onboard,
- installation drawings,
- paintworks,
- paint material purchasing cost,
- configuration of ship system (ship automation system, fire safety plans, mimic panels, drencher station, CCTV, misc. printed instructions), and
- inspection and approval cost.

The purchasing costs of materials and equipment was estimated based on figures from system component and material suppliers. Cost for establishing procedures, crew training and integration on board was estimated based on Stena best practice experience.

5.1.1.1.1.2 Operation cost

No operational cost considered.

5.1.1.1.1.3 Maintenance cost

Maintenance cost estimation was based on necessary renewal according to Stena best practice experience.

5.1.1.1.1.4 End of life cost

No end of life cost considered.

5.1.1.1.2 System#02: Guidelines for the standardization and formalization of manual fire confirmation and localization (Op4)

5.1.1.1.2.1 Investment cost

The following items are considered:

- Establish procedures in company,
- establish procedures onboard,
- investigation and assessment onboard,
- training per vessel,
- UHF repeater system purchasing cost:
    - Base system,
    - UHF repeater antennas,
    - cables & connection points.
- installation and integration cost.

The purchasing costs of equipment was estimated based on figures from system component suppliers. Cost for establishing procedures, crew training and installation on board was estimated based on Stena best practice experience.

5.1.1.1.2.2 Operation cost

No operation costs considered.

5.1.1.1.2.3 Maintenance cost

Maintenance cost estimation was based on necessary renewal of equipment according to Stena best practice experience and costs of equipment estimated based on figures from system component suppliers.

5.1.1.1.2.4 No maintenance cost considered. End of life cost

No end of life cost considered.

5.1.1.1.3 System#03: Fire patrol. Fire confirmation & localization (RCO1)

Cost assumptions are based on RCM's Op1 (Ref, Chapter 4.1.1.1.1) and Op4.

5.1.1.1.3.1 Investment cost

The following items are considered:

- Added equipment:
  - safety torch,
  - check point reader,
  - push to talk button, and
  - hand held ir camera.
- establish procedures in company,
- establish procedures onboard,
- investigation and assessment onboard,
- training per vessel,
- UHF repeater system purchasing cost:
  - base system,
  - UHF repeater antennas,
  - cables & connection points.
- Installation and integration cost.

The purchasing costs of equipment was estimated based on figures from system component suppliers. Cost for establishing procedures, crew training and installation on board was estimated based on Stena best practice experience.

5.1.1.1.3.2 Operation cost

No operation costs considered.

5.1.1.1.3.3 Maintenance cost

Maintenance cost estimation was based on necessary renewal of equipment according to Stena best practice experience and costs of equipment estimated based on figures from system component suppliers.

5.1.1.1.3.4 No maintenance cost considered. End of life cost

No end of life cost considered.

5.1.1.2 Life cycle cost component for ro-ro cargo newbuilding

5.1.1.2.1 Investment cost

The estimated cost for the installation of the system solutions, respectively, on a ro-ro cargo new building is summarized in Table 10.

Table 21 Action 6B- The estimated cost for the installation of the system solutions, respectively, on a ro-ro cargo new building

System Number		System#01	System#02	System#03
System Name		OP 3 - The improvem	OP 4 - Guidelines fo	RCO1: Fire patrol. Fir
Investment cost				
Purchasing cost	EUR	200.00	8 340.00	9 400.00
Insurance cost	EUR	-	-	-
Integration design & validation cost	EUR	4 640.00	640.00	640.00
Disassemble and modify the old system or structure	EUR	-	-	-
Road transporter cost	EUR	-	-	-
Ship transporter cost	EUR	-	-	-
Assembly/Installation cost	EUR	3 000.00	6 000.00	6 000.00
Comissioning cost	EUR	-	-	-
Document, certification and other administration costs	EUR	1 000.00	960.00	2 400.00
Loss of hire costs	EUR	-	-	-
Operator traning cost	EUR	-	2 880.00	2 880.00
Other cost	EUR	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total cost	EUR	8 840.00	18 820.00	21 320.00

5.1.1.2.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and energy consumption is negligible and therefore not considered.

5.1.1.2.3 Maintenance cost

The estimated cost for the two system solutions on a ro-ro cargo new building is summarized in Table 22.

Table 22. Action 6B- The estimated cost for the inspection, testing and maintenance of the system solutions for a ro-ro cargo newbuilding

System Number		System#01	System#02	System#03
System Name		OP 3 - The improvem	OP 4 - Guidelines fo	RCO1: Fire patrol. Fir
Maintenance cost				
Annual maintenance				
Annual system maintenance cost	EUR/year	500.00	-	576.00
Loss due to vessel downtime during maintenance	EUR/year	-	-	-
Other annual maintenance cost	EUR/year	-	-	-
		-	-	-
Total annual maintenance cost	EUR/year	500.00	-	576.00
Periodic maintenance				
Spare part cost	EUR	-	14 340.00	14 340.00
Service repair cost	EUR	-	-	-
Loss due to vessel downtime during repair	EUR	-	-	-
Other periodic maintenance cost	EUR	-	-	-
		-	-	-
Inspection				
Periodic inspection and certification cost	EUR	100.00	-	-
Other cost	EUR	-	-	-
		-	-	-
		-	-	-

5.1.1.2.4 End of life cost

No end of life cost considered

5.1.1.3 Life cycle cost component for ro-ro cargo existing ship

5.1.1.3.1 Investment cost

The estimated cost for the installation of the system solutions on a ro-ro cargo existing ship are summarized in Table 23.

Table 23 Action 6B- The estimated cost for the installation of the system solutions on a ro-ro cargo existing ship

		System#01	System#02	System#03
System Number				
System Name		OP 3 - The improvem	OP 4 - Guidelines fo	RCO1: Fire patrol. Fir
Investment cost				
Purchasing cost	EUR	200.00	8 340.00	9 400.00
Insurance cost	EUR	-	-	-
Integration design & validation cost	EUR	4 640.00	640.00	640.00
Disassemble and modify the old system or structure	EUR	-	-	-
Road transporter cost	EUR	-	-	-
Ship transporter cost	EUR	-	-	-
Assembly/Installation cost	EUR	25 000.00	6 000.00	6 000.00
Comissioning cost	EUR	-	-	-
Document, certification and other administration costs	EUR	1 000.00	960.00	2 400.00
Loss of hire costs	EUR	-	-	-
Operator traning cost	EUR	-	2 880.00	2 880.00
Other cost	EUR	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total cost	EUR	30 840.00	18 820.00	21 320.00

5.1.1.3.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and the energy consumption is negligible and therefore not considered.

5.1.1.3.3 Maintenance cost

It was assumed that the maintenance cost is similar to a newbuilding, refer to the cost figures listed in Table 22.

5.1.1.3.4 End of life cost

No end of life cost considered.

5.1.1.4 Life cycle cost component for ro-pax newbuilding

5.1.1.4.1 Investment cost

The estimated cost for the installation of the system solutions on a ro-pax new building ship are summarized in Table 24.

Table 24 Action 6B- The estimated cost for the installation of the system solutions, respectively, on a ro-pax new building

System Number		System#01	System#02	System#03
System Name		OP 3 - The improvem	OP 4 - Guidelines fo	RCO1: Fire patrol. Fir
Investment cost				
Purchasing cost	EUR	200.00	8 340.00	9 400.00
Insurance cost	EUR	-	-	-
Integration design & validation cost	EUR	4 640.00	640.00	640.00
Disassemble and modify the old system or structure	EUR	-	-	-
Road transporter cost	EUR	-	-	-
Ship transporter cost	EUR	-	-	-
Assembly/Installation cost	EUR	3 000.00	6 000.00	6 000.00
Comissioning cost	EUR	-	-	-
Document, certification and other administration costs	EUR	1 000.00	960.00	2 400.00
Loss of hire costs	EUR	-	-	-
Operator traning cost	EUR	-	2 880.00	5 760.00
Other cost	EUR	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total cost	EUR	8 840.00	18 820.00	24 200.00

5.1.1.4.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and energy consumption is negligible and therefore not considered.

5.1.1.4.3 Maintenance cost

It was assumed that the maintenance cost is similar to a ro-ro cargo newbuilding, refer to the cost figures listed in Table 22.

5.1.1.4.4 End of life cost

No end of life cost considered.

5.1.1.5 Life cycle cost component for ro-pax existing ship

5.1.1.5.1 Investment cost

The estimated cost for the installation of the system solutions on a ro-ro cargo existing ship are summarized in

Table 25.

Table 25 Action 6B- The estimated cost for the installation of the system solutions on a ro-pax existing ship

System Number		System#01	System#02	System#03
System Name		OP 3 - The improvem	OP 4 - Guidelines fo	RCO1: Fire patrol. Fir
Investment cost				
Purchasing cost	EUR	200.00	8 340.00	9 400.00
Insurance cost	EUR	-	-	-
Integration design & validation cost	EUR	4 640.00	640.00	640.00
Disassemble and modify the old system or structure	EUR	-	-	-
Road transporter cost	EUR	-	-	-
Ship transporter cost	EUR	-	-	-
Assembly/Installation cost	EUR	25 000.00	6 000.00	6 000.00
Comissioning cost	EUR	-	-	-
Document, certification and other administration costs	EUR	1 000.00	960.00	2 400.00
Loss of hire costs	EUR	-	-	-
Operator traning cost	EUR	-	2 880.00	5 760.00
Other cost	EUR	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total cost	EUR	30 840.00	18 820.00	24 200.00

5.1.1.5.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and energy consumption is negligible and therefore not considered.

5.1.1.5.3 Maintenance cost

It was assumed that the maintenance cost is similar to a ro-ro cargo newbuilding, refer to the cost figures listed in Table 22.

5.1.1.5.4 End of life cost

No end of life cost considered

5.1.1.6 Life cycle cost component for vehicle carrier newbuilding

5.1.1.6.1 Investment cost

The estimated cost for the installation of the two system solutions on a vehicle carrier newbuilding are summarized in

Table 26.

Table 26 Action 6B- The estimated cost for the installation of the system solutions on a vehicle carrier newbuilding

System Number		System#01	System#02	System#03
System Name		OP 3 - The improvem	OP 4 - Guidelines fo	RCO1: Fire patrol. Fir
Investment cost				
Purchasing cost	EUR	400.00	8 340.00	8 340.00
Insurance cost	EUR	-	-	-
Integration design & validation cost	EUR	4 640.00	640.00	640.00
Disassemble and modify the old system or structure	EUR	-	-	-
Road transporter cost	EUR	-	-	-
Ship transporter cost	EUR	-	-	-
Assembly/Installation cost	EUR	6 000.00	6 000.00	6 000.00
Comissioning cost	EUR	-	-	-
Document, certification and other administration costs	EUR	1 000.00	960.00	960.00
Loss of hire costs	EUR	-	-	-
Operator traning cost	EUR	-	2 880.00	2 880.00
Other cost	EUR	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total cost	EUR	12 040.00	18 820.00	18 820.00

5.1.1.6.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and the energy consumption is negligible and therefore not considered.

5.1.1.6.3 Maintenance cost

The estimated cost for the two system solutions on a ro-ro cargo new building is summarized in Table 27.

Table 27. Action 6B- The estimated cost for the inspection, testing and maintenance of the system solutions for a vehicle carrier newbuilding

System Number		System#01	System#02	System#03
System Name		OP 3 - The improvem	OP 4 - Guidelines fo	RCO1: Fire patrol. Fir
Maintenance cost				
Annual maintenance				
Annual system maintenance cost	EUR/year	500.00	-	-
Loss due to vessel downtime during maintenance	EUR/year	-	-	-
Other annual maintenance cost	EUR/year	-	-	-
		-	-	-
Total annual maintenance cost	EUR/year	500.00	-	-
Periodic maintenance				
Spare part cost	EUR	-	14 340.00	14 340.00
Service repair cost	EUR	-	-	-
Loss due to vessel downtime during repair	EUR	-	-	-
Other periodic maintenance cost	EUR	-	-	-
		-	-	-
Inspection				
Periodic inspection and certification cost	EUR	100.00	-	-
Other cost	EUR	-	-	-
		-	-	-
		-	-	-

5.1.1.6.4 End of life cost

No end of life cost considered.

5.1.1.7 Life cycle cost component for vehicle carrier existing ship

5.1.1.7.1 Investment cost

The estimated cost for the installation of the two system solutions on a vehicle carrier existing ship are summarized in Table 28.

Table 28 Action 6B- The estimated cost for the installation of the system solutions on a vehicle carrier existing ship

		System#01	System#02	System#03
System Number				
System Name		OP 3 - The improvem	OP 4 - Guidelines fo	RCO1: Fire patrol. Fir
Investment cost				
Purchasing cost	EUR	400.00	8 340.00	8 340.00
Insurance cost	EUR	-	-	-
Integration design & validation cost	EUR	4 640.00	640.00	640.00
Disassemble and modify the old system or structure	EUR	-	-	-
Road transporter cost	EUR	-	-	-
Ship transporter cost	EUR	-	-	-
Assembly/Installation cost	EUR	30 000.00	6 000.00	6 000.00
Comissioning cost	EUR	-	-	-
Document, certification and other administration costs	EUR	1 000.00	960.00	960.00
Loss of hire costs	EUR	-	-	-
Operator traning cost	EUR	-	2 880.00	2 880.00
Other cost	EUR	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total cost	EUR	36 040.00	18 820.00	18 820.00

5.1.1.7.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and the energy consumption is negligible and therefore not considered.

5.1.1.7.3 Maintenance cost

It was assumed that the maintenance cost is similar to a vehicle carrier newbuilding, refer to the cost figures listed in Table 27.

5.1.1.7.4 End of life cost

No end of life cost considered.

5.1.2 LCC Result

Main author of the chapter: Vito Radolovic, FLOW

The LCC results for a ro-ro cargo new building is shown in Table 29.

Table 29. Action 6B- The LCC results for a ro-ro cargo new building

System Number		System#01	System#02	System#03
System Name		OP 3 - The improvem	OP 4 - Guidelines for	RCO1
Unit		**Per Ship**		
Total Investment cost	EUR	8 840.00 €	18 820.00 €	21 320.00 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	11 711.85 €	23 280.58 €	26 684.95 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	20 551.85 €	42 100.58 €	48 004.95 €
Unit		**Per Lane meter**		
Total Investment cost	EUR	2.31 €	4.91 €	5.57 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	3.06 €	6.08 €	9.48 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	5.36 €	10.99 €	15.05 €

The LCC results for a ro-ro cargo existing ship is shown in Table 30.

Table 30. Action 6B- The LCC results for a ro-ro cargo existing ship

System Number		System#01	System#02	System#03
System Name		OP 3 - The improvem	OP 4 - Guidelines for	RCO1
Unit		**Per Ship**		
Total Investment cost	EUR	30 840.00 €	18 820.00 €	21 320.00 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	8 348.60 €	17 372.69 €	26 684.95 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	39 188.60 €	36 192.69 €	48 004.95 €
Unit		**Per Lane meter**		
Total Investment cost	EUR	8.05 €	4.91 €	5.57 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	2.18 €	4.53 €	6.97 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	10.23 €	9.45 €	12.53 €

The LCC results for a ro-pax new building is shown in

Table 31.

Table 31. Action 6B- The LCC results for a ro-pax new building.

System Number		System#01	System#02	System#03
System Name		OP 3 - The improvem	OP 4 - Guidelines for	RCO1
Unit		**Per Ship**		
Total Investment cost	EUR	8 840.00 €	18 820.00 €	24 200.00 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	12 189.08 €	27 676.61 €	41 240.64 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	21 029.08 €	46 496.61 €	65 440.64 €
Unit		**Per Lane meter**		
Total Investment cost	EUR	4.02 €	8.55 €	11.00 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	5.54 €	12.58 €	18.75 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	9.56 €	21.13 €	29.75 €

The LCC results for a ro-pax existing ship is shown in Table 32.

Table 32. Action 6B- The LCC results for a ro-pax existing ship

System Number		System#01	System#02	System#03
System Name		OP 3 - The improvem	OP 4 - Guidelines for	RCO1
Unit		**Per Ship**		
Total Investment cost	EUR	30 840.00 €	18 820.00 €	24 200.00 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	8 348.60 €	17 372.69 €	26 684.95 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	39 188.60 €	36 192.69 €	50 884.95 €
Unit		**Per Lane meter**		
Total Investment cost	EUR	14.02 €	8.55 €	11.00 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	3.79 €	7.90 €	12.13 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	17.81 €	16.45 €	23.13 €

The LCC results for a vehicle carrier new building is shown in Table 33.

Table 33. Action 6B- The LCC results for a vehicle carrier new building

System Number		System#01	System#02	System#03
System Name		OP 3 - The improvem	OP 4 - Guidelines for	RCO1
Unit		**Per Ship**		
Total Investment cost	EUR	12 040.00 €	18 820.00 €	18 820.00 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	9 640.86 €	17 372.69 €	17 372.69 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	21 680.86 €	36 192.69 €	36 192.69 €
Unit		**Per CEU**		
Total Investment cost	EUR	1.90 €	2.96 €	2.96 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	1.52 €	2.74 €	2.74 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	3.41 €	5.70 €	5.70 €

The LCC results for a vehicle carrier existing ship is shown in Table 34.

Table 34. Action 6B- The LCC results for a vehicle carrier existing ship

System Number		System#01	System#02	System#03
System Name		OP 3 - The improvem	OP 4 - Guidelines for	RCO1
Unit		**Per Ship**		
Total Investment cost	EUR	36 040.00 €	18 820.00 €	18 820.00 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	6 761.84 €	10 165.90 €	10 165.90 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	42 801.84 €	28 985.90 €	28 985.90 €
Unit		**Per CEU**		
Total Investment cost	EUR	5.68 €	2.96 €	2.96 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	1.06 €	1.60 €	1.60 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	6.74 €	4.56 €	4.56 €

Results summary is shown in Table 35.

Table 35. Action 6B - Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-pax		ro-ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Op3	Improvement of current signage and markings standards/conditions to support effective wayfinding and localization	Investment	8 840.00 €	30 840.00 €	8 840.00 €	30 840.00 €	12 040.00 €	36 040.00 €
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		Maintance	12 189.08 €	8 348.60 €	11 711.85 €	8 348.60 €	9 640.86 €	6 761.84 €
		TOTAL	**21 029.08 €**	**39 188.60 €**	**20 551.85 €**	**39 188.60 €**	**21 680.86 €**	**42 801.84 €**
Op4	Guidelines for the standardization and formalization of manual fire confirmation and localization	Investment	18 820.00 €	18 820.00 €	18 820.00 €	18 820.00 €	18 820.00 €	18 820.00 €
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		Maintance	27 676.61 €	17 372.69 €	23 280.58 €	17 372.69 €	17 372.69 €	10 165.90 €
		TOTAL	**46 496.61 €**	**36 192.69 €**	**42 100.58 €**	**36 192.69 €**	**36 192.69 €**	**28 985.90 €**
RCO1	Fire patrol. Fire confirmation & localization	Investment	24 200.00 €	24 200.00 €	21 320.00 €	21 320.00 €	18 820.00 €	18 820.00 €
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		Maintance	41 240.64 €	26 684.95 €	26 684.95 €	26 684.95 €	17 372.69 €	10 165.90 €
		TOTAL	**65 440.64 €**	**50 884.95 €**	**48 004.95 €**	**48 004.95 €**	**36 192.69 €**	**28 985.90 €**
RCO2	Signage and markings for effective wayfinding and localization	Investment	8 840.00 €	30 840.00 €	8 840.00 €	30 840.00 €	12 040.00 €	36 040.00 €
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		Maintance	12 189.08 €	8 348.60 €	11 711.85 €	8 348.60 €	9 640.86 €	6 761.84 €
		TOTAL	**21 029.08 €**	**39 188.60 €**	**20 551.85 €**	**39 188.60 €**	**21 680.86 €**	**42 801.84 €**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed

5.2 Conclusion

An assessment of the lifecycle cost for the solutions proposed by Action 6-B was performed. Further, the assessment was performed for three ship types, the selected generic ro-ro cargo, ro-pax and vehicle carrier ships that were used for integration and LCC assessment.

6 Efficient first response - Action 6-C

Main author of the chapter: Martin Carlsson, STL

This chapter presents an overview of the life cycle cost assessment for the solutions proposed by Action 6-C i.e. Efficient first response. Two RCMs were proposed by WP06 and one RCO selected (Ref. D04.6 ""Cost-effectiveness assessment report" [2]) 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
- RCO3 - Efficient first response

For the description of the RCM's please refer to Deliverable D04.9 "Preliminary impact of solutions and related testing and demonstrations plan" [1], for the description of the RCO please refer to Deliverable D04.6, [2].

6.1 Life cycle cost assessment

An installation cost assessment for two different system solutions was made:

- **System#01** - First response guidelines (RCM Op5)
- **System#02** - Technology for localization of first responders through digital information processed via network (RCM Op6)

Cost assessment for the RCO3 was found to be same as for System#1, RCM Op5.

The cost assessment was made for reference ships selected by the project with respect to the applicability of the solutions proposed; Magnolia Seaways the generic ro-ro cargo ship operated by DFDS, Stena Flavia, the generic ro-pax ship and Torrens, the generic vehicle carrier operated by Wallenius. The cost assessment was made for new buildings and existing ships.

6.1.1 Description of the developed solution

6.1.1.1 System#01: First response guidelines (Op5)

The content of this RCM is not fully established a time performing the cost assessment. For the cost assessment purpose, the content was assumed to be the following:

- Establish **First response** concept and the role of **Designated First Responder** in most efficient way and issue a standard role description
- Develop standard communication terminology protocol to secure prompt understanding.

6.1.1.2 System#02: Technology for localization of first responders through digital information processed via network (Op6)

For the cost assessment purpose, the content of this RCM was assumed to be as follows:

- Localization system based on image recognition technology,
- master unit for overview on bridge or other location,
- user devices provided to fire patrol and fire teams,
- system to be functional in all roro cargo spaces and car decks, and
- system to be operational for weather decks, open roro decks and closed roro decks.

6.1.2 Life cycle cost model

6.1.2.1 Cost items description and assumptions

Independent of the system and ship type the following costs were considered:

- Investment cost,
- operation cost,
- inspections, testing, and maintenance, and
- end of life cost.

It was assumed that all system solutions will be serviceable during the entire time if properly maintained.

6.1.2.1.1 System#01: First response guidelines (Op5)

6.1.2.1.1.1 Investment cost

The following items are considered:

- Training of corporate safety management,
- company procedure updates,
- establish procedures per vessel, and
- crew training.

6.1.2.1.1.2 Operation cost

The following items are considered:

- Crew training, yearly refresh.

6.1.2.1.1.3 Maintenance cost

No maintenance cost considered.

6.1.2.1.1.4 End of life cost

No end of life cost considered.

6.1.2.1.2 System#02: Technology for localization of first responders through digital information processed via network (Op6)

6.1.2.1.2.1 Investment cost

The following items are considered:

- Server cost,
- network,
- IR smartphones,
- fixed screens at bridge and ECR,
- investigation onboard,
- integration onboard,
- training of safety management,
- company procedure updates,
- ship procedure update, and
- crew training.

6.1.2.1.2.2 Operation cost

The following items are considered:

- Software rental.

6.1.2.1.2.3 Maintenance cost

Maintenance cost estimation was based on necessary renewal of equipment according to Stena best practice experience.

6.1.2.1.2.4 End of life cost

No end of life cost considered.

6.1.2.2 Life cycle cost component for ro-ro cargo newbuilding

6.1.2.2.1 Investment cost

The estimated cost for the installation of the two system solutions, respectively, on a ro-ro cargo new building is summarized in Table 36.

Table 36 Action 6C- The estimated cost for the installation of the system solutions, respectively, on a ro-ro cargo new building

System Number		System#01	System#02
System Name		Opt-05 First Responc	Opt-06 - Localizatior
Investment cost			
Purchasing cost	EUR	-	37 300.00
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	-	5 000.00
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	-	10 000.00
Comissioning cost	EUR	-	-
Document, certification and other administration costs	EUR	1 440.00	1 440.00
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	5 110.00	3 720.00
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	6 550.00	57 460.00

6.1.2.2.2 Operation cost

The operational cost for the installation of the two systems, respectively, on a ro-ro cargo new building was considered and summarized in

Table 37.

Table 37. Action 6C- The estimated operation cost for the installation of the system solutions, respectively, on a ro-pax new building

System Number		System#01	System#02
System Name		Opt-05 First Responc	Opt-06 - Localizatior
Operation cost			
Additional Energy consumption	kWh/year	-	-
Additional Fuel Consumption	t/year	-	-
Reduce Fuel Consumption	t/year	-	-
Operator cost	EUR/year	880.00	500.00
Insurance, taxes, and other fees cost	EUR/year	-	-
Loss of cargo/loss revenue	EUR/year	-	-
Additional of cargo/profit revenue	EUR/year	-	-
Other operation cost	EUR/year	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total operation cost exc. Energy cost	EUR/year	880.00	500.00

6.1.2.2.3 Maintenance cost

The estimated cost for the system solutions on a ro-ro cargo new building is summarized in Table 38.

Table 38. Action 6C- The estimated cost for the inspection, testing and maintenance of the two system solutions, respectively, on a ro-ro cargo newbuilding

System Number		System#01	System#02
System Name		Opt-05 First Responc	Opt-06 - Localizatior
Maintenance cost			
Annual maintenance			
Annual system maintenance cost	EUR/year	-	-
Loss due to vessel downtime during maintenance	EUR/year	-	-
Other annual maintenance cost	EUR/year	-	-
		-	-
Total annual maintenance cost	EUR/year	-	-
Periodic maintenance			
Spare part cost	EUR	-	13 466.67
Service repair cost	EUR	-	-
Loss due to vessel downtime during repair	EUR	-	-
Other periodic maintenance cost	EUR	-	-
		-	-
Inspection			
Periodic inspection and certification cost	EUR	-	-
Other cost	EUR	-	-
		-	-
		-	-

6.1.2.2.4 End of life cost

No end of life cost considered

6.1.2.3 Life cycle cost component for ro-ro cargo existing ship

6.1.2.3.1 Investment cost

The estimated cost for the installation of the two system solutions on a ro-ro cargo existing ship are summarized in Table 39.

Table 39 Action 6C- The estimated cost for the installation of the system solutions, respectively, on a ro-ro cargo existing ship

System Number		System#01	System#02
System Name		Opt-05 First Responc	Opt-06 - Localizatior
Investment cost			
Purchasing cost	EUR	-	50 300.00
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	-	5 000.00
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	-	20 000.00
Comissioning cost	EUR	-	-
Document, certification and other administration costs	EUR	1 440.00	1 440.00
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	5 110.00	3 720.00
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	6 550.00	80 460.00

6.1.2.3.2 Operation cost

It was assumed that the maintenance cost is similar to a ro-ro cargo newbuilding, refer to the cost figures listed in Table 37.

6.1.2.3.3 Maintenance cost

The estimated cost for inspections, testing, and maintenance for the system solutions on a ro-ro cargo existing ship is summarized in

Table 40.

Table 40. Action 6C- The estimated cost for the inspection, testing and maintenance of the system solutions, respectively, on a ro-ro cargo existing ship

System Number		System#01	System#02
System Name		Opt-05 First Responc	Opt-06 - Localizatior
Maintenance cost			
Annual maintenance			
Annual system maintenance cost	EUR/year	-	-
Loss due to vessel downtime during maintenance	EUR/year	-	-
Other annual maintenance cost	EUR/year	-	-
		-	-
Total annual maintenance cost	EUR/year	-	-
Periodic maintenance			
Spare part cost	EUR	-	17 800.00
Service repair cost	EUR	-	-
Loss due to vessel downtime during repair	EUR	-	-
Other periodic maintenance cost	EUR	-	-
		-	-
Inspection			
Periodic inspection and certification cost	EUR	-	-
Other cost	EUR	-	-
		-	-
		-	-

6.1.2.3.4 End of life cost

No end of life cost considered.

6.1.2.4 Life cycle cost component for ro-pax newbuilding

6.1.2.4.1 Investment cost

The estimated cost for the installation of the system solutions, respectively, on a ro-pax new building is summarized in

Table 41.

Table 41 Action 6C- The estimated cost for the installation of two system solutions, respectively, on a ro-pax new building

System Number		System#01	System#02
System Name		Opt-05 First Responc	Opt-06 - Localizatior
Investment cost			
Purchasing cost	EUR	-	50 000.00
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	-	5 000.00
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	-	10 000.00
Comissioning cost	EUR	-	-
Document, certification and other administration costs	EUR	1 440.00	1 440.00
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	7 150.00	5 760.00
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	8 590.00	72 200.00

6.1.2.4.2 Operation cost

The operational cost for the installation of the two systems, respectively, on a ro-ro cargo new building was considered and summarized in

Table 42.

Table 42. Action 6C- The estimated operation cost for the installation of the two system solutions, respectively, on a ro-pax new building

System Number		System#01	System#02
System Name		Opt-05 First Respond	Opt-06 - Localizatior
Operation cost			
Additional Energy consumption	kWh/year	-	-
Additional Fuel Consumption	t/year	-	-
Reduce Fuel Consumption	t/year	-	-
Operator cost	EUR/year	1 390.00	500.00
Insurance, taxes, and other fees cost	EUR/year	-	-
Loss of cargo/loss revenue	EUR/year	-	-
Additional of cargo/profit revenue	EUR/year	-	-
Other operation cost	EUR/year	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total operation cost exc. Energy cost	EUR/year	1 390.00	500.00

6.1.2.4.3 Maintenance cost

The estimated cost for inspections, testing, and maintenance for the system solutions on a ro-pax new building is summarized in Table 43.

Table 43. Action 6C- The estimated cost for the inspection, testing and maintenance of the system solutions, respectively, on a ro-pax newbuilding

System Number		System#01	System#02
System Name		Opt-05 First Respond	Opt-06 - Localizatior
Maintenance cost			
Annual maintenance			
Annual system maintenance cost	EUR/year	-	-
Loss due to vessel downtime during maintenance	EUR/year	-	-
Other annual maintenance cost	EUR/year	-	-
		-	-
Total annual maintenance cost	EUR/year	-	-
Periodic maintenance			
Spare part cost	EUR	-	30 666.67
Service repair cost	EUR	-	-
Loss due to vessel downtime during repair	EUR	-	-
Other periodic maintenance cost	EUR	-	-
		-	-

6.1.2.4.4 End of life cost

No end of life cost considered.

6.1.2.5 Life cycle cost component for ro-pax existing ship

6.1.2.5.1 Investment cost

The estimated cost for the installation of the system solutions, respectively, on a ro-pax new building is summarized in Table 44.

Table 44 Action 6C- The estimated cost for the installation of the system solutions, respectively, on a ro-pax existing ship

System Number		System#01	System#02
System Name		Opt-05 First Responc	Opt-06 - Localizatior
Investment cost			
Purchasing cost	EUR	-	60 000.00
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	-	5 000.00
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	-	20 000.00
Comissioning cost	EUR	-	-
Document, certification and other administration costs	EUR	1 440.00	1 440.00
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	7 150.00	5 760.00
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	8 590.00	92 200.00

6.1.2.5.2 Operation cost

It was assumed that the maintenance cost is similar to a ro-pax newbuilding, refer to the cost figures listed in

Table 42.

6.1.2.5.3 Maintenance cost

The estimated cost for inspections, testing, and maintenance for the system solutions on a ro-pax existing ship is summarized in

Table 45.

Table 45. Action 6C- The estimated cost for the inspection, testing and maintenance of the system solutions, respectively, on a ro-pax existing ship

System Number			System#01	System#02
System Name			Opt-05 First Responc	Opt-06 - Localizatior
Maintenance cost				
Annual maintenance				
Annual system maintenance cost	EUR/year		-	-
Loss due to vessel downtime during maintenance	EUR/year		-	-
Other annual maintenance cost	EUR/year		-	-
			-	-
Total annual maintenance cost	EUR/year		-	-
Periodic maintenance				
Spare part cost	EUR		-	34 000.00
Service repair cost	EUR		-	-
Loss due to vessel downtime during repair	EUR		-	-
Other periodic maintenance cost	EUR		-	-
			-	-
Inspection				
Periodic inspection and certification cost	EUR		-	-
Other cost	EUR		-	-
			-	-
			-	-
End of Life cost				
Resale	EUR		-	-
Recycling	EUR		-	-
Other cost			-	-
			-	-
Total cost		EUR	-	-

6.1.2.5.4 End of life cost

No end of life cost considered

6.1.2.6 Life cycle cost component for vehicle carrier newbuilding

6.1.2.6.1 Investment cost

The estimated cost for the installation of the two system solutions on a vehicle carrier newbuilding are summarized in Table 46.

Table 46 Action 6C- The estimated cost for the installation of the system solutions, respectively, on a vehicle carrier newbuilding

System Number		System#01	System#02
System Name		Opt-05 First Responc	Opt-06 - Localizatior
Investment cost			
Purchasing cost	EUR	-	111 300.00
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	-	5 000.00
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	-	10 000.00
Comissioning cost	EUR	-	-
Document, certification and other administration costs	EUR	1 440.00	1 440.00
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	5 110.00	3 720.00
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	6 550.00	131 460.00

6.1.2.6.2 Operation cost

The operational cost for the installation of the systems solutions, respectively, on a vehicle carrier new building was considered and summarized in

Table 47.

Table 47. Action 6C- The estimated operation cost for the installation of the system solutions, respectively, on a vehicle carrier new building

System Number		System#01	System#02
System Name		Opt-05 First Responc	Opt-06 - Localizatior
Operation cost			
Additional Energy consumption	kWh/year	-	-
Additional Fuel Consumption	t/year	-	-
Reduce Fuel Consumption	t/year	-	-
Operator cost	EUR/year	880.00	500.00
Insurance, taxes, and other fees cost	EUR/year	-	-
Loss of cargo/loss revenue	EUR/year	-	-
Additional of cargo/profit revenue	EUR/year	-	-
Other operation cost	EUR/year	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total operation cost exc. Energy cost	EUR/year	880.00	500.00

6.1.2.6.3 Maintenance cost

The estimated cost for inspections, testing, and maintenance for the system solutions on a vehicle carrier new building is summarized inTable 48.

Table 48. Action 6C- The estimated cost for the inspection, testing and maintenance of the system solutions, respectively, on a vehicle carrier new building

System Number		System#01	System#02
System Name		Opt-05 First Responc	Opt-06 - Localizatior
Maintenance cost			
Annual maintenance			
Annual system maintenance cost	EUR/year	-	-
Loss due to vessel downtime during maintenance	EUR/year	-	-
Other annual maintenance cost	EUR/year	-	-
		-	-
Total annual maintenance cost	EUR/year	-	-
Periodic maintenance			
Spare part cost	EUR	-	38 133.33
Service repair cost	EUR	-	-
Loss due to vessel downtime during repair	EUR	-	-
Other periodic maintenance cost	EUR	-	-
		-	-
Inspection			
Periodic inspection and certification cost	EUR	-	-
Other cost	EUR	-	-
		-	-
		-	-

6.1.2.6.4 End of life cost

No end of life cost considered.

6.1.2.7 Life cycle cost component for vehicle carrier existing ship

6.1.2.7.1 Investment cost

The estimated cost for the installation of the two system solutions on a vehicle carrier existing ship are summarized in Table 49.

Table 49 Action 6C- The estimated cost for the installation of the system solutions, respectively, on a vehicle carrier existing ship

System Number		System#01	System#02
System Name		Opt-05 First Responc	Opt-06 - Localizatior
Investment cost			
Purchasing cost	EUR	-	161 300.00
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	-	5 000.00
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	-	20 000.00
Comissioning cost	EUR	-	-
Document, certification and other administration costs	EUR	1 440.00	1 440.00
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	5 110.00	3 720.00
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	6 550.00	191 460.00

6.1.2.7.2 Operation cost

It was assumed that the maintenance cost is similar to a vehicle carrier new building, refer to the cost figures listed in

Table 47.

6.1.2.7.3 Maintenance cost

The estimated cost for inspections, testing, and maintenance for the system solutions on a vehicle carrier existing ship is summarized in

Table 50.

Table 50. Action 6C- The estimated cost for the inspection, testing and maintenance of th etwo system solutions, respectively, on a vehicle carrier existing ship

System Number		System#01	System#02
System Name		Opt-05 First Responc	Opt-06 - Localizatior
Maintenance cost			
Annual maintenance			
Annual system maintenance cost	EUR/year	-	-
Loss due to vessel downtime during maintenance	EUR/year	-	-
Other annual maintenance cost	EUR/year	-	-
		-	-
Total annual maintenance cost	EUR/year	-	-
Periodic maintenance			
Spare part cost	EUR	-	54 800.00
Service repair cost	EUR	-	-
Loss due to vessel downtime during repair	EUR	-	-
Other periodic maintenance cost	EUR	-	-
		-	-
Inspection			
Periodic inspection and certification cost	EUR	-	-
Other cost	EUR	-	-
		-	-
		-	-

6.1.2.7.4 End of life cost

No end of life cost considered.

6.1.3 LCC results

The LCC results for a ro-ro cargo new building is shown in Table 51.

Table 51. Action 6C- The LCC results for a ro-ro cargo new building

System Number		System#01	System#02
System Name		Opt-05 First Responce	Opt-06 - Localization tech
Unit		**Per Ship**	
Total Investment cost	EUR	6 550.00 €	57 460.00 €
Total Operation cost	EUR	19 936.86 €	11 327.76 €
Total Maintenance cost	EUR	- €	51 723.66 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	26 486.86 €	120 511.42 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	1.71 €	15.00 €
Total Operation cost	EUR	5.20 €	2.96 €
Total Maintenance cost	EUR	- €	13.50 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	6.91 €	31.46 €

The LCC results for a ro-ro cargo existing ship is shown in Table 52.

Table 52. Action 6C- The LCC results for a ro-ro cargo existing ship

System Number		System#01	System#02
System Name		Opt-05 First Responce	Opt-06 - Localization tech
Unit		**Per Ship**	
Total Investment cost	EUR	6 550.00 €	80 460.00 €
Total Operation cost	EUR	14 227.07 €	8 083.56 €
Total Maintenance cost	EUR	- €	47 176.20 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	20 777.07 €	135 719.77 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	1.71 €	21.00 €
Total Operation cost	EUR	3.71 €	2.11 €
Total Maintenance cost	EUR	- €	12.31 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	5.42 €	35.43 €

The LCC results for a ro-pax new building is shown in Table 53

Table 53. Action 6C- The LCC results for a ro-pax new building.

System Number		System#01	System#02
System Name		Opt-05 First Responce	Opt-06 - Localization tech
Unit		**Per Ship**	
Total Investment cost	EUR	8 590.00 €	72 200.00 €
Total Operation cost	EUR	32 732.65 €	11 774.34 €
Total Maintenance cost	EUR	- €	127 187.62 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	41 322.65 €	211 161.96 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	3.90 €	32.82 €
Total Operation cost	EUR	14.88 €	5.35 €
Total Maintenance cost	EUR	- €	57.81 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	18.78 €	95.98 €

The LCC results for a ro-pax existing ship is shown in Table 54

Table 54. Action 6C- The LCC results for a ro-pax existing ship

System Number		System#01	System#02
System Name		Opt-05 First Responce	Opt-06 - Localization tech
Unit		**Per Ship**	
Total Investment cost	EUR	8 590.00 €	92 200.00 €
Total Operation cost	EUR	22 472.30 €	8 083.56 €
Total Maintenance cost	EUR	- €	90 111.85 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	31 062.30 €	190 395.41 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	3.90 €	41.91 €
Total Operation cost	EUR	10.21 €	3.67 €
Total Maintenance cost	EUR	- €	40.96 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	14.12 €	86.54 €

The LCC results for a vehicle carrier new building is shown in Table 55.

Table 55. Action 6C- The LCC results for a vehicle carrier new building

System Number		System#01	System#02
System Name		Opt-05 First Responce	Opt-06 - Localization tech
Unit		**Per Ship**	
Total Investment cost	EUR	6 550.00 €	131 460.00 €
Total Operation cost	EUR	16 426.98 €	9 333.51 €
Total Maintenance cost	EUR	- €	117 202.63 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	22 976.98 €	257 996.14 €
Unit		**Per CEU**	
Total Investment cost	EUR	1.03 €	20.70 €
Total Operation cost	EUR	2.59 €	1.47 €
Total Maintenance cost	EUR	- €	18.46 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	3.62 €	40.63 €

The LCC results for a vehicle carrier existing ship is shown in Table 56

Table 56. Action 6C- The LCC results for a vehicle carrier existing ship

System Number		System#01	System#02
System Name		Opt-05 First Responce	Opt-06 - Localization tech
Unit		**Per Ship**	
Total Investment cost	EUR	6 550.00 €	191 460.00 €
Total Operation cost	EUR	11 522.82 €	6 547.06 €
Total Maintenance cost	EUR	- €	117 698.49 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	18 072.82 €	315 705.54 €
Unit		**Per CEU**	
Total Investment cost	EUR	1.03 €	30.15 €
Total Operation cost	EUR	1.81 €	1.03 €
Total Maintenance cost	EUR	- €	18.54 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	2.85 €	49.72 €

Results summary is shown in Table 57.

Table 57. Action 6C - Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-pax		ro-ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Op5	First response guidelines and new equipment to put out the fire in the initial stage	Investment	8 590.00 €	8 590.00 €	6 550.00 €	6 550.00 €	6 550.00 €	6 550.00 €
		Operation	32 732.65 €	22 472.30 €	19 936.86 €	14 227.07 €	16 426.98 €	11 522.82 €
		Maintance	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		TOTAL	**41 322.65 €**	**31 062.30 €**	**26 486.86 €**	**20 777.07 €**	**22 976.98 €**	**18 072.82 €**
Op6	Technology for localization of first responders through digital information processed via network	Investment	72 200.00 €	92 200.00 €	57 460.00 €	80 460.00 €	131 460.00 €	191 460.00 €
		Operation	11 774.34 €	8 083.56 €	11 327.76 €	8 083.56 €	9 333.51 €	6 547.06 €
		Maintance	127 187.62 €	90 111.85 €	51 723.66 €	47 176.20 €	117 202.63 €	117 698.49 €
		TOTAL	**211 161.96 €**	**190 395.41 €**	**120 511.42 €**	**135 719.76 €**	**257 996.14 €**	**315 705.55 €**
RCO3	Efficient first response	Investment	8 590.00 €	8 590.00 €	6 550.00 €	6 550.00 €	6 550.00 €	6 550.00 €
		Operation	32 732.65 €	22 472.30 €	19 936.86 €	14 227.07 €	16 426.98 €	11 522.82 €
		Maintance	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		TOTAL	**41 322.65 €**	**31 062.30 €**	**26 486.86 €**	**20 777.07 €**	**22 976.98 €**	**18 072.82 €**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed

6.2 Conclusion

An assessment of the lifecycle cost for the solutions proposed by Action 6-C was performed. Further, the assessment was performed for three ship types, the selected generic ro-ro cargo, ro-pax and vehicle carrier that were used for integration and LCC assessment.

The considered solutions are independent of the arrangement of the vessel, instead cargo volumes and crew size are dominant parameters.

7 Effective and efficient manual firefighting- Action 6-D

Main author of the chapter: Martin Carlsson, STL

This chapter presents an overview of the life cycle cost and environmental assessment for the solutions proposed by Action 6-D i.e. Effective and efficient manual firefighting. One RCMs proposed by WP06 and one RCO selected (Ref. D04.6 "Cost-effectiveness assessment report" [2]) and assessed within this report:

- RCM Op7 -Training, new equipment and procedures to suppress APV fires with special focus on Li-Ion batteries fires
- RCO4 - Manual firefighting for Alternatively Powered Vehicles

For the description of the RCM please refer to Deliverable D04.9 "Preliminary impact of solutions and related testing and demonstrations plan" [1], for the description of the RCO please refer to Deliverable D04.6, [2].

7.1 Life cycle cost assessment

An installation cost assessment for the system solution was made:

- **System#01** - Training, new equipment and procedures to suppress APV fires with special focus on Li-Ion batteries fires (RCM Op7)

Cost assessment for the RCO4 was found to be same as for System#1, RCM Op7.

The cost assessment was made for reference ships selected by the project with respect to the applicability of the solutions proposed; Magnolia Seaways the generic ro-ro cargo ship operated by DFDS Seaways, and Stena Flavia, the generic ro-pax ship and Torrens, the generic vehicle carrier. The cost assessment was made for new buildings and existing ships.

7.1.1 Description of the developed solution

7.1.1.1 System#01: Training, new equipment and procedures to suppress APV fires with special focus on Li-Ion batteries fires (Op7)

For the LCC assessment the following content was assumed:

- 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, and
- method for post treatment of gear and crew.

7.1.2 Life cycle cost model

7.1.2.1 Cost items description and assumptions

Independent of the system and ship type the following costs were considered:

- Investment cost,
- operation cost,
- inspections, testing, and maintenance, and
- end of life cost.

It was assumed that all system solutions will be serviceable during the entire time if properly maintained.

7.1.2.1.1 System#01: Improved fire patrol procedures (Op1)

7.1.2.1.1.1 Investment cost

The following items are considered:

- Additional equipment:
  - cooling devices
  - fire blankets
  - fognail
  - push talk button units
  - fire suits EN 469 level 2 wheel
  - hoods
  - spare second layers
  - post mission treatment kit
- company procedures development, AND
- ship procedures development.

The purchasing costs of equipment was estimated based on figures from system component suppliers. Cost for establishing procedures and crew training on board was estimated based on Stena best practice experience.

7.1.2.1.1.2 Operation cost

The following items are considered:

- Training cost (Advanced fire fighting).

7.1.2.1.1.3 Maintenance cost

Maintenance cost estimation was based on necessary renewal of equipment according to Stena best practice experience.

7.1.2.1.1.4 End of life cost

No end of life cost considered.

7.1.2.2 Life cycle cost component for ro-pax newbuilding

7.1.2.2.1 Investment cost

The estimated cost for the installation of the system solution on a ro-pax newbuilding is summarized in

Table 58.

Table 58 Action 6D- The estimated cost for the installation of the system solutions on a ro-pax new building

System Number		System#01
System Name		Op7 - AVF method ar
Investment cost		
Purchasing cost	EUR	16 500.00
Insurance cost	EUR	-
Integration design & validation cost	EUR	-
Disassemble and modify the old system or structure	EUR	-
Road transporter cost	EUR	-
Ship transporter cost	EUR	-
Assembly/Installation cost	EUR	-
Comissioning cost	EUR	-
Document, certification and other administration costs	EUR	2 400.00
Loss of hire costs	EUR	-
Operator traning cost	EUR	4 800.00
Other cost	EUR	-
		-
		-
		-
		-
		-
		-
Total cost	EUR	23 700.00

7.1.2.2.2 Operation cost

The operational cost for the installation of the systems on a ro-pax newbuilding was considered and summarized in Table 59.

Table 59. Action 6D- The estimated operation cost for the installation of the system solution on a ro-pax new building

System Number		System#01
System Name		Op7 - AVF method ar
Operation cost		
Additional Energy consumption	kWh/year	-
Additional Fuel Consumption	t/year	-
Reduce Fuel Consumption	t/year	-
Operator cost	EUR/year	960.00
Insurance, taxes, and other fees cost	EUR/year	-
Loss of cargo/loss revenue	EUR/year	-
Additional of cargo/profit revenue	EUR/year	-
Other operation cost	EUR/year	-
		-
		-
		-
		-
		-
		-
		-
Total operation cost exc. Energy cost	EUR/year	960.00

7.1.2.2.3 Maintenance cost

The estimated cost for inspections, testing, and maintenance for the system solution on a ro-pax newbuilding is summarized in Table 60.

Table 60. Action 6D- The estimated cost for the inspection, testing and maintenance of the system solution for a ro-pax new building

System Number		System#01
System Name		Op7 - AVF method ar
Maintenance cost		
Annual maintenance		
Annual system maintenance cost	EUR/year	-
Loss due to vessel downtime during maintenance	EUR/year	-
Other annual maintenance cost	EUR/year	-
		-
Total annual maintenance cost	EUR/year	-
Periodic maintenance		
Spare part cost	EUR	16 500.00
Service repair cost	EUR	-
Loss due to vessel downtime during repair	EUR	-
Other periodic maintenance cost	EUR	-
		-
Inspection		
Periodic inspection and certification cost	EUR	-
Other cost	EUR	-
		-
		-

7.1.2.2.4 End of life cost

No end of life cost considered.

7.1.2.3 Life cycle cost component for ro-pax existing ship

7.1.2.3.1 Investment cost

It was assumed that the installation of the system solution on a ro-pax existing ship is similar to a ro-pax newbuilding, refer to the cost figures listed in Table 58

7.1.2.3.2 Operation cost

It was assumed that the operational cost is similar to a ro-pax newbuilding, refer to the cost figures listed in Table 59.

7.1.2.3.3 Maintenance cost

It was assumed that the maintenance cost is similar to a ro-pax newbuilding, refer to the cost figures listed in Table 60.

7.1.2.3.4 End of life cost

No end of life cost considered

7.1.2.4 Life cycle cost component for ro-ro cargo newbuilding

7.1.2.4.1 Investment cost

The estimated cost for the installation of the system solution on a ro-ro cargo newbuilding is summarized in Table 61.

Table 61 Action 6D- The estimated cost for the installation of the system solutions on a ro-ro cargo newbuilding

System Number		System#01
System Name		Op7 - AVF method ar
Investment cost		
Purchasing cost	EUR	16 500.00
Insurance cost	EUR	-
Integration design & validation cost	EUR	-
Disassemble and modify the old system or structure	EUR	-
Road transporter cost	EUR	-
Ship transporter cost	EUR	-
Assembly/Installation cost	EUR	-
Comissioning cost	EUR	-
Document, certification and other administration costs	EUR	2 400.00
Loss of hire costs	EUR	-
Operator traning cost	EUR	3 360.00
Other cost	EUR	-
		-
		-
		-
		-
		-
		-
		-
Total cost	EUR	22 260.00

7.1.2.4.2 Operation cost

The operational cost for the installation of the system on a ro-ro cargo newbuilding was considered and summarized in Table 62.

Table 62. Action 6D- The estimated operation cost for the installation of the system solution on a ro-ro cargo newbuilding

System Number		System#01
System Name		Op7 - AVF method ar
Operation cost		
Additional Energy consumption	kWh/year	-
Additional Fuel Consumption	t/year	-
Reduce Fuel Consumption	t/year	-
Operator cost	EUR/year	672.00
Insurance, taxes, and other fees cost	EUR/year	-
Loss of cargo/loss revenue	EUR/year	-
Additional of cargo/profit revenue	EUR/year	-
Other operation cost	EUR/year	-
		-
		-
		-
		-
		-
		-
		-
Total operation cost exc. Energy cost	EUR/year	672.00

7.1.2.4.3 Maintenance cost

It was assumed that the maintenance cost of a ro-ro cargo newbuilding is similar to a ro-pax newbuilding, refer to the cost figures listed in Table 60.

7.1.2.4.4 End of life cost

No end of life cost considered

7.1.2.5 Life cycle cost component for ro-ro cargo existing ship

7.1.2.5.1 Investment cost

It was assumed that the installation of the system solution on a ro-ro cargo existing ship is similar to a ro-ro cargo newbuilding, refer to the cost figures listed in Table 61.

7.1.2.5.2 Operation cost

It was assumed that the maintenance cost is on a ro-ro cargo existing ship is similar to a ro-ro cargo newbuilding, refer to the cost figures listed in Table 62

7.1.2.5.3 Maintenance cost

It was assumed that the maintenance cost of a ro-ro cargo existing ship is similar to a ro-pax newbuilding, refer to the cost figures listed in Table 60.

7.1.2.5.4 End of life cost

No end of life cost considered.

7.1.2.6 Life cycle cost component for vehicle carrier newbuilding

7.1.2.6.1 Investment cost

The estimated cost for the installation of the system solution on a vehicle carrier newbuilding are summarized in

Table 63.

Table 63 Action 6D- The estimated cost for the installation of the system solution on a vehicle carrier newbuilding

System Number		System#01
System Name		Op7 - AVF method ar
Investment cost		
Purchasing cost	EUR	21 500.00
Insurance cost	EUR	-
Integration design & validation cost	EUR	-
Disassemble and modify the old system or structure	EUR	-
Road transporter cost	EUR	-
Ship transporter cost	EUR	-
Assembly/Installation cost	EUR	-
Comissioning cost	EUR	-
Document, certification and other administration costs	EUR	2 400.00
Loss of hire costs	EUR	-
Operator traning cost	EUR	3 360.00
Other cost	EUR	-
		-
		-
		-
		-
		-
		-
Total cost	EUR	27 260.00

7.1.2.6.2 Operation cost

It was assumed that the maintenance cost is on a vehicle carrier newbuilding is similar to a ro-ro cargo newbuilding, refer to the cost figures listed in Table 62.

7.1.2.6.3 Maintenance cost

The estimated cost for inspections, testing, and maintenance for the system solution on a vehicle carrier newbuilding is summarized in Table 64.

Table 64. Action 6D- The estimated cost for the inspection, testing and maintenance of the system solution for a vehicle carrier newbuilding

System Number		System#01
System Name		Op7 - AVF method ar
Maintenance cost		
Annual maintenance		
Annual system maintenance cost	EUR/year	-
Loss due to vessel downtime during maintenance	EUR/year	-
Other annual maintenance cost	EUR/year	-
		-
Total annual maintenance cost	EUR/year	-
Periodic maintenance		
Spare part cost	EUR	21 500.00
Service repair cost	EUR	-
Loss due to vessel downtime during repair	EUR	-
Other periodic maintenance cost	EUR	-
		-
Inspection		
Periodic inspection and certification cost	EUR	-
Other cost	EUR	-
		-
		-

7.1.2.6.4 End of life cost

No end of life cost considered.

7.1.2.7 Life cycle cost component for vehicle carrier existing ship

7.1.2.7.1 Investment cost

It was assumed that the installation of the system solution on a vehicle carrier existing ship is similar to a vehicle carrier newbuilding, refer to the cost figures listed in Table 63.

Table 26

7.1.2.7.2 Operation cost

It was assumed that the maintenance cost is on a vehicle carrier existing ship is similar to a ro-ro cargo newbuilding, refer to the cost figures listed in Table 62

7.1.2.7.3 Maintenance cost

It was assumed that the maintenance cost of a vehicle carrier existing ship is similar to a vehicle carrier newbuilding, refer to the cost figures listed in Table 64.

7.1.2.7.4 End of life cost

No end of life cost considered.

7.1.3 LCC Result

Main author of the chapter: Vito Radolovic, FLOW

The LCC results for a ro-pax newbuilding is shown in Table 65.

Table 65. Action 6D- The LCC results for a ro-pax newbuilding.

System Number		System#01
System Name		Op7 - AVF method a
Unit		**Per Ship**
Total Investment cost	EUR	23 700.00 €
Total Operation cost	EUR	22 606.72 €
Total Maintenance cost	EUR	31 845.47 €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	78 152.19 €
Unit		**Per Lane meter**
Total Investment cost	EUR	10.77 €
Total Operation cost	EUR	10.28 €
Total Maintenance cost	EUR	14.48 €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	35.52 €

The LCC results for a ro-pax existing ship is shown in Table 66.

Table 66. Action 6D- The LCC results for a ro-pax existing ship

System Number		System#01
System Name		Op7 - AVF method a
Unit		**Per Ship**
Total Investment cost	EUR	23 700.00 €
Total Operation cost	EUR	15 520.44 €
Total Maintenance cost	EUR	19 989.50 €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	59 209.94 €
Unit		**Per Lane meter**
Total Investment cost	EUR	10.77 €
Total Operation cost	EUR	7.05 €
Total Maintenance cost	EUR	9.09 €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	26.91 €

The LCC results for a ro-ro cargo newbuilding is shown in Table 67.

Table 67. Action 6D- The LCC results for a ro-ro cargo newbuilding

System Number		System#01
System Name		Op7 - AVF method a
Unit		**Per Ship**
Total Investment cost	EUR	22 260.00 €
Total Operation cost	EUR	15 224.51 €
Total Maintenance cost	EUR	26 787.28 €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	64 271.79 €
Unit		**Per Lane meter**
Total Investment cost	EUR	5.81 €
Total Operation cost	EUR	3.97 €
Total Maintenance cost	EUR	6.99 €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	16.78 €

The LCC results for a ro-ro cargo existing ship is shown in Table 68.

Table 68. Action 6D- The LCC results for a ro-ro cargo existing ship

System Number		System#01
System Name		Op7 - AVF method a
Unit		**Per Ship**
Total Investment cost	EUR	22 260.00 €
Total Operation cost	EUR	10 864.31 €
Total Maintenance cost	EUR	19 989.50 €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	53 113.81 €
Unit		**Per Lane meter**
Total Investment cost	EUR	5.81 €
Total Operation cost	EUR	2.84 €
Total Maintenance cost	EUR	5.22 €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	13.86 €

The LCC results for a vehicle carrier newbuilding is shown in Table 69.

Table 69. Action 6D- The LCC results for a vehicle carrier newbuilding

System Number		System#01
System Name		Op7 - AVF method ai
Unit		**Per Ship**
Total Investment cost	EUR	27 260.00 €
Total Operation cost	EUR	12 544.24 €
Total Maintenance cost	EUR	26 046.92 €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	65 851.16 €
Unit		**Per CEU**
Total Investment cost	EUR	4.29 €
Total Operation cost	EUR	1.98 €
Total Maintenance cost	EUR	4.10 €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	10.37 €

The LCC results for a vehicle carrier existing ship is shown in Table 70.

Table 70. Action 6D- The LCC results for a vehicle carrier existing ship

System Number		System#01
System Name		Op7 - AVF method ai
Unit		**Per Ship**
Total Investment cost	EUR	27 260.00 €
Total Operation cost	EUR	8 799.25 €
Total Maintenance cost	EUR	15 241.75 €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	51 301.00 €
Unit		**Per CEU**
Total Investment cost	EUR	4.29 €
Total Operation cost	EUR	1.39 €
Total Maintenance cost	EUR	2.40 €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	8.08 €

Results summary is shown in Table 71.

Table 71. Action 6D - Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-pax		ro-ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Op7	Training, new equipment and procedures to suppress fires in Alternatively Powered Vehicles with special focus on Li-ion batteries fires	Investment	23 700.00 €	23 700.00 €	22 260.00 €	22 260.00 €	27 260.00 €	27 260.00 €
		Operation	22 606.72 €	15 520.44 €	15 224.51 €	10 864.31 €	12 544.24 €	8 799.25 €
		Maintance	31 845.47 €	19 989.50 €	26 787.28 €	19 989.50 €	26 046.92 €	15 241.75 €
		TOTAL	**78 152.19 €**	**59 209.94 €**	**64 271.79 €**	**53 113.81 €**	**65 851.16 €**	**51 301.00 €**
RCO4	Manual firefighting for Alternatively Powered Vehicles	Investment	23 700.00 €	23 700.00 €	22 260.00 €	22 260.00 €	27 260.00 €	27 260.00 €
		Operation	22 606.72 €	15 520.44 €	15 224.51 €	10 864.31 €	12 544.24 €	8 799.25 €
		Maintance	31 845.47 €	19 989.50 €	26 787.28 €	19 989.50 €	26 046.92 €	15 241.75 €
		TOTAL	**78 152.19 €**	**59 209.94 €**	**64 271.79 €**	**53 113.81 €**	**65 851.16 €**	**51 301.00 €**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed

7.2 Environmental assessment

Main author of the chapter: Francine Amon, RISE

Life cycle assessment (LCA) is utilized to compare the environmental impacts of a collection of manual firefighting devices and their respective operational procedures in response to a fire originating in an alternative powered vehicle (APV) on a ro-pax ship car deck, see IR05.66 for the full LCA report. The devices include three types of handheld extinguisher (CO_2, ABC, and compressed air foam (CAF)), a fire blanket, and three water application devices (standard nozzle, fognail nozzle, and water-cooling nozzle).

7.2.1 Approach

The approach used to evaluate the devices is largely shaped by the fire suppression tests conducted in the spring of 2022 at Centro Jovellanos, Spain, and reported in D06.8. *Development and testing of APV firefighting routines, equipment and tactics Ref.* [10]. The overall system boundaries include an entire ro-pax ship, represented by the Stena Flavia, shown in Figure 4. These system boundaries ensure that the environmental burden of a vehicle fire is not simply shifted elsewhere, e.g., outside the scope of the LASH FIRE project or to other systems or operations within the ship.

Figure 4: Stena Flavia, the reference ship used for the LCAs.

Ordinarily manual firefighting of a well-developed fire would take place concurrently with the use of a fixed fire protection system, typically a drencher system. However, a drencher system would have added significant complexity to the fire suppression tests, possibly obscuring the results of the manual firefighting operations that are the focus of WP6 (Effective *Manual* Operations), so a drencher system was not included in the fire tests. This made it difficult to construct a realistic reference (REF) case to compare with the manual firefighting devices.

Following the approach used in the fire suppression tests, the water application devices are compared together as a package against a reference “worst case” in which a fire occurs but is only suppressed by the drencher system. Theoretically, the REF case fire *could* spread to all the cars on the deck, resulting in as many as 83 burned cars if the car deck (deck 2 of the Stena Flavia) were loaded to full capacity, however, it is highly unlikely that the damage would be so widespread if a drencher system were activated. Given the extensive research conducted at RISE regarding the spread of vehicle fires in areas protected by drencher systems, it was assumed that the fire in the REF case would damage 50 % of the vehicles adjacent to the vehicle in which the fire originates, i.e., a total of 3 vehicles would need to be replaced.

7.2.2 Assumptions

It was necessary to make assumptions when insufficient resources and/or information were available to support the LCA models, particularly regarding the damage caused by a fire. If the same conditions

and challenges are used for all the manual firefighting devices in the comparison, then their relative fire performance can be preserved; however, it is not recommended to generalise these results to other systems or conditions. The assumptions are listed below.

- The extinguishers and the fire blanket are used beginning at 3 minutes after the fire starts.
- The water application devices are used beginning at 12 minutes after the fire starts.
- The REF case and the case in which the fire is well-developed before being suppressed using manual water application devices results in fire damage to 50 % of the vehicles adjacent to the vehicle in which the fire originates, i.e., a total of 3 vehicles are replaced.
- No adjacent vehicles are damaged if a traction battery fire occurs and is suppressed using handheld fire extinguishers and/or a fire blanket.
- The vehicle in which the fire originates is replaced 50 % of the time and only the traction battery is replaced 50 % of the time if handheld extinguishers and/or a blanket are used within 3 min of the fire starting.
- A drencher system prevents fire spread to other vehicles in case of a well-developed vehicle fire.
- The service life of the manual firefighting devices is 10 years, except the fire blanket, which was assumed to be used once if a fire occurs.
- The foam used in the CAF handheld fire extinguisher is fluorine free foam (3F), as recommended by the LASH FIRE partner F4M.

7.2.3 Results

The detailed LCA results are shown in Figure 5, where replacing the traction battery or the entire vehicle is shown to have the most impact compared with the lifecycle impacts of the manual firefighting devices in most of the impact categories. The global warming category is the exception, where manufacturing of the products has a higher impact.

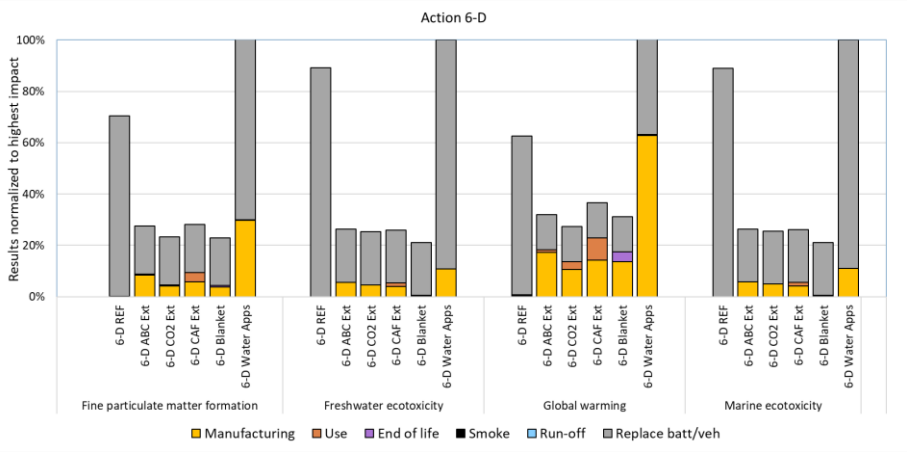

Figure 5: Detailed results for manual firefighting devices, compared with the REF case in which no manual firefighting devices are used.

The impacts from the fire (smoke and fire water run-off) are minimal, in fact they are barely visible compared with the other contributing factors. The overall impacts of the three handheld fire extinguishers are similar, while the water application devices have higher manufacturing impacts in all four categories. The fire blanket has relatively low impacts, however, its end-of-life phase is relatively

high due to its status as hazardous waste. The use phase impacts account for some of the difference between the three handheld extinguishers because of the fate of the suppressants, e.g., CO_2 and CAF.

7.2.4 Discussion

Replacing a burned vehicle or APV traction battery carries a large environmental burden, most of which is attributed to transporting the vehicle or battery long distances. Both items are heavy and may be transported on the ground (roads or rails) and via ships. This why replacing the vehicle or battery dominates the impacts in most of the categories chosen for this analysis.

The number of scrapped vehicles has a large influence on the results of the study, as indicated by the sensitivity analysis. This does not show up in the uncertainty results because of the way the input is handled in the LCA software, which is dependent on the distribution of process input values. The number of scrapped vehicles is, in fact, a very uncertain parameter as no information could be found about how the decision to scrap a vehicle is made.

In most cases the fire blanket has the least impact when used during the initial stages of a fire. This is because the fire blanket is a simple device requiring relatively minimal manufacturing and it has no maintenance, assuming it is only used once. The fire residue deposited on the blanket could be toxic to touch and it could off-gas for some time after a fire if stored in anticipation of additional uses. For these reasons it is recommended to dispose of the blanket as hazardous waste after a single use.

The contributions from smoke and fire water run-off are very small because it was assumed that only one traction battery or vehicle burns. Even in the REF and water application cases, where half of the adjacent vehicles suffer collateral damage, only one vehicle produces smoke and contributes pollutants to the fire water run-off.

The manufacturing phase of the water application devices is higher than the handheld fire extinguishers because the water application devices (three types of nozzles) are grouped together and compared to individual handheld extinguishers. This was done because the water application devices were used together during the fire tests, so their individual suppression performance could not be distinguished.

7.3 Conclusion

An assessment of the life cycle cost for the solutions proposed by Action 6-D was performed. Further, the assessment was performed for three ship types, the selected generic ro-ro cargo, ro-pax and vehicle carrier that were used for integration and LCC assessment. The here considered solution is dependent of the arrangement of the vessel and crew.

7.3.1 LCA conclusion

The LCA models used in this analysis include smoke emitted to the atmosphere, fire water run-off into surface water, replacing damaged vehicles and/or traction batteries, and the manufacturing, use, and end-of-life phases of three types of handheld fire extinguisher (ABC, CO_2, CAF), a fire blanket, and three types of nozzles. These results are compared with a reference case in which a fire occurs but there are no manual firefighting operations on the car deck. The performance of the manual firefighting devices was based on fire tests reported in D06.8, although many assumptions were made as well.

The results of this analysis reinforce the concept that the ability to arrive at a fire quickly and use handheld fire extinguishers and/or a fire blanket reduces the overall impact of the fire considerably when compared with manual firefighting operations after the fire has developed. All three handheld fire extinguishers and the fire blanket had similar results, assuming the CAF extinguisher uses fluorine free foam.

It is normal protocol for a drencher system to be activated if a fire on a car deck cannot be controlled quickly. Thus, it is unlikely that a fire will spread from the original burning vehicle, however, it is possible that collateral damage will occur to adjacent vehicles, e.g., damaged plastic parts, paint, windows, soot deposition, etc. Replacing damaged vehicles and/or a traction battery account for most of the environmental impact of a vehicle fire in most cases, but no information is available about the extent of damage leading to the need to replace a vehicle or traction battery. This is a sensitive and uncertain condition and a weakness of the analysis.

These results are based on extensive assumptions and should not be generalised to other situations or conditions.

8 Improved bridge alarm panel design - Action 7-A

Main author of the chapter: Vito Radolovic, FLOW

This chapter presents an overview of the life cycle cost assessment for the solutions proposed by Action 7-A i.e. Improved bridge alarm panel design. Two RCMs were proposed by WP07 and one RCO selected (Ref. D04.6, [2]) and assessed within this report:

- RCM Des1: User friendly alarm system interface design guidelines
- RCM Des2: Alarm system interface prototype
- RCO5: Alarm system interface prototype

For the description of the RCM's please refer to Deliverable D04.9, [1], for the description of the RCO please refer to Deliverable D04.6, [2].

8.1 Life cycle cost assessment

An installation cost assessment for selected system solutions was made:

- **System#01** - User friendly alarm system interface design guidelines (Des1)
- **System#02** - Alarm system interface prototype (Des2)

Cost assessment for the RCO5 was found to be same as for System#2, RCM Des2.

The cost assessment was assessed for reference ships selected by the project with respect to the applicability of the solutions proposed; Magnolia Seaways the generic ro-ro cargo ship operated by DFDS Seaways, Stena Flavia, the generic ro-pax ship and Torrens, the generic vehicle carrier operated by Wallenius. The cost assessment was made for new buildings only as for existing ships the cost estimation was found not feasible, Ref D05.7 [3].

8.1.1 Description of the developed solution

8.1.1.1 System#01: User friendly alarm system interface design guidelines (Des1)

The proposed solution provides a set of design guidelines with shipping companies and systems manufacturers as prospective end-users. While these guidelines will give generic guidance towards alarm systems interface design, it is also understood that most projects require tailoring to the specific context, e.g. the individual ship and operational characteristics. Therefore, these guidelines will also target the design process, its participants, activities and working methods, allowing stakeholders to consistently identify and pursue user-centered design goals in a variety of contexts. The issue of fire alarm system interfaces is used throughout as a case for demonstration of alternative design approaches (Des2).

The guidelines as they are envisioned are not limited to simple design specifications that can be applied without adaptation by any shipping company. Instead, the need for new (albeit cost-effective) practices in ship design and procurement is emphasized. Changes in existing practices, adopting new ideas in design, is associated with higher costs than simply buying alternative products.

8.1.1.2 System#02: Alarm system interface prototype (Des2)

For the cost assessment purpose, the content of this RCM was assumed to be a fire alarm system interface demonstrator resulting from the alternative design approaches according to the solution Des1. The solution considers both the alarm system interface installation and integration within ship systems, comprising at least the following:

- Alarm state for each fire detector,
- temperature measured by each temperature sensor,
- smoke measured by each smoke detector,
- fire damper status (through feedback contacts),
- fire extinguishing system status, and
- health information from all connected systems and subsystems.

Moreover, the design assumes access to command resources in the fire extinguishing system, including start and stop of ventilators, fire system resources like fire pumps and water mist systems, closing of fire dampers etc.

8.1.2 Life cycle cost model

8.1.2.1 Cost items description and assumptions

Independent of the system and ship type the following costs were considered:

- Investment cost,
- operation cost, and
- inspections, testing, and maintenance,

The expected lifetime for a newly built ship was assumed to be 43 years for the ro-pax, 40.3 years for the ro-ro cargo and 28.8 years for the vehicle carrier. Further, it was assumed that all system solutions will be serviceable during the entire time if properly maintained.

8.1.2.1.1 System#01: User friendly alarm system interface design guidelines (Des1)

8.1.2.1.1.1 Investment cost

The following items are considered:

- Consultation at Shipyard/design office – the potential need for external assistance when adopting and realizing new design process practices,
- design process development,
- design, engineering and integration, additional cost due to deviation from established practice and standard installation,
- ship operator procedure updates, and
- crew training.

Cost for establishing procedures and crew training on board was estimated based on best practice experience.

8.1.2.1.1.2 Operation cost

No additional operational cost considered as assumed that crew training is part of standard fire drills as per ship operator best practice.

8.1.2.1.1.3 Maintenance cost

No maintenance cost considered.

8.1.2.1.2 System#02: Alarm system interface prototype (Des2)

8.1.2.1.2.1 Investment cost

The following items are considered:

- The cost for system components (Large screen display, Computer, supports),

- consultation at shipyard/design office – the potential need for external assistance when adopting and realizing new design process practices,
- design process development,
- design, engineering and integration, additional cost due to deviation from established practice and standard installation,
- installation and interfacing cost,
- commissioning cost,
- ship operator procedure updates, and
- crew training.

The purchasing costs of equipment was estimated based on figures from system component suppliers. Cost for establishing procedures and crew training on board was estimated based on best practice experience.
Assumed no additional cost for ship systems equipment and software adjustments, as found feasible for the system providers. However, it was found as a very optimistic approach as at this stage it is not feasible to estimate eventual cost increase and support by system suppliers. Further, It was considered that all system suppliers will adopt to the proposed Des2 requirements, including equipment and software adjustments/developments (suppliers investment). This is NOT likely for a near future and a small number of installations. It is more likely if such requirements would be class/authorities requirement and/or a mass installation. Deviations of the assumptions may significantly affect the cost assessment.

However, more conservative assumption was considered for the investment cost related to the consultation, design process and additional cost due to deviation from established practice and standard installation as it is more likely that this costs are related more to the shipyard and ship operator practice for the first instalment rather than for each ship.

8.1.2.2 Operation cost

No additional operational cost considered as assumed that crew training is part of standard fire drills as per ship operator best practice.

8.1.2.3 Maintenance cost

Maintenance cost estimation was based on necessary renewal of equipment (screen, personal computer) according to best practice experience.

8.1.2.4 Life cycle cost component for ro-pax newbuilding

8.1.2.4.1 Investment cost

The estimated cost for the installation of the system solutions on a ro-pax newbuilding is summarized in

Table 72.

Table 72 Action 7A- The estimated cost for the installation of the system solutions on a ro-pax newbuilding

System Number		System#01	System#02
System Name		Des1 - User friendly a	Des2-Alarm system
Investment cost			
Purchasing cost	EUR	-	14 000.00
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	24 800.00	24 800.00
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	15 000.00	25 000.00
Comissioning cost	EUR	500.00	500.00
Document, certification and other administration costs	EUR	-	-
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	9 400.00	9 400.00
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	49 700.00	73 700.00

8.1.2.4.2 Operation cost

No operation cost considered.

8.1.2.4.3 Maintenance cost

The estimated cost for inspections, testing, and maintenance for the system solution on a ro-pax newbuilding is summarized in

Table 73.

Table 73. Action 7A- The estimated cost for the inspection, testing and maintenance of the system solutions for a ro-pax new building

System Number		System#01	System#02
System Name		Des1 - User friendly a	Des2-Alarm system
Maintenance cost			
Annual maintenance			
Annual system maintenance cost	EUR/year	-	-
Loss due to vessel downtime during maintenance	EUR/year	-	-
Other annual maintenance cost	EUR/year	-	-
		-	-
Total annual maintenance cost	EUR/year	-	-
Periodic maintenance			
Spare part cost	EUR	-	12 000.00
Service repair cost	EUR	-	-
Loss due to vessel downtime during repair	EUR	-	-
Other periodic maintenance cost	EUR	-	-
		-	-
Inspection			
Periodic inspection and certification cost	EUR	-	-
Other cost	EUR	-	-
		-	-
		-	-

8.1.2.4.4 End of life cost

No end of life cost considered.

8.1.2.5 Life cycle cost component for ro-ro cargo new building

8.1.2.5.1 Investment cost

It was assumed that the installation of the system solution on a ro-pax existing ship is similar to a ro-pax newbuilding, refer to the cost figures listed in

Table 72

8.1.2.5.2 Operation cost

No operation cost considered.

8.1.2.5.3 Maintenance cost

It was assumed that the maintenance cost is similar to a ro-pax newbuilding, refer to the cost figures listed in Table 73.

8.1.2.5.4 End of life cost

No end of life cost considered.

8.1.2.6 Life cycle cost component for vehicle carrier newbuilding

8.1.2.6.1 Investment cost

It was assumed that the installation of the system solution on a ro-pax existing ship is similar to a ro-pax newbuilding, refer to the cost figures listed in

Table 72.

8.1.2.6.2 Operation cost

No operation cost considered.

8.1.2.6.3 Maintenance cost

It was assumed that the maintenance cost is similar to a ro-pax newbuilding, refer to the cost figures listed in Table 73.

8.1.2.6.4 End of life cost

No end of life cost considered.

8.1.3 LCC Result

The LCC results for a ro-pax newbuilding is shown in Table 74.

Table 74. Action 7A- The LCC results for a ro-pax newbuilding.

System Number		System#01	System#02
System Name		Des1 - User friendly a	Des2-Alarm system
Unit		**Per Ship**	
Total Investment cost	EUR	49 700.00 €	73 700.00 €
Total Operation cost	EUR	- €	- €
Total Maintenance cost	EUR	- €	12 106.53 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	49 700.00 €	85 806.53 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	22.59 €	33.50 €
Total Operation cost	EUR	- €	- €
Total Maintenance cost	EUR	- €	5.50 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	22.59 €	39.00 €

The LCC results for a ro-ro cargo newbuilding is shown in Table 75.

Table 75. Action 7A- The LCC results for a ro-ro cargo newbuilding

System Number		System#01	System#02
System Name		Des1 - User friendly a	Des2-Alarm system
Unit		**Per Ship**	
Total Investment cost	EUR	49 700.00 €	73 700.00 €
Total Operation cost	EUR	- €	- €
Total Maintenance cost	EUR	- €	12 106.53 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	49 700.00 €	85 806.53 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	12.97 €	19.24 €
Total Operation cost	EUR	- €	- €
Total Maintenance cost	EUR	- €	3.16 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	12.97 €	22.40 €

The LCC results for a vehicle carrier newbuilding is shown in Table 76.

Table 76. Action 7A- The LCC results for a vehicle carrier newbuilding

System Number		System#01	System#02
System Name		Des1 - User friendly a	Des2-Alarm system
Unit		**Per Ship**	
Total Investment cost	EUR	49 700.00 €	73 700.00 €
Total Operation cost	EUR	- €	- €
Total Maintenance cost	EUR	- €	7 162.69 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	49 700.00 €	80 862.69 €
Unit		**Per CEU**	
Total Investment cost	EUR	7.83 €	11.61 €
Total Operation cost	EUR	- €	- €
Total Maintenance cost	EUR	- €	1.13 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	7.83 €	12.73 €

Results summary is shown in Table 77.

Table 77. Action 7A - Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Des1	User friendly alarm system interface design guidelines	Investment	49 700.00 €	N/A	49 700.00 €	N/A	49 700.00 €	N/A
		Operation	0.00 €	N/A	0.00 €	N/A	0.00 €	N/A
		Maintance	0.00 €	N/A	0.00 €	N/A	0.00 €	N/A
		TOTAL	**49 700.00 €**	**N/A**	**49 700.00 €**	**N/A**	**49 700.00 €**	**N/A**
Des2	Alarm system interface prototype	Investment	73 700.00 €	N/A	73 700.00 €	N/A	73 700.00 €	N/A
		Operation	0.00 €	N/A	0.00 €	N/A	0.00 €	N/A
		Maintance	12 106.53 €	N/A	12 106.53 €	N/A	7 162.69 €	N/A
		TOTAL	**85 806.53 €**	**N/A**	**85 806.53 €**	**N/A**	**80 862.69 €**	**N/A**
RCO5	Alarm system interface prototype	Investment	73 700.00 €	N/A	73 700.00 €	N/A	73 700.00 €	N/A
		Operation	0.00 €	N/A	0.00 €	N/A	0.00 €	N/A
		Maintance	12 106.53 €	N/A	12 106.53 €	N/A	7 162.69 €	N/A
		TOTAL	**85 806.53 €**	**N/A**	**85 806.53 €**	**N/A**	**80 862.69 €**	**N/A**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed

8.2 Conclusion

An assessment of the lifecycle cost for the solutions proposed by Action 7-A was performed. Three ship types, the ro-ro cargo, ro-pax and vehicle carrier were assessed. Further, the assessment was performed for new buildings only as for existing ships the cost estimation was found not feasible (Ref. D05.7 "Ship integration evaluation ", [3]). For System #2 (RCM Des2, RCO5) optimistic assumptions were maid related to ship additional cost of ship systems equipment and software adjustments, which are found acceptable for a mass installation on new buildings and/or if Des2/RCO5 requirements would be class/authorities requirement. Deviations of the assumptions may significantly affect the cost assessment.

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

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This chapter presents an overview of the life cycle cost assessment for the solutions proposed by Action 7-B i.e. Firefighting resource management centre. Two RCMs were proposed by WP07 and two RCO's selected (Ref. D04.6 "Cost-effectiveness assessment report" [2]) and assessed within this report:

- RCM Des3: Procedures and design for efficient extinguishment system activation
- RCM Des4: Training module for activation of extinguishing systems
- RCO6: Process for development of procedures and design for efficient activation of extinguishing system
- RCO7: Training module for efficient activation of extinguishing system

For the description of the RCM's please refer to Deliverable D04.9 "Preliminary impact of solutions and related testing and demonstrations plan" [1], for the description of the RCO please refer to Deliverable D04.6, [2].

9.1 Life cycle cost assessment

An installation cost assessment for selected system solutions was made:

- **System#01** - Procedures and design for efficient extinguishment system activation (Des3)
- **System#02** - Training module for activation of extinguishment systems (Des4)

Cost assessment for the RCO6 was found to be same as for System#1, RCM Des3. Cost assessment for the RCO7 was found to be same as for System#2, RCM Des4.

According to the integration evaluation assessment results, the impact on the cost assessment of the solution Des3 may significantly vary for existing ro-ro cargo and ro-pax existing ships. For that reason, two integration examples were provided considering major (System #01) and minor impact (System #03) on the cost (Ref. D05.7, [3]), for sensitivity assessment purposes:

- **System#03** - Procedures and design for efficient extinguishment system activation (Des3)

The cost assessment was assessed for reference ships selected by the project with respect to the applicability of the solutions proposed; Magnolia Seaways the generic ro-ro cargo ship operated by DFDS Seaways, Stena Flavia, the generic ro-pax ship and Torrens, the generic vehicle carrier operated by Wallenius. The cost assessment was made for new buildings and existing ships.

9.1.1 Description of the developed solution

9.1.1.1 System#01/#03: Procedures and design for efficient extinguishment system activation (Des3)

The solution Des3 Procedures for efficient extinguishing system activation describes a bundle of context-sensitive tools for improving/adapting work processes (procedures) and design related to extinguishing system activation, in order to improve efficiency of fixed fire extinguishing system activation and design. The solution prescribes reflection, evaluation and changes in the processes that will be undertaken to improve work processes and extinguishing system design related issues on

each particular ship – being sensitive to existing material/technological and organizational context on each ship.

The solution consists of ship-internal workshops in connection with ordinary fire drills where problems are identified, and improved work processes and design that fits each ship are described. The solution was based on a reflection and practice oriented learning framework – where learning is understood as permanent change in behavior.

Two examples are provided to illustrate concrete implementations and outcomes of Des3, which differ by impact on the cost i.e minor or major impact.

Minor changes imply guidelines that empowers the crew to reflect, evaluate and change processes/aspects within their own mandate, e.g. procedures, labels, equipment that the vessel is responsible for in regards to procurement etc. Major changes imply guidelines for processes leading to system upgrades, e.g. changing of piping, pulling of cables, procurement and installation of new panels.

9.1.1.1.1 Integration description on new buildings

For all three ship types integration minor changes are considered where solution Des3 integration to reflect upon existing practices, evaluate them and change them for the better was considered.

9.1.1.1.2 Integration description on existing ships

For all three ship types integration, minor change was considered similar as for newbuilding with additional modification of extinguishing system activation instructions (poster). However, minor modifications on ro-pax and ro-ro cargo are considered for sensitivity analysis purposes (System #03). Further, both for ro-pax and ro-ro cargo integration, both major changes (System#01) are considered. For vehicle carriers it was found that major changes are not feasible.

Major changes considers the drencher system activation retrofit, including modification of extinguishing system activation instructions along with changes considered for new buildings. Retrofit of the drencher system includes the additional feature of remote activation from bridge, which is not available on considered generic ships (Stena Flavia, Magnolia Seaways). The system modifications are comprising the following:

- Retrofit of drencher valves for each drencher section (20 valves on Stena Flavia, 13 valves on Magnolia seaways),
- control cabinet installation within the Engine room,
- control panel installation within the wheelhouse,
- signal and power cabling installation (total of 620 m of cables on Stena Flavia, 380 m on Magnolia seaways), and
- Updated activation instructions.

9.1.1.2 System#02: Training module for activation of extinguishment systems (Des4)

A realistic training module is suggested within Des4, addressing shortcomings of existing training schemes and drills. The training module also integrates issues from solution Des3.

For the LCC assessment it was assumed to contain, both new buildings and existing ships, as follows:

- CO2 system activation training/course ashore for Vehicle carrier, and
- drencher activation training/course, combined ashore/onboard for ro-pax and ro-ro cargo.

9.1.2 Life cycle cost model

9.1.2.1 Cost items description and assumptions

Independent of the system and ship type the following costs were considered:

- Investment cost,
- operation cost, and
- inspections, testing, and maintenance,

It was assumed that all system solutions will be serviceable during the entire time if properly maintained.

9.1.2.1.1 System#01/#03: Procedures and design for efficient extinguishment system activation (Des3)

9.1.2.1.2 Investment cost

The following items are considered:

- The cost for system components (valve actuator, control cabinet, control panel, signa land power cabling), where applicable,
- assembly and installation of system components, where applicable,
- class approval (existing ships only), where applicable,
- ship operator procedure updates, and
- crew training.

Cost for establishing procedures and crew training on board was estimated based on best practice experience.

9.1.2.1.2.1 Operation cost

The following item was considered:

- Crew training, yearly refresh.

9.1.2.1.2.2 Maintenance cost

The following items was considered:

- Additional maintenance cost for added system functionality.

9.1.2.1.3 System#02: Training module for activation of extinguishment systems (Des4)

9.1.2.1.3.1 Investment cost

The following items are considered:

- Ship operator procedure updates, and
- crew training/course.

The following assumptions are considered:

- CO_2 system activation training/course:
  - Ashore training as part of other obligatory course every 5 years. Following costs considered,
  - 8x crew participation,
  - crew travel cost, and
  - cost of course provider.
- Drencher system activation training/course:
  - Ashore training as initial course, then onboard/ashore every 5 years,
  - course cost: initial ashore cost then average cost ashore/onboard every 5 years,

- 8x crew participation,
- crew travel cost for ashore courses,
- cost of course provider for ashore course,
- certification cost for onboard course.

9.1.2.1.3.2 Operation cost

The following item was considered:

- Crew training, yearly refresh according to assumptions described at 9.1.2.1.3.1

9.1.2.1.3.3 Maintenance cost

No maintenance cost considered.

9.1.2.2 Life cycle cost component for ro-pax newbuilding

9.1.2.2.1 Investment cost

The estimated cost for the installation of the system solutions on a ro-pax newbuilding is summarized in Table 78.

Table 78 Action 7B- The estimated cost for the installation of the system solutions on a ro-pax newbuilding

System Number		System#01	System#02	System#03
System Name		Des3 - Procedures an	Des4 - Training mod	N/A
Investment cost				
Purchasing cost	EUR	-	-	-
Insurance cost	EUR	-	-	-
Integration design & validation cost	EUR	-	-	-
Disassemble and modify the old system or structure	EUR	-	-	-
Road transporter cost	EUR	-	-	-
Ship transporter cost	EUR	-	-	-
Assembly/Installation cost	EUR	-	-	-
Comissioning cost	EUR	-	-	-
Document, certification and other administration costs	EUR	-	-	-
Loss of hire costs	EUR	-	-	-
Operator traning cost	EUR	3 640.00	24 330.00	-
Other cost	EUR	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total cost	EUR	3 640.00	24 330.00	-

9.1.2.2.2 Operation cost

The operational cost for the installation of the system solutions on a ro-pax newbuilding is summarized in

Table 79.

Table 79. Action 7B- The estimated operation cost for the installation of the system solutions on a ro-pax new building

System Number		System#01	System#02	System#03
System Name		Des3 - Procedures an	Des4 - Training mod	N/A
Operation cost				
Additional Energy consumption	kWh/year	-	-	-
Additional Fuel Consumption	t/year	-	-	-
Reduce Fuel Consumption	t/year	-	-	-
Operator cost	EUR/year	872.00	2 741.00	-
Insurance, taxes, and other fees cost	EUR/year	-	-	-
Loss of cargo/loss revenue	EUR/year	-	-	-
Additional of cargo/profit revenue	EUR/year	-	-	-
Other operation cost	EUR/year	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total operation cost exc. Energy cost	EUR/year	872.00	2 741.00	-

9.1.2.2.3 Maintenance cost

No cost for inspections, testing, and maintenance considered.

9.1.2.2.4 End of life cost

No end of life cost considered.

9.1.2.3 Life cycle cost component for ro-pax existing ships

9.1.2.3.1 Investment cost

The estimated cost for the installation of the system solutions on a ro-pax existing ship is summarized in

Table 80.

Table 80 Action 7B- The estimated cost for the installation of the system solutions on a ro-pax existing ship

System Number		System#01	System#02	System#03
System Name		Des3 - Procedures an	Des4 - Training mod	Des3-for sensitivity
Investment cost				
Purchasing cost	EUR	35 500.00	-	1 500.00
Insurance cost	EUR	-	-	-
Integration design & validation cost	EUR	8 000.00	-	-
Disassemble and modify the old system or structure	EUR	-	-	-
Road transporter cost	EUR	-	-	-
Ship transporter cost	EUR	-	-	-
Assembly/Installation cost	EUR	22 400.00	-	-
Comissioning cost	EUR	3 000.00	-	-
Document, certification and other administration costs	EUR	12 000.00	-	-
Loss of hire costs	EUR	-	-	-
Operator traning cost	EUR	3 640.00	24 330.00	3 640.00
Other cost	EUR	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total cost	EUR	84 540.00	24 330.00	5 140.00

9.1.2.3.2 Operation cost

The operational cost for the installation of the system solutions on a ro-pax existing ship is summarized in Table 81.

Table 81. Action 7B- The estimated operation cost for the installation of the system solutions on a ro-pax existing ship

System Number		System#01	System#02	System#03
System Name		Des3 - Procedures an	Des4 - Training mod	N/A
Operation cost				
Additional Energy consumption	kWh/year	-	-	-
Additional Fuel Consumption	t/year	-	-	-
Reduce Fuel Consumption	t/year	-	-	-
Operator cost	EUR/year	872.00	2 741.00	872.00
Insurance, taxes, and other fees cost	EUR/year	-	-	-
Loss of cargo/loss revenue	EUR/year	-	-	-
Additional of cargo/profit revenue	EUR/year	-	-	-
Other operation cost	EUR/year	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total operation cost exc. Energy cost	EUR/year	872.00	2 741.00	872.00

9.1.2.3.3 Maintenance cost

The estimated cost for inspections, testing, and maintenance for the system solutions on a ro-pax existing ship is summarized in Table 82.

Table 82. Action 7B- The estimated cost for the inspection, testing and maintenance of the system solutions on a ro-pax existing ship

System Number		System#01	System#02	System#03
System Name		Des3 - Procedures an	Des4 - Training mod	N/A
Maintenance cost				
Annual maintenance				
Annual system maintenance cost	EUR/year	100.00	-	-
Loss due to vessel downtime during maintenance	EUR/year	-	-	-
Other annual maintenance cost	EUR/year	-	-	-
		-	-	-
Total annual maintenance cost	EUR/year	100.00	-	-

9.1.2.3.4 End of life cost

No end of life cost considered.

9.1.2.4 Life cycle cost component for ro-ro cargo newbuilding

9.1.2.4.1 Investment cost

It was assumed that the installation of the system solution on a ro-ro cargo newbuilding is similar to a ro-pax newbuilding, refer to the cost figures summarized in Table 78.

9.1.2.4.2 Operation cost

It was assumed that the operational cost of the system solution on a ro-ro cargo newbuilding is similar to a ro-pax newbuilding, refer to the cost figures summarized in Table 79.

9.1.2.4.3 Maintenance cost

No cost for inspections, testing, and maintenance considered.

9.1.2.4.4 End of life cost

No end of life cost considered

9.1.2.5 Life cycle cost component for ro-ro cargo existing ship

9.1.2.5.1 Investment cost

The estimated cost for the installation of the two system solutions on a ro-ro cargo existing ship are summarized in

Table 83.

Table 83 Action 7B- The estimated cost for the installation of the two system solutions, respectively, on a ro-ro cargo existing ship

System Number		System#01	System#02	System#03
System Name		Des3 - Procedures an	Des4 - Training mod	Des3-for sensitivity
Investment cost				
Purchasing cost	EUR	27 100.00	-	1 500.00
Insurance cost	EUR	-	-	-
Integration design & validation cost	EUR	8 000.00	-	-
Disassemble and modify the old system or structure	EUR	-	-	-
Road transporter cost	EUR	-	-	-
Ship transporter cost	EUR	-	-	-
Assembly/Installation cost	EUR	14 360.00	-	-
Comissioning cost	EUR	3 000.00	-	-
Document, certification and other administration costs	EUR	12 000.00	-	-
Loss of hire costs	EUR	-	-	-
Operator traning cost	EUR	3 640.00	24 330.00	3 640.00
Other cost	EUR	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total cost	EUR	68 100.00	24 330.00	5 140.00

9.1.2.5.2 Operation cost

It was assumed that the maintenance cost is similar to a ro-pax existing ship, refer to the cost figures listed in Table 81.

9.1.2.5.3 Maintenance cost

It was assumed that the maintenance cost is similar to a ro-pax existing ship, refer to the cost figures listed in Table 82.

9.1.2.5.4 End of life cost

No end of life cost considered.

9.1.2.6 Life cycle cost component for vehicle carrier newbuilding

9.1.2.6.1 Investment cost

The estimated cost for the installation of the system solutions on a vehicle carrier new building are summarized in

Table 84.

Table 84 Action 7B- The estimated cost for the installation of the two system solutions, respectively, on a vehicle carrier newbuilding

System Number		System#01	System#02	System#03
System Name		Des3 - Procedures an	Des4 - Training mod	N/A
Investment cost				
Purchasing cost	EUR	-	-	-
Insurance cost	EUR	-	-	-
Integration design & validation cost	EUR	-	-	-
Disassemble and modify the old system or structure	EUR	-	-	-
Road transporter cost	EUR	-	-	-
Ship transporter cost	EUR	-	-	-
Assembly/Installation cost	EUR	-	-	-
Comissioning cost	EUR	-	-	-
Document, certification and other administration costs	EUR	-	-	-
Loss of hire costs	EUR	-	-	-
Operator traning cost	EUR	3 640.00	23 730.00	-
Other cost	EUR	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total cost	EUR	3 640.00	23 730.00	-

9.1.2.6.2 Operation cost

The operational cost for the installation of the systems solutions on a vehicle carrier new building was considered and summarized in Table 85

Table 85. Action 7B- The estimated operation cost for the installation of the two system solutions, respectively, on a vehicle carrier new building

System Number		System#01	System#02	System#03
System Name		Des3 - Procedures an	Des4 - Training mod	N/A
Operation cost				
Additional Energy consumption	kWh/year	-	-	-
Additional Fuel Consumption	t/year	-	-	-
Reduce Fuel Consumption	t/year	-	-	-
Operator cost	EUR/year	872.00	4 746.00	-
Insurance, taxes, and other fees cost	EUR/year	-	-	-
Loss of cargo/loss revenue	EUR/year	-	-	-
Additional of cargo/profit revenue	EUR/year	-	-	-
Other operation cost	EUR/year	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total operation cost exc. Energy cost	EUR/year	872.00	4 746.00	-

9.1.2.6.3 Maintenance cost

No cost for inspections, testing, and maintenance considered.

9.1.2.6.4 End of life cost

No end of life cost considered.

9.1.2.7 Life cycle cost component for vehicle carrier existing ships

9.1.2.7.1 Investment cost

The estimated cost for the installation of the two system solutions on a vehicle carrier existing ship are summarized in Table 86.

Table 86 Action 7B- The estimated cost for the installation of the system solutions on a vehicle carrier existing ship

System Number		System#01	System#02	System#03
System Name		Des3 - Procedures an	Des4 - Training mod	N/A
Investment cost				
Purchasing cost	EUR	1 500.00	-	-
Insurance cost	EUR	-	-	-
Integration design & validation cost	EUR	-	-	-
Disassemble and modify the old system or structure	EUR	-	-	-
Road transporter cost	EUR	-	-	-
Ship transporter cost	EUR	-	-	-
Assembly/Installation cost	EUR	-	-	-
Comissioning cost	EUR	-	-	-
Document, certification and other administration costs	EUR	-	-	-
Loss of hire costs	EUR	-	-	-
Operator traning cost	EUR	3 640.00	23 730.00	-
Other cost	EUR	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total cost	EUR	5 140.00	23 730.00	-

9.1.2.7.2 Operation cost

It was assumed that the maintenance cost is similar to a ro-pax existing ship, refer to the cost figures listed in

Table 47.

9.1.2.7.3 Maintenance cost

No cost for inspections, testing, and maintenance considered.

9.1.2.7.4 End of life cost

No end of life cost considered.

9.1.3 LCC Result

The LCC results for a ro-pax newbuilding is shown in

Table 87.

Table 87. Action 7B- The LCC results for a ro-pax new building.

System Number		System#01	System#02	System#03
System Name		Des3	Des4	N/A
Unit		**Per Ship**		
Total Investment cost	EUR	3 640.00 €	24 330.00 €	- €
Total Operation cost	EUR	20 534.44 €	64 546.91 €	#N/A
Total Maintenance cost	EUR	- €	- €	- €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	24 174.44 €	88 876.91 €	#N/A
Unit		**Per Lane meter**		
Total Investment cost	EUR	1.65 €	11.06 €	- €
Total Operation cost	EUR	9.33 €	29.34 €	#N/A
Total Maintenance cost	EUR	- €	- €	- €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	10.99 €	40.40 €	#N/A

The LCC results for a ro-pax existing ship is shown in Table 88 .

Table 88. Action 7B- The LCC results for a ro-pax existing ship.

System Number		System#01	System#02	System#03
System Name		Des3	Des4	N/A
Unit		**Per Ship**		
Total Investment cost	EUR	84 540.00 €	24 330.00 €	5 140.00 €
Total Operation cost	EUR	14 097.73 €	44 314.09 €	14 097.73 €
Total Maintenance cost	EUR	1 616.71 €	- €	- €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	100 254.45 €	68 644.09 €	19 237.73 €
Unit		**Per Lane meter**		
Total Investment cost	EUR	38.43 €	11.06 €	2.34 €
Total Operation cost	EUR	6.41 €	20.14 €	6.41 €
Total Maintenance cost	EUR	0.73 €	- €	- €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	45.57 €	31.20 €	8.74 €

The LCC results for a ro-ro cargo new building ship is shown in Table 89.

Table 89. Action 7B- The LCC results for a ro-ro cargo new building.

System Number		System#01	System#02	System#03
System Name		Des3	Des4	N/A
Unit		**Per Ship**		
Total Investment cost	EUR	3 640.00 €	24 330.00 €	- €
Total Operation cost	EUR	19 755.62 €	62 098.80 €	- €
Total Maintenance cost	EUR	- €	- €	- €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	23 395.62 €	86 428.80 €	- €
Unit		**Per Lane meter**		
Total Investment cost	EUR	0.95 €	6.35 €	- €
Total Operation cost	EUR	5.16 €	16.21 €	- €
Total Maintenance cost	EUR	- €	- €	- €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	6.11 €	22.56 €	- €

The LCC results for a ro-ro cargo existing ship is shown in Table 90.

Table 90. Action 7B- The LCC results for a ro-ro cargo existing ship

System Number		System#01	System#02	System#03
System Name		Des3	Des4	N/A
Unit		**Per Ship**		
Total Investment cost	EUR	68 100.00 €	24 330.00 €	5 140.00 €
Total Operation cost	EUR	14 097.73 €	44 314.09 €	14 097.73 €
Total Maintenance cost	EUR	1 616.71 €	- €	- €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	83 814.45 €	68 644.09 €	19 237.73 €
Unit		**Per Lane meter**		
Total Investment cost	EUR	17.78 €	6.35 €	1.34 €
Total Operation cost	EUR	3.68 €	11.57 €	3.68 €
Total Maintenance cost	EUR	0.42 €	- €	- €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	21.88 €	17.92 €	5.02 €

The LCC results for a vehicle carrier new building is shown in Table 91.

Table 91. Action 7B- The LCC results for a vehicle carrier new building

System Number		System#01	System#02	System#03
System Name		Des3	Des4	N/A
Unit		**Per Ship**		
Total Investment cost	EUR	3 640.00 €	23 730.00 €	- €
Total Operation cost	EUR	16 277.64 €	88 593.67 €	- €
Total Maintenance cost	EUR	- €	- €	- €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	19 917.64 €	112 323.67 €	- €
Unit		**Per CEU**		
Total Investment cost	EUR	0.57 €	3.74 €	- €
Total Operation cost	EUR	2.56 €	13.95 €	- €
Total Maintenance cost	EUR	- €	- €	- €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	3.14 €	17.69 €	- €

The LCC results for a vehicle carrier existing ship is shown in Table 92.

Table 92. Action 7B- The LCC results for a vehicle carrier existing ship

System Number		System#01	System#02	System#03
System Name		Des3	Des4	N/A
Unit		**Per Ship**		
Total Investment cost	EUR	5 140.00 €	23 730.00 €	- €
Total Operation cost	EUR	11 418.07 €	62 144.68 €	- €
Total Maintenance cost	EUR	- €	- €	- €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	16 558.07 €	85 874.68 €	- €
Unit		**Per CEU**		
Total Investment cost	EUR	0.81 €	3.74 €	- €
Total Operation cost	EUR	1.80 €	9.79 €	- €
Total Maintenance cost	EUR	- €	- €	- €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	2.61 €	13.52 €	- €

Results summary is shown in Table 93.

Table 93. Action 7B - Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Des3	Procedures and design for efficient extinguishment system activation	Investment	3 640.00 €	84 540.00 €	3 640.00 €	68 100.00 €	3 640.00 €	5 140.00 €
		Operation	20 534.44 €	14 097.73 €	19 755.62 €	14 097.73 €	16 277.64 €	11 418.07 €
		Maintance	0.00 €	1 616.71 €	0.00 €	1 616.71 €	0.00 €	0.00 €
		TOTAL	**24 174.44 €**	**100 254.44 €**	**23 395.62 €**	**83 814.44 €**	**19 917.64 €**	**16 558.07 €**
Des4	Training module for activation of extinguishment systems	Investment	24 330.00 €	24 330.00 €	24 330.00 €	24 330.00 €	23 730.00 €	23 730.00 €
		Operation	64 546.91 €	44 314.09 €	62 098.80 €	44 314.09 €	88 593.67 €	62 144.68 €
		Maintance	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		TOTAL	**88 876.91 €**	**68 644.09 €**	**86 428.80 €**	**68 644.09 €**	**112 323.67 €**	**85 874.68 €**
RCO6	Process for development of procedures and design for efficient activation of extinguishing system	Investment	3 640.00 €	84 540.00 €	3 640.00 €	68 100.00 €	3 640.00 €	5 140.00 €
		Operation	20 534.44 €	14 097.73 €	19 755.62 €	14 097.73 €	16 277.64 €	11 418.07 €
		Maintance	0.00 €	1 616.71 €	0.00 €	1 616.71 €	0.00 €	0.00 €
		TOTAL	**24 174.44 €**	**100 254.44 €**	**23 395.62 €**	**83 814.44 €**	**19 917.64 €**	**16 558.07 €**
RCO7	Training module for efficient activation of extinguishing system	Investment	24 330.00 €	24 330.00 €	24 330.00 €	24 330.00 €	23 730.00 €	23 730.00 €
		Operation	64 546.91 €	44 314.09 €	62 098.80 €	44 314.09 €	88 593.67 €	62 144.68 €
		Maintance	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		TOTAL	**88 876.91 €**	**68 644.09 €**	**86 428.80 €**	**68 644.09 €**	**112 323.67 €**	**85 874.68 €**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed

9.2 Conclusion

Main author of the chapter: Vito Radolovic, FLOW

An assessment of the lifecycle cost for the solutions proposed by Action 7-B was performed. Three ship types, the ro-ro cargo, ro-pax and vehicle carrier were assessed.

Further, sensitivity assessment was performed for the Des3 solution as the life cycle cost assessment result may significantly vary for ro-ro cargo and ro-pax existing ships and new buildings.

Finally, minor and major impact of the solution on the life cycle cost was assessed considering two integration examples, resulting is a considerable difference in the total life cycle cost.

10 Firefighting resource management centre - Action 7-C

Main author of the chapter: Vito Radolovic, FLOW

This chapter presents an overview of the life cycle cost assessment for the solutions proposed by 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 “Preliminary impact of solutions and related testing and demonstrations plan” [1].

10.1 Life cycle cost assessment

An installation cost assessment for two different system solutions was made:

- **System#01** - Integrated solutions for fire resource management, combining relevant sources of information, including drone and camera monitoring system (RCM Des5)
- **System#02** - Guidelines for organizing the response in case of a fire emergency (RCM Des6)

The cost assessment was assessed for reference ships selected by the project with respect to the applicability of the solutions proposed; Magnolia Seaways the generic ro-ro cargo ship operated by DFDS Seaways, Stena Flavia, the generic ro-pax ship and Torrens, the generic vehicle carrier operated by Wallenius. The cost assessment was made for new buildings and existing ships where applicable.

Further, System #1 (Des5) was considered as an add on to the RCM Des2 (Action 7-A, Chapter 9). As the RCM Des2 assessment is only for new buildings, RCM Des5 follows the same and is only assessed for new buildings.

10.1.1 Description of the developed solution

10.1.1.1 System#01: - Integrated solutions for fire resource management, combining relevant sources of information, including drone and camera monitoring system (Des5)

The solution was considered as an add on to the RCM Des2 (Action 7-A, Chapter 9).

For the cost assessment purposes, the drone system for monitoring the open decks and system add-ons required by deploying a drone on ship are considered. The drone system is detailed in D07.7. including feasibility, usefulness, and SWOT. The cost related to the process part of RCM Des5 is not considered, as was considered within the RCM Des2 cost assessment.

It is to be noted, that the system is in prototype stage. Extensive testing (especially, long-term tests in operation) and some further developments are required in order to be production ready.

Further, the system is an add-on and not considered as a part of the fixed fire alarm systems, thus, it is not subject to the maritime equipment directive (2014/90/EU). It is, however, subject to EU airspace regulations 2019/947 and 2019/945. Therefore, a “Specific Operations Risk Assessment” will need to be performed in order to apply for operational authorization. However, as this cost depends on the sailing area and it is hard to estimate, it is not considered in the cost assessment.

10.1.1.2 System#02 - Guidelines for organizing the response in case of a fire emergency (Des6)

Integration was considered as a part of debriefing and learning from exercises, as well as to be used in creating or updating fire management plans. Further, The Work system analysis/WSA (previously known as the safety assessment tool) intended to improve the processes and awareness regarding fire safety, was considered. Related costs considered the time spent by the land organization to do an initial analysis of the specific ship, and follow up work to keep the analysis in line with any changes on the ship. Video recording of the drills using GoPro cameras carried by the crew was considered.

The cost of implementation at the three generic ships Magnolia Seaways (ro-ro cargo), Stena Flavia (ro-pax) and Torrens (vehicle carrier) is expected to be the same. Implementations costs are also expected to be the same for existing ships and new builds.

10.1.2 Life cycle cost model

10.1.2.1 Cost items description and assumptions

Independent of the system and ship type the following costs were considered:

- Investment cost,
- Operation cost
- inspections, testing, and maintenance,

It was assumed that all system solutions will be serviceable during the entire time if properly maintained.

10.1.2.1.1 System#01: - Integrated solutions for fire resource management, combining relevant sources of information, including drone and camera monitoring system (Des5)

10.1.2.1.1.1 Investment cost

The following items are considered:

- The cost for system components (drone, ground control station including positioning and communication systems, weather and fireproof autonomous charging station),
- design integration,
- assembly and installation of system components,
- ship operator procedure updates, and
- crew training.

The purchasing costs of equipment was estimated based on figures from system component suppliers. Cost for establishing procedures and crew training on board was estimated based on best practice experience.

10.1.2.1.1.2 Operation cost

No operation cost considered.

10.1.2.2 Maintenance cost

The following items are considered:

- Equipment renewal.

10.1.2.2.1 System#02 - Guidelines for organizing the response in case of a fire emergency (Des6)

10.1.2.2.1.1 Investment cost

The following items are considered:

- The cost for system components (GoPro Cameras with body GoPro Chesty),
- ship operator procedure updates,
- crew training, and
- WSA: initial on-shore ship analysis.

The purchasing costs of equipment was estimated based on figures from system component suppliers. Cost for establishing procedures and crew training on board was estimated based on best practice experience.

10.1.2.2.1.2 Operation cost

The following item was considered:

- WSA: on-shore ship analysis follow up.

10.1.2.2.1.3 Maintenance cost

The following items are considered:

- Equipment renewal.

10.1.2.3 Life cycle cost component for ro-pax new building

10.1.2.3.1 Investment cost

The estimated cost for the installation of the system solutions on a ro-pax new building is summarized in Table 94.

Table 94 Action 7C- The estimated cost for the installation of the system solutions on a ro-pax new building

System Number		System#01	System#02
System Name		Des5	Des6
Investment cost			
Purchasing cost	EUR	22 000.00	1 200.00
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	500.00	-
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	1 000.00	-
Comissioning cost	EUR	-	-
Document, certification and other administration costs	EUR	-	-
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	3 000.00	5 500.00
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	26 500.00	6 700.00

10.1.2.3.2 Operation cost

The operation cost for the installation of the system solutions on a ro-pax new building is summarized in Table 95.

Table 95. Action 7C- The estimated operation cost for the installation of the system solutions on a ro-pax new building

System Number		System#01	System#02
System Name		Des5	Des6
Operation cost			
Additional Energy consumption	kWh/year	-	-
Additional Fuel Consumption	t/year	-	-
Reduce Fuel Consumption	t/year	-	-
Operator cost	EUR/year	-	1 000.00
Insurance, taxes, and other fees cost	EUR/year	-	-
Loss of cargo/loss revenue	EUR/year	-	-
Additional of cargo/profit revenue	EUR/year	-	-
Other operation cost	EUR/year	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total operation cost exc. Energy cost	EUR/year	-	1 000.00

10.1.2.3.3 Maintenance cost

The estimated cost for inspections, testing, and maintenance for the system solutions on a ro-pax new building is summarized in Table 96.

Table 96. Action 7C- The estimated cost for the inspection, testing and maintenance of the system solutions on a ro-pax new building

System Number		System#01	System#02
System Name		Des5	Des6
Maintenance cost			
Annual maintenance			
Annual system maintenance cost	EUR/year	1 000.00	240.00
Loss due to vessel downtime during maintenance	EUR/year	-	-
Other annual maintenance cost	EUR/year	-	-
		-	-
Total annual maintenance cost	EUR/year	1 000.00	240.00

10.1.3 End of life cost

No end of life cost considered.

10.1.3.1 Life cycle cost component for ro-pax existing ships

10.1.3.1.1 Investment cost

It was assumed that the investment cost of the system #2 (RCM Des6) on a ro-pax existing ship is similar to a ro-pax new building, refer to the cost figures summarized in Table 94Table 4. System #1 (RCM Des5) is not applicable for ro-pax existing ships.

10.1.3.1.2 Operation cost

It was assumed that the operation cost of the system solution #2 (RCM Des6) on a ro-pax existing ship is similar to a ro-pax new building, refer to the cost figures summarized inTable 95. System #1 (RCM Des5) is not applicable for ro-pax existing ships.

10.1.3.1.3 Maintenance cost

It was assumed that the maintenance cost of the system solution #2 (RCM Des6) on a ro-pax existing ship is similar to a ro-pax new building, refer to the cost figures summarized in Table 96. System #1 (RCM Des5) is not applicable for ro-pax existing ships.

10.1.3.1.4 End of life cost

No end of life cost considered

10.1.3.2 Life cycle cost component for ro-ro cargo new building

10.1.3.2.1 Investment cost

It was assumed that the investment cost of the system solutions on a ro-ro cargo new building ship is similar to a ro-pax new building, refer to the cost figures summarized in Table 94.

10.1.3.2.2 Operation cost

It was assumed that the operation cost of the system solution on a ro-ro cargo new building is similar to a ro-pax new building, refer to the cost figures summarized in Table 95.

10.1.3.2.3 Maintenance cost

It was assumed that the maintenance cost of the system solutions on a ro-ro cargo new building is similar to a ro-pax new building, refer to the cost figures summarized in Table 96.

10.1.3.2.4 End of life cost

No end of life cost considered

10.1.3.3 Life cycle cost component for ro-ro cargo existing ship

10.1.3.3.1 Investment cost

It was assumed that the investment cost of the system solution #2 (RCM Des6) on a ro-ro cargo existing ship is similar to a ro-pax new building, refer to the cost figures summarized in Table 94. System solution #1 (RCM Des5) is not applicable for ro-ro-cargo existing ships.

10.1.3.3.2 Operation cost

It was assumed that the operation cost of the system solution #2 (RCM Des6) on a ro-ro cargo existing ship is similar to a ro-pax new building, refer to the cost figures summarized in Table 95. System solution #1 (RCM Des5) is not applicable for ro-ro-cargo existing ships.

10.1.3.3.3 Maintenance cost

It was assumed that the maintenance cost of the system solution #2 (Des6) on a ro-ro cargo existing ship is similar to a ro-pax new building, refer to the cost figures summarized in Table 96. System solution #1 (Des5) is not applicable for ro-ro-cargo existing ships.

10.1.3.3.4 End of life cost

No end of life cost considered

10.1.3.4 Life cycle cost component for vehicle carrier new building

10.1.3.4.1 Investment cost

It was assumed that the investment cost of the system solutions on a vehicle carrier new building is similar to a ro-pax new building, refer to the cost figures summarized in Table 94.

10.1.3.4.2 Operation cost

It was assumed that the operation cost of the system solution on a vehicle carrier new building is similar to a ro-pax new building, refer to the cost figures summarized in Table 95.

10.1.3.4.3 Maintenance cost

It was assumed that the maintenance cost of the system solutions on a vehicle carrier new building is similar to a ro-pax new building, refer to the cost figures summarized in Table 96.

10.1.3.4.4 End of life cost

No end of life cost considered

10.1.3.5 Life cycle cost component for vehicle carrier existing ships

10.1.3.5.1 Investment cost

It was assumed that the investment cost of the system solution #2 (RCM Des6) on a vehicle carrier existing ship is similar to a ro-pax new building, refer to the cost figures summarized in Table 94. System solution #1 (RCM Des5) is not applicable for vehicle carriers existing ships.

10.1.3.5.2 Operation cost

It was assumed that the operation cost of the system solution #2 (RCM Des6) on a vehicle carrier existing ship is similar to a ro-pax new building, refer to the cost figures summarized in Table 95. System #1 (RCM Des5) is not applicable for vehicle carriers existing ships.

10.1.3.5.3 Maintenance cost

It was assumed that the maintenance cost of the system solution #2 (RCM Des6) on a vehicle carrier existing ship is similar to a ro-pax new building, refer to the cost figures summarized in Table 96. System #1 (RCM Des5) is not applicable for vehicle carriers existing ships.

10.1.3.5.4 End of life cost

No end of life cost considered

10.1.4 LCC results

The LCC results for a ro-pax new building is shown in Table 97.

Table 97. Action 7C- The LCC results for a ro-pax new building.

System Number		System#01	System#02
System Name		Des5	Des6
Unit		**Per Ship**	
Total Investment cost	EUR	26 500.00 €	6 700.00 €
Total Operation cost	EUR	- €	23 548.67 €
Total Maintenance cost	EUR	23 548.67 €	5 651.68 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	50 048.67 €	35 900.35 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	12.05 €	3.05 €
Total Operation cost	EUR	- €	10.70 €
Total Maintenance cost	EUR	10.70 €	2.57 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	22.75 €	16.32 €

The LCC results for a ro-pax existing ship is shown in Table 98.

Table 98. Action 7C- The LCC results for a ro-pax existing ship.

System Number		System#01	System#02
System Name		Des5	Des6
Unit		**Per Ship**	
Total Investment cost	EUR	- €	6 700.00 €
Total Operation cost	EUR	- €	16 167.12 €
Total Maintenance cost	EUR	- €	3 880.11 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	- €	26 747.23 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	- €	3.05 €
Total Operation cost	EUR	- €	7.35 €
Total Maintenance cost	EUR	- €	1.76 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	- €	12.16 €

The LCC results for a ro-pax existing ship is shown in Table 99.

Table 99. The Action 7C- LCC results for a ro-ro cargo new building.

System Number		System#01	System#02
System Name		Des5	Des6
Unit		**Per Ship**	
Total Investment cost	EUR	26 500.00 €	6 700.00 €
Total Operation cost	EUR	- €	22 655.53 €
Total Maintenance cost	EUR	22 655.53 €	5 437.33 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	49 155.53 €	34 792.85 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	6.92 €	1.75 €
Total Operation cost	EUR	- €	5.91 €
Total Maintenance cost	EUR	5.91 €	1.42 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	12.83 €	9.08 €

The LCC results for a ro-pax existing ship is shown in Table 100.

Table 100. Action 7C- The LCC results for a ro-ro cargo existing ship

System Number		System#01	System#02
System Name		Des5	Des6
Unit		**Per Ship**	
Total Investment cost	EUR	- €	6 700.00 €
Total Operation cost	EUR	- €	16 167.12 €
Total Maintenance cost	EUR	- €	3 880.11 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	- €	26 747.23 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	- €	1.75 €
Total Operation cost	EUR	- €	4.22 €
Total Maintenance cost	EUR	- €	1.01 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	- €	6.98 €

The LCC results for a vehicle carrier new building is shown in Table 101.

Table 101. Action 7C- The LCC results for a vehicle carrier new building

System Number		System#01	System#02
System Name		Des5	Des6
Unit		**Per Ship**	
Total Investment cost	EUR	26 500.00 €	6 700.00 €
Total Operation cost	EUR	- €	18 667.02 €
Total Maintenance cost	EUR	18 667.02 €	4 480.08 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	45 167.02 €	29 847.10 €
Unit		**Per CEU**	
Total Investment cost	EUR	4.17 €	1.06 €
Total Operation cost	EUR	- €	2.94 €
Total Maintenance cost	EUR	2.94 €	0.71 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	7.11 €	4.70 €

The LCC results for a vehicle carrier existing ship is shown in Table 102.

Table 102. Action 7C- The LCC results for a vehicle carrier existing ship

System Number		System#01	System#02
System Name		Des5	Des6
Unit		**Per Ship**	
Total Investment cost	EUR	- €	6 700.00 €
Total Operation cost	EUR	- €	13 094.12 €
Total Maintenance cost	EUR	- €	3 142.59 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	- €	22 936.70 €
Unit		**Per CEU**	
Total Investment cost	EUR	- €	1.06 €
Total Operation cost	EUR	- €	2.06 €
Total Maintenance cost	EUR	- €	0.49 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	- €	3.61 €

Results summary is shown in Table 103.

Table 103. Action 7C - Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Des5	Integrated solutions for fire resource management, combining relevant sources of information, including drone and camera monitoring system	Investment	26 500.00 €	N/A	26 500.00 €	N/A	26 500.00 €	N/A
		Operation	0.00 €	N/A	0.00 €	N/A	0.00 €	N/A
		Maintance	23 548.67 €	N/A	22 655.53 €	N/A	18 667.02 €	N/A
		TOTAL	**50 048.67 €**	**N/A**	**49 155.53 €**	**N/A**	**45 167.02 €**	**N/A**
Des6	Guidelines for organizing the response in case of a fire emergency	Investment	6 700.00 €	6 700.00 €	6 700.00 €	6 700.00 €	6 700.00 €	6 700.00 €
		Operation	23 548.67 €	16 167.12 €	22 655.53 €	16 167.12 €	18 667.02 €	13 094.12 €
		Maintance	5 651.68 €	3 880.11 €	5 437.33 €	3 880.11 €	4 480.08 €	3 142.59 €
		TOTAL	**35 900.35 €**	**26 747.23 €**	**34 792.86 €**	**26 747.23 €**	**29 847.10 €**	**22 936.71 €**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed

10.2 Conclusion

An assessment of the lifecycle cost for the solutions proposed by Action 7-C was performed. Three ship types, the ro-ro cargo, ro-pax and vehicle carrier were assessed.

As the system #1 (RCM Des5) was considered in the prototype stage at the time the cost assessment was performed as well as the required “Specific Operations Risk Assessment” were not considered in this assessment. Thus, the life cycle cost assessment results may differ in the future assessments.

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

Main author of the chapter: Martin Carlsson, STL

This chapter presents an overview of the life cycle cost assessment for the solutions proposed by 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 Life cycle cost assessment

An installation cost assessment for selected system solutions was made:

- **System#01** - Cargo scanning and identification and tracking system by the means of a called Vehicle Hot Spot Detector system (Pre1a)
- **System#02** - Stowage planning tool with optimization algorithm for cargo distribution (Pre2)

The proposed RCM Pre1b (Automatic screening with rolling drone) was not assessed as the development was found to be not mature for ship integration and further assessments, Ref. D05.7 [3].

The cost assessment was made for reference ships selected by the project with respect to the applicability of the solutions proposed; Magnolia Seaways the generic ro-ro cargo ship operated by DFDS, Stena Flavia, the generic ro-pax ship and Torrens the generic vehicle carrier, operated by Wallenius Marine. The cost assessment was made for new buildings and existing ships.

11.1.1 Description of the developed solution

11.1.1.1 System#01: Cargo scanning and identification and tracking system by the means of a called Vehicle Hot Spot Detector system (Pre1a)

For information on the concept, challenges, and proposed solution please refer to Deliverable D04.9, [1].

11.1.1.2 System#02: Stowage planning tool with optimization algorithm for cargo distribution (Pre2)

The Stowage Planning Tool integration by means of a software including an algorithm that manages fire hazards during the cargo distribution was considered.

11.1.2 Life cycle cost model

11.1.2.1 Cost items description and assumptions

Independent of the system and ship type the following costs were considered:

- Investment cost,
- operation cost,
- inspections, testing, and maintenance, and
- end of life cost.

It was assumed that all system solutions will be serviceable during the entire time if properly maintained.

11.1.2.1.1 System#01: Cargo scanning and identification and tracking system by the means of a called Vehicle Hot Spot Detector system (Pre1a)

11.1.2.1.1.1 Investment cost

The following items are considered:

- Sensor system ,
- other required equipment,
- software and licenses,
- integration with operators/terminal IT system,
- brackets frame for sensor system,
- foundations, ground works, underground cables etc.,
- arrangement of parking spaces for identified elevated risk unit,
- installation of devices,
- cable routing & connections,
- commissioning,
- engineering, documentation and administration,
- procedures development, and
- Cost of staff/crew training.

The purchasing costs of equipment was estimated based on figures from system component suppliers. Cost for integration of the systems and establishing procedures and crew training on board was estimated based on Stena best practice experience.

11.1.2.1.1.2 Operation cost

The following items are considered:

- Cost of staff/crew training,
- cost for handling identified units, and
- operation supervision cost.

It was assumed that scanning by portal will not influence departure time of the vessel.

11.1.2.1.1.3 Maintenance cost

Maintenance cost estimation was based on necessary renewal of equipment according to Stena best practice experience.

11.1.2.1.1.4 End of life cost

No end-of-life cost considered.

11.1.2.1.2 System#02: Stowage planning tool with optimization algorithm for cargo distribution (Pre2)

11.1.2.1.2.1 Investment cost

The following items are considered:

- Cost of the systems per components:
  - Server, and
  - Wi-Fi.
- heavy duty hand tablets (4 for vessel + 2 for terminal),
- cost of installation and commissioning,
- integration with existing cargo planning system,
- ship specific configurations,
- central procedures development, and
- cost of crew training.

The purchasing costs of equipment was estimated based on figures from system component suppliers. Cost for system integration and establishing procedures and crew training on board was estimated based on Stena best practice experience.

11.1.2.1.2.2 Operation cost

The following items are considered:

- software rental,
- cost of crew training,
- extra turnaround time due to unit by unit sequence loading, and
- extra turnaround time due to stowage re-arrangements.

11.1.2.1.2.3 Maintenance cost

No maintenance cost considered.

11.1.2.1.2.4 End of life cost

No end-of-life cost considered.

11.1.2.2 Life cycle cost component for ro-pax newbuilding

11.1.2.2.1 Investment cost

The estimated cost for the installation of the system solutions on a ro-pax newbuilding are summarized in Table 104.

Table 104 Action 8A- The estimated cost for the installation of the system solutions on a ro-pax new building

	System Number		System#01	System#02
	System Name		Pre 1a - Cargo scanni	Pre2 - Stowage plan
Investment cost				
	Purchasing cost	EUR	310 000.00	53 600.00
	Insurance cost	EUR	-	-
	Integration design & validation cost	EUR	4 000.00	12 000.00
	Disassemble and modify the old system or structure	EUR	-	-
	Road transporter cost	EUR	-	-
	Ship transporter cost	EUR	-	-
	Assembly/Installation cost	EUR	61 450.00	-
	Comissioning cost	EUR	1 600.00	5 000.00
	Document, certification and other administration costs	EUR	2 000.00	16 000.00
	Loss of hire costs	EUR	-	-
	Operator traning cost	EUR	2 400.00	5 200.00
	Other cost	EUR	-	-
			-	-
			-	-
			-	-
			-	-
			-	-
	Total cost	EUR	381 450.00	91 800.00

11.1.2.2.2 Operation cost

The operational cost for the installation of the systems on a ro-pax newbuilding was considered and summarized in Table 105.

Table 105. Action 8A- The estimated operation cost for the installation of the system solution on a ro-pax new building

	System Number		System#01	System#02
	System Name		Pre 1a - Cargo scanni	Pre2 - Stowage plan
Operation cost				
	Additional Energy consumption	kWh/year	-	-
	Additional Fuel Consumption	t/year	-	-
	Reduce Fuel Consumption	t/year	-	-
	Operator cost	EUR/year	27 200.00	-
	Insurance, taxes, and other fees cost	EUR/year	-	3 000.00
	Loss of cargo/loss revenue	EUR/year	-	-
	Additional of cargo/profit revenue	EUR/year	-	-
	Other operation cost	EUR/year	-	420 000.00
			-	-
			-	-
			-	-
			-	-
			-	-
			-	-
			-	-
	Total operation cost exc. Energy cost	EUR/year	27 200.00	423 000.00

11.1.2.2.3 Maintenance cost

The estimated cost for inspections, testing, and maintenance for the system solution on a ro-pax newbuilding is summarized in Table 106.

Table 106. Action 8A- The estimated cost for the inspection, testing and maintenance of the system solutions for a ro-pax newbuilding

	System Number		System#01	System#02
	System Name		Pre 1a - Cargo scanni	Pre2 - Stowage plan
Maintenance cost				
	Annual maintenance			
	Annual system maintenance cost	EUR/year	3 000.00	-
	Loss due to vessel downtime during maintenance	EUR/year	-	-
	Other annual maintenance cost	EUR/year	-	-
			-	-
	Total annual maintenance cost	EUR/year	3 000.00	-
	Periodic maintenance			
	Spare part cost	EUR	-	3 600.00
	Service repair cost	EUR	-	-
	Loss due to vessel downtime during repair	EUR	-	-
	Other periodic maintenance cost	EUR	-	-
			-	-
	Inspection			
	Periodic inspection and certification cost	EUR	-	-
	Other cost	EUR	-	-
			-	-
			-	-

11.1.2.2.4 End of life cost

No end-of-life cost considered.

11.1.2.3 Life cycle cost component for ro-pax existing ship

11.1.2.3.1 Investment cost

It was assumed that the installation of the system solution on a ro-pax existing ship is similar to a ro-pax newbuilding, refer to the cost figures listed in Table 104.

11.1.2.3.2 Operation cost

It was assumed that the operational cost is similar to a ro-pax new building, refer to the cost figures listed in Table 105.

11.1.2.3.3 Maintenance cost

It was assumed that the maintenance cost is similar to a ro-pax new building, refer to the cost figures listed in Table 106.

11.1.2.3.4 End of life cost

No end-of-life cost considered

11.1.2.4 Life cycle cost component for ro-ro cargo newbuilding

11.1.2.4.1 Investment cost

It was assumed that the installation of the system solution on a ro-ro cargo newbuilding ship is similar to a ro-pax newbuilding, refer to the cost figures listed in Table 104.

11.1.2.4.2 Operation cost

It was assumed that the operational cost is similar to a ro-pax new building, refer to the cost figures listed in Table 105.

11.1.2.4.3 Maintenance cost

It was assumed that the maintenance cost is similar to a ro-pax new building, refer to the cost figures listed in Table 106.

11.1.2.4.4 End of life cost

No end-of-life cost considered

11.1.2.5 Life cycle cost component for ro-ro cargo existing ship

11.1.2.5.1 Investment cost

It was assumed that the installation of the system solution on a ro-ro cargo existing ship is similar to a ro-pax newbuilding, refer to the cost figures listed in Table 104.

11.1.2.5.2 Operation cost

It was assumed that the operational cost is similar to a ro-pax new building, refer to the cost figures listed in Table 105.

11.1.2.5.3 Maintenance cost

It was assumed that the maintenance cost is similar to a ro-pax new building, refer to the cost figures listed in Table 106.

11.1.2.5.4 End of life cost

No end-of-life cost considered

11.1.2.6 Life cycle cost component for vehicle carrier new building

11.1.2.6.1 Investment cost

The estimated cost for the installation of the system solution on a vehicle carrier new building are summarized in Table 107.

Table 107 Action 8A- The estimated cost for the installation of the system solution on a vehicle carrier new building

System Number		System#01	System#02
System Name		Pre 1a - Cargo scanni	Pre2 - Stowage plan
Investment cost			
Purchasing cost	EUR	310 000.00	53 600.00
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	4 000.00	12 000.00
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	61 450.00	-
Comissioning cost	EUR	1 600.00	5 000.00
Document, certification and other administration costs	EUR	2 000.00	16 000.00
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	2 400.00	2 960.00
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	381 450.00	89 560.00

11.1.2.6.2 Operation cost

The operational cost for the installation of the systems on a vehicle carrier new building was considered and summarized in Table 108.

Table 108. Action 8A- The estimated operation cost for the installation of the system solutions on a vehicle carrier new building

Operation cost			
Additional Energy consumption	kWh/year	-	-
Additional Fuel Consumption	t/year	-	-
Reduce Fuel Consumption	t/year	-	-
Operator cost	EUR/year	14 000.00	-
Insurance, taxes, and other fees cost	EUR/year	-	3 000.00
Loss of cargo/loss revenue	EUR/year	-	-
Additional of cargo/profit revenue	EUR/year	-	-
Other operation cost	EUR/year	-	420 000.00
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total operation cost exc. Energy cost	EUR/year	14 000.00	423 000.00

11.1.2.6.3 Maintenance cost

It was assumed that the maintenance cost is similar to a ro-pax new building, refer to the cost figures listed in Table 106.

11.1.2.6.4 End of life cost

No end-of-life cost considered.

11.1.2.7 Life cycle cost component for vehicle carrier existing ship

11.1.2.7.1 Investment cost

It was assumed that the installation of the system solution on a vehicle carrier existing ship is similar to a vehicle carrier newbuilding, refer to the cost figures listed in Table 107

11.1.2.7.2 Operation cost

It was assumed that the maintenance cost is on a vehicle carrier existing ship is similar to a ro-ro cargo newbuilding, refer to the cost figures listed in Table 108

11.1.2.7.3 Maintenance cost

It was assumed that the maintenance cost is similar to a ro-pax newbuilding, refer to the cost figures listed in Table 106.

11.1.2.7.4 End of life cost

No end-of-life cost considered.

11.1.3 LCC Result

Main author of the chapter: Vito Radolovic, FLOW

The LCC results for a ro-pax newbuilding is shown in Table 109.

Table 109. Action 8A- The LCC results for a ro-pax newbuilding.

System Number		System#01	System#02
System Name		Pre 1a - Cargo scanni	Pre2 - Stowage plan
Unit		**Per Ship**	
Total Investment cost	EUR	381 450.00 €	91 800.00 €
Total Operation cost	EUR	640 523.87 €	9 961 088.09 €
Total Maintenance cost	EUR	70 646.01 €	14 930.72 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	1 092 619.88 €	10 067 818.81 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	173.39 €	41.73 €
Total Operation cost	EUR	291.15 €	4 527.77 €
Total Maintenance cost	EUR	32.11 €	6.79 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	496.65 €	4 576.28 €

The LCC results for a ro-pax existing ship is shown in Table 110.

Table 110. Action 8A- The LCC results for a ro-pax existing ship

System Number		System#01	System#02
System Name		Pre 1a - Cargo scanni	Pre2 - Stowage plan
Unit		**Per Ship**	
Total Investment cost	EUR	381 450.00 €	91 800.00 €
Total Operation cost	EUR	439 745.80 €	6 838 693.81 €
Total Maintenance cost	EUR	48 501.37 €	9 541.25 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	869 697.17 €	6 940 035.06 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	173.39 €	41.73 €
Total Operation cost	EUR	199.88 €	3 108.50 €
Total Maintenance cost	EUR	22.05 €	4.34 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	395.32 €	3 154.56 €

The LCC results for a ro-ro cargo newbuilding is shown in Table 111.

Table 111. Action 8A- The LCC results for a ro-ro cargo newbuilding

System Number		System#01	System#02
System Name		Pre 1a - Cargo scanni	Pre2 - Stowage plan
Unit		**Per Ship**	
Total Investment cost	EUR	381 450.00 €	91 800.00 €
Total Operation cost	EUR	616 230.35 €	9 583 288.15 €
Total Maintenance cost	EUR	67 966.58 €	13 827.12 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	1 065 646.93 €	9 688 915.27 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	99.57 €	23.96 €
Total Operation cost	EUR	160.85 €	2 501.51 €
Total Maintenance cost	EUR	17.74 €	3.61 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	278.16 €	2 529.08 €

The LCC results for a ro-ro cargo existing ship is shown in Table 112.

Table 112. Action 8A- The LCC results for a ro-ro cargo existing ship

System Number		System#01	System#02
System Name		Pre 1a - Cargo scanni	Pre2 - Stowage plan
Unit		**Per Ship**	
Total Investment cost	EUR	381 450.00 €	91 800.00 €
Total Operation cost	EUR	439 745.80 €	6 838 693.81 €
Total Maintenance cost	EUR	48 501.37 €	9 541.25 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	869 697.17 €	6 940 035.06 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	99.57 €	23.96 €
Total Operation cost	EUR	114.79 €	1 785.09 €
Total Maintenance cost	EUR	12.66 €	2.49 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	227.02 €	1 811.55 €

The LCC results for a vehicle carrier newbuilding is shown in Table 113.

Table 113. Action 8A- The LCC results for a vehicle carrier newbuilding

System Number		System#01	System#02
System Name		Pre 1a - Cargo scanni	Pre2 - Stowage plan
Unit		**Per Ship**	
Total Investment cost	EUR	381 450.00 €	89 560.00 €
Total Operation cost	EUR	261 338.26 €	7 896 148.97 €
Total Maintenance cost	EUR	56 001.06 €	11 064.58 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	698 789.32 €	7 996 773.56 €
Unit		**Per CEU**	
Total Investment cost	EUR	60.07 €	14.10 €
Total Operation cost	EUR	41.16 €	1 243.49 €
Total Maintenance cost	EUR	8.82 €	1.74 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	110.05 €	1 259.33 €

The LCC results for a vehicle carrier existing ship is shown in Table 114.

Table 114. Action 8A- The LCC results for a vehicle carrier existing ship

System Number		System#01	System#02
System Name		Pre 1a - Cargo scanni	Pre2 - Stowage plan
Unit		**Per Ship**	
Total Investment cost	EUR	381 450.00 €	89 560.00 €
Total Operation cost	EUR	183 317.64 €	5 538 811.41 €
Total Maintenance cost	EUR	39 282.35 €	7 732.02 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	604 049.99 €	5 636 103.43 €
Unit		**Per CEU**	
Total Investment cost	EUR	60.07 €	14.10 €
Total Operation cost	EUR	28.87 €	872.25 €
Total Maintenance cost	EUR	6.19 €	1.22 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	95.13 €	887.58 €

Results summary is shown in Table 115.

Table 115. Action 8A - Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Pre1a	Cargo scanning and identification and tracking system by the means of a called Vehicle Hot Spot Detector system	Investment	381 450.00 €	381 450.00 €	381 450.00 €	381 450.00 €	381 450.00 €	381 450.00 €
		Operation	640 523.87 €	439 745.80 €	616 230.35 €	439 745.80 €	261 338.26 €	183 317.64 €
		Maintance	70 646.01 €	48 501.37 €	67 966.58 €	48 501.37 €	56 001.06 €	39 282.35 €
		TOTAL	**1 092 619.88 €**	**869 697.17 €**	**1 065 646.93 €**	**869 697.17 €**	**698 789.32 €**	**604 049.99 €**
Pre1b	Automatic screening and management of cargo fire hazards by means of Automated Guided Vehicles	Investment	N/A	N/A	N/A	N/A	N/A	N/A
		Operation	N/A	N/A	N/A	N/A	N/A	N/A
		Maintance	N/A	N/A	N/A	N/A	N/A	N/A
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Pre2	Stowage planning tool with optimization algorithm for cargo distribution	Investment	91 800.00 €	91 800.00 €	91 800.00 €	91 800.00 €	89 560.00 €	89 560.00 €
		Operation	9 961 088.09 €	6 838 693.81 €	9 583 288.15 €	6 838 693.81 €	7 896 148.97 €	5 538 811.41 €
		Maintance	14 930.72 €	9 541.25 €	13 827.12 €	9 541.25 €	11 064.58 €	7 732.02 €
		TOTAL	**10 067 818.81 €**	**6 940 035.06 €**	**9 688 915.27 €**	**6 940 035.06 €**	**7 996 773.55 €**	**5 636 103.43 €**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed

11.2 Conclusion

An assessment of the lifecycle cost for the two RCMs proposed by Action 8-A was performed, RCM Pre1a and RCM Pre2 respectively. The proposed RCM Pre1b (Automatic screening with rolling drone) was not assessed as the development was found to be not mature for ship integration and further assessments. Further, the assessment was performed for three ship types, the selected generic ro-ro cargo, ro-pax and vehicle carrier that were used for integration and LCC assessment.

A relatively high total life cycle cost for the solution RCM Pre2 compared to the initial investment cost is related to the dominant part of the operation cost caused by the longer stowage and thereby longer turnaround time. This is due to the more time consuming vehicle by vehicle loading rather than batch loading.

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

Main author of the chapter: Martin Carlsson, STL

This chapter presents an overview of the life cycle cost assessment for the solutions proposed by Action 8-B i.e. Guidelines and solutions for safe electrical connections. Two RCMs were proposed by WP07 and two RCO's were selected (Ref. D04.6 "Cost-effectiveness assessment report" [2]) and assessed within this report:

- 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
- RCO8 - Safe electrical connection for reefers
- RCO9 - Safe electrical connection of reefers and electric vehicles (EVs)

For the description of the RCM's please refer to Deliverable D04.9 "Preliminary impact of solutions and related testing and demonstrations plan" [1], for the description of the RCO please refer to Deliverable D04.6, [2].

12.1 Life cycle cost assessment

An installation cost assessment for selected system solutions was made:

- **System#01** – Safe reefer connections (RCM Pre3)
- **System#02** – Safe EV connections (RCM Pre4)
- **System#03**– Safe EV connections (RCO9)

Cost assessment for the RCO8 was found to be same as for System#1, RCM Pre3.

12.1.1 Description of the developed solution

12.1.1.1 System#01: Safe reefer connections (RCM Pre3)

It was proposed that from the ship's power circuit, each outlet is equipped with a main breaker, power sensors and communication devices which monitor and gather data for automated analysis using algorithms to detect anomalies. This will give the ship the current state of each phase in the socket, with higher resolution than what was considered standard today. This solution will also be open to implementation of communication architecture like reefer containers have today.

12.1.1.1.1 Ro-pax integration description

Integrated example of the proposed system on Stena Flavia consists of 90 sockets, where 18 boxes with 5 sockets, at cargo Deck 3 and Deck 4, as illustrated on Figure 6. Installation of suitable cabinets on walls and/or columns in the cargo was proposed as necessary. These cabinets are to house remotely controllable breakers, energy meters in series with each socket connection, and current sensors for insulation and power measurements. The computing unit, which is the panel PC, along with analog to digital converters and insulation fault locators, were proposed to be housed at Deck 4 along with existing cabinets and other electrical equipment.

Total of 1974 m of signal cables is estimated. Power cables are not considered as assumed to be re-used for existing ships and not considered as additional cost for new buildings.

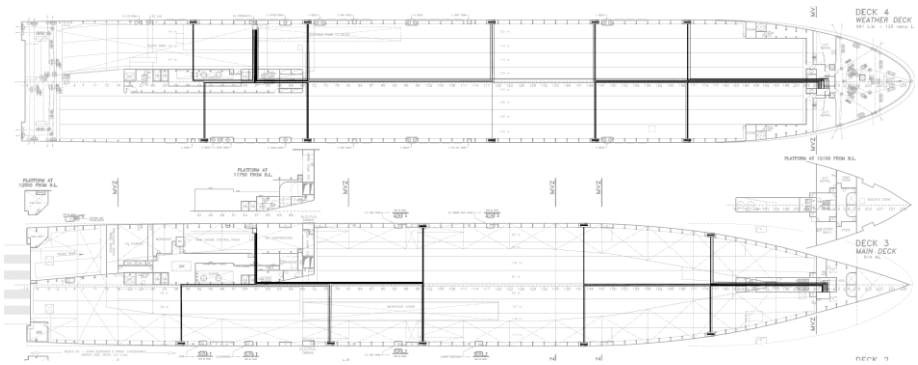

Figure 6: Integrated example of a Safe reefer connections on Stena Flavia

12.1.1.1.2 Ro-ro cargo integration description

Integrated example of the proposed system on Magnolia Seaways consists of 90 sockets where 18 boxes with 5 sockets, at the cargo decks, as illustrated on Figure 7. Installation of system equipment is similar as on the ro-pax integration example. Total of 686 m of signal cables is estimated. Power cables are not considered as assumed to be re-used for existing ships and not considered as additional cost for new buildings.

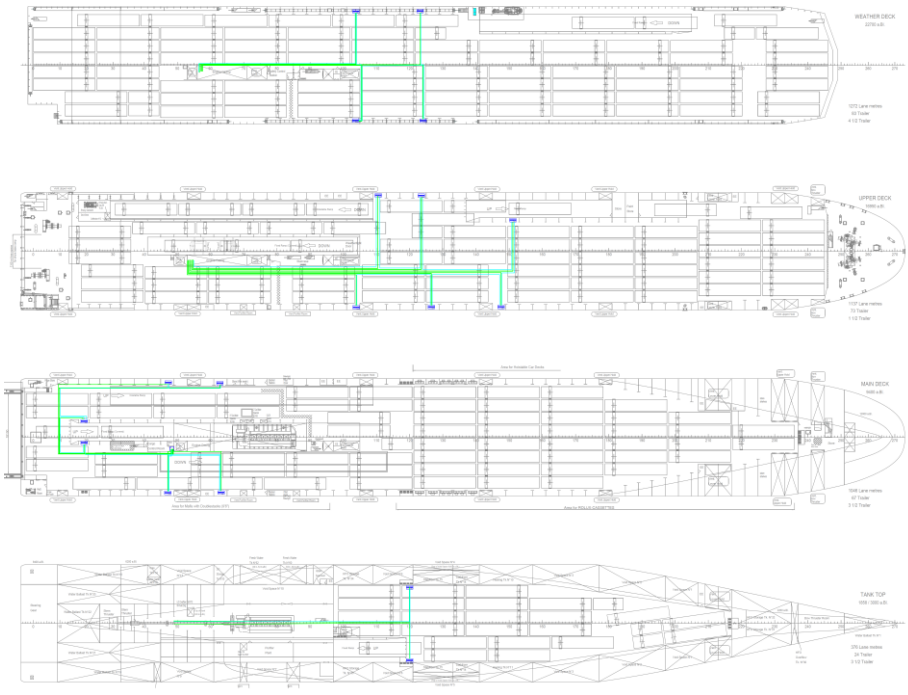

Figure 7: Integrated example of a Safe reefer connections on Magnolia Seaways.

12.1.1.2 System#02: Safe EV connections (RCM Pre4)

Monitoring of chargers and EVs are also to be done by measuring important parameters. Unlike in the case of reefer connections where only the reefer unit was a black box with only one connection to the electrical output of the ferry, there are two black boxes in case of the EV charging infrastructure: the EVs and the chargers. This corresponds to two connections that can be monitored: between the EV and the charger, and, between the charger and the ship's supply. Except for the insulation measurement, other parameters like power, voltage, currents, and temperatures are to be measured like the reefer solution except that the measurements shall be at two junctions and not one. This dual measurement shall also allow a comparison of the behaviours on either side of the charger unit which may give more details about the origin of the fault.

12.1.1.2.1 Ro-pax integration description

For the EV charge monitoring on Stena Flavia, the cabinets from which the car connections are drawn from are also used for the monitoring equipment. Each of these cabinets will then have 3 energy meters, current measuring coils and a remotely controllable breaker. A total of 9 charging sockets are considered and are divided into three of these cabinets. The computing unit and auxiliary systems like analog to digital converters are used as common hardware between the two system solutions (Pre3, Pre4). This then makes the EV charge monitoring system suitable for both centralized and decentralized charging units which is advantageous as various service providers have numerous solutions for charger units.

12.1.1.3 System#03: Safe electrical connection of reefers and electric vehicles (EVs) (RCO9)

System #3 (RCO9) was considered as a combination of System#1(RCM Pre3) and System#2. For the description of the RCO please refer to Deliverable D04.6, [2].

12.1.2 Life cycle cost model

Main author of the chapter: Vito Radolovic, FLOW

12.1.2.1 Cost items description and assumptions

Independent of the system and ship type the following costs were considered:

- Investment cost,
- operation cost,
- inspections, testing, and maintenance, and
- end of life cost.

The expected lifetime for a newly built ship was assumed to be 43 years for the ro-pax and 40.3 years for the ro-ro cargo. Further, it was assumed that all system solutions will be serviceable during the entire time if properly maintained.

12.1.2.1.1 System#01: Safe reefer connections (RCM Pre3)

12.1.2.1.1.1 Investment cost

The following items are considered:

- System components,
- vessel technical investigation,
- installation work,

- ship cable routing including sensor cables,
- integration with ship safety system,
- procedures in company,
- procedures on vessel, and
- training on vessel.

The purchasing costs of equipment was estimated based on figures from system component suppliers. Cost for establishing procedures and crew training on board was estimated based on Stena best practice experience.

12.1.2.1.1.2 Operation cost

No operational cost considered.

12.1.2.1.1.3 Maintenance cost

Maintenance cost estimation was based on necessary renewal of equipment according to Stena best practice experience.

12.1.2.1.1.4 End of life cost

No end of life cost considered.

12.1.3 System#02: Safe EV connections (Pre4)

12.1.3.1.1.1 Investment cost

The following items are considered:

- System components,
- vessel technical investigation,
- installation work,
- ship cable routing including sensor cables,
- integration with ship safety system,
- procedures in company,
- procedures on vessel, and
- training on vessel.

The purchasing costs of equipment was estimated based on figures from system component suppliers. Cost for establishing procedures and crew training on board was estimated based on Stena best practice experience.

12.1.3.1.1.2 Operation cost

No operational cost considered.

12.1.3.1.1.3 Maintenance cost

Maintenance cost estimation was based on necessary renewal of equipment according to Stena best practice experience.

12.1.3.1.1.4 End of life cost

No end of life cost considered.

12.1.3.2 Life cycle cost component for ro-pax newbuilding

12.1.3.2.1 Investment cost

The estimated cost for the installation of the two system solutions, respectively, on a ro-pax new building is summarized in Table 116.

Table 116 Action 8B- The estimated cost for the installation of the two system solutions, respectively, on a ro-pax new building

System Number		System#01	System#02	System#03
System Name		Pre3 - Reefer monito	Pre4 - EV monitorin	RCO9
Investment cost				
Purchasing cost	EUR	69 336.00	6 124.68	75 460.68
Insurance cost	EUR	-	-	-
Integration design & validation cost	EUR	2 600.00	2 600.00	5 200.00
Disassemble and modify the old system or structure	EUR	-	-	-
Road transporter cost	EUR	-	-	-
Ship transporter cost	EUR	-	-	-
Assembly/Installation cost	EUR	64 350.00	18 000.00	82 350.00
Comissioning cost	EUR	-	-	-
Document, certification and other administration costs	EUR	1 200.00	1 200.00	2 400.00
Loss of hire costs	EUR	-	-	-
Operator traning cost	EUR	1 440.00	1 440.00	2 880.00
Other cost	EUR	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total cost	EUR	138 926.00	29 364.68	168 290.68

12.1.3.2.2 Maintenance cost

The estimated cost for inspections, testing, and maintenance for the two system solutions on a ro-ro cargo new building is summarized in Table 117.

Table 117. Action 8B- The estimated cost for the inspection, testing and maintenance of the two system solutions for a ro-pax newbuilding

System Number		System#01	System#02	System#03
System Name		Pre3 - Reefer monito	Pre4 - EV monitorin	RCO9
Maintenance cost				
Annual maintenance				
Annual system maintenance cost	EUR/year	1 000.00	1 000.00	2 000.00
Loss due to vessel downtime during maintenance	EUR/year	-	-	-
Other annual maintenance cost	EUR/year	-	-	-
		-	-	-
Total annual maintenance cost	EUR/year	1 000.00	1 000.00	2 000.00

12.1.3.3 Life cycle cost component for ro-pax existing ship

12.1.3.3.1 Investment cost

The estimated cost for the installation of the two system solutions, respectively, on a ro-pax existing ship is summarized in

Table 118.

Table 118 Action 8B- The estimated cost for the installation of the two system solutions, respectively, on a ro-pax existing ship

System Number		System#01	System#02	System#03
System Name		Pre3 - Reefer monito	Pre4 - EV monitoring	RCO9
Investment cost				
Purchasing cost	EUR	78 336.10	6 124.68	84 450.78
Insurance cost	EUR	-	-	-
Integration design & validation cost	EUR	2 600.00	2 600.00	5 200.00
Disassemble and modify the old system or structure	EUR	-	-	-
Road transporter cost	EUR	-	-	-
Ship transporter cost	EUR	-	-	-
Assembly/Installation cost	EUR	84 220.00	18 000.00	102 220.00
Comissioning cost	EUR	-	-	-
Document, certification and other administration costs	EUR	1 200.00	1 200.00	2 400.00
Loss of hire costs	EUR	-	-	-
Operator traning cost	EUR	1 440.00	1 440.00	2 880.00
Other cost	EUR	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total cost	EUR	167 796.10	29 364.68	197 150.78

12.1.3.3.2 Maintenance cost

It was assumed that the maintenance cost is similar to a newbuilding, refer to the cost figures listed in Table 117.

12.1.3.4 Life cycle cost component for ro-ro cargo newbuilding

12.1.3.4.1 Investment cost

The estimated cost for the installation of the system solution on a ro-ro cargo new building is summarized in

Table 119.

Table 119 Action 8B- The estimated cost for the installation of the system solution on a ro-ro cargo new building

System Number		System#01
System Name		Pre3 - Reefer monito
Investment cost		
Purchasing cost	EUR	69 336.00
Insurance cost	EUR	-
Integration design & validation cost	EUR	2 600.00
Disassemble and modify the old system or structure	EUR	-
Road transporter cost	EUR	-
Ship transporter cost	EUR	-
Assembly/Installation cost	EUR	32 150.00
Comissioning cost	EUR	-
Document, certification and other administration costs	EUR	1 200.00
Loss of hire costs	EUR	-
Operator traning cost	EUR	1 440.00
Other cost	EUR	-
		-
		-
		-
		-
		-
		-
Total cost	EUR	106 726.00

12.1.3.4.2 Maintenance cost

The estimated maintenance cost for the system solution on a ro-ro cargo new building is summarized in Table 120.

Table 120. Action 8B- The estimated cost for the inspection, testing and maintenance of the system solution for a ro-ro cargo new building

System Number		System#01
System Name		Pre3 - Reefer monito
Maintenance cost		
Annual maintenance		
Annual system maintenance cost	EUR/year	1 000.00
Loss due to vessel downtime during maintenance	EUR/year	-
Other annual maintenance cost	EUR/year	-
		-
Total annual maintenance cost	EUR/year	1 000.00

12.1.3.5 Life cycle cost component for ro-ro cargo existing ship

12.1.3.5.1 Investment cost

The estimated cost for the installation of the system solution on a ro-ro cargo existing ship are summarized in

Table 121.

Table 121 Action 8B- The estimated cost for the installation of the system solution on a ro-ro cargo existing ship

System Number		System#01
System Name		Pre3 - Reefer monito
Investment cost		
Purchasing cost	EUR	78 336.10
Insurance cost	EUR	-
Integration design & validation cost	EUR	2 600.00
Disassemble and modify the old system or structure	EUR	-
Road transporter cost	EUR	-
Ship transporter cost	EUR	-
Assembly/Installation cost	EUR	40 580.00
Comissioning cost	EUR	-
Document, certification and other administration costs	EUR	1 200.00
Loss of hire costs	EUR	-
Operator traning cost	EUR	1 440.00
Other cost	EUR	-
		-
		-
		-
		-
		-
		-
Total cost	EUR	124 156.10

12.1.3.5.2 Maintenance cost

It was assumed that the maintenance cost is similar to a new building, refer to the cost figures listed in Table 120.

12.1.4 Life cycle cost Result

Main author of the chapter: Vito Radolovic, FLOW

The LCC results for a ro-pax new building is shown in Table 122.

Table 122. Action 8B- The LCC results for a ro-pax new building

System Number		System#01	System#02	System#03
System Name		Pre3 - Reefer monitoring	Pre4 - EV monitoring	RCO9
Unit		**Per Ship**		
Total Investment cost	EUR	138 926.00 €	29 364.68 €	168 290.68 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	23 548.67 €	23 548.67 €	47 097.34 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	162 474.67 €	52 913.35 €	215 388.02 €
Unit		**Per Lane meter**		
Total Investment cost	EUR	63.15 €	13.35 €	76.50 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	10.70 €	10.70 €	21.41 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	73.85 €	24.05 €	97.90 €

The LCC results for a ro-pax existing ship is shown in Table 123.

Table 123. Action 8B- The LCC results for a ro-pax existing ship

System Number		System#01	System#02	System#03
System Name		Pre3 - Reefer monitoring	Pre4 - EV monitoring	RCO9
Unit		**Per Ship**		
Total Investment cost	EUR	167 796.10 €	29 364.68 €	197 150.78 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	16 167.12 €	16 167.12 €	32 334.25 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	183 963.22 €	45 531.80 €	229 485.03 €
Unit		**Per Lane meter**		
Total Investment cost	EUR	76.27 €	13.35 €	89.61 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	7.35 €	7.35 €	14.70 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	83.62 €	20.70 €	104.31 €

The LCC results for a ro-ro cargo new building is shown in Table 124.

Table 124. Action 8B- The LCC results for a ro-ro cargo new building

System Number		System#01
System Name		Pre3 - Reefer monitoring
Unit		**Per Ship**
Total Investment cost	EUR	106 726.00 €
Total Operation cost	EUR	- €
Total Maintenance cost	EUR	22 655.53 €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	129 381.53 €
Unit		**Per Lane meter**
Total Investment cost	EUR	27.86 €
Total Operation cost	EUR	- €
Total Maintenance cost	EUR	5.91 €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	33.77 €

The LCC results for a ro-ro cargo existing ship is shown in Table 125.

Table 125. Action 8B- The LCC results for a ro-ro cargo existing ship

System Number		System#01
System Name		Pre3 - Reefer monitorin
Unit		**Per Ship**
Total Investment cost	EUR	124 156.10 €
Total Operation cost	EUR	- €
Total Maintenance cost	EUR	16 167.12 €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	140 323.22 €
Unit		**Per Lane meter**
Total Investment cost	EUR	32.41 €
Total Operation cost	EUR	- €
Total Maintenance cost	EUR	4.22 €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	36.63 €

Results summary is shown in Table 126.

Table 126. Action 8B - Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Pre3	Develop guidelines for safe electrical power connections in ro-ro spaces for reefer units	Investment	138 926.00 €	167 796.10 €	106 726.00 €	124 156.10 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	23 548.67 €	16 167.12 €	22 655.53 €	16 167.12 €	N/A	N/A
		TOTAL	**162 474.67 €**	**183 963.22 €**	**129 381.53 €**	**140 323.22 €**	**N/A**	**N/A**
Pre4	Develop guidelines for safe electrical power connections in ro-ro spaces for charging of Evs	Investment	29 364.68 €	29 364.68 €	N/A	N/A	N/A	N/A
		Operation	0.00 €	0.00 €	N/A	N/A	N/A	N/A
		Maintance	23 548.67 €	16 167.12 €	N/A	N/A	N/A	N/A
		TOTAL	**52 913.35 €**	**45 531.80 €**	**N/A**	**N/A**	**N/A**	**N/A**
RCO8	Safe electrical connection for reefers	Investment	138 926.00 €	167 796.10 €	106 726.00 €	124 156.10 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	23 548.67 €	16 167.12 €	22 655.53 €	16 167.12 €	N/A	N/A
		TOTAL	**162 474.67 €**	**183 963.22 €**	**129 381.53 €**	**140 323.22 €**	**N/A**	**N/A**
RCO9	Safe electrical connection of reefers and electric vehicles (EVs)	Investment	168 290.68 €	197 150.78 €	N/A	N/A	N/A	N/A
		Operation	0.00 €	0.00 €	N/A	N/A	N/A	N/A
		Maintance	47 097.34 €	32 334.25 €	N/A	N/A	N/A	N/A
		TOTAL	**215 388.02 €**	**229 485.03 €**	**N/A**	**N/A**	**N/A**	**N/A**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed

12.2 Conclusion

An assessment of the life cycle cost for the solutions proposed by Action 8-B was performed. Further, the assessment was performed for two ship types, the selected generic ro-ro cargo, and ro-pax, ships that were used for integration and LCC assessment.

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

Main author of the chapter: Vito Radolovic, FLOW

RCM proposed by WP08 at the Action 8-C i.e. Fire requirements for new deck materials 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 “Preliminary impact of solutions and related testing and demonstrations plan” [1].
The proposed RCM was not assessed as LCC assessment was not found relevant for further developments, Ref. D05.7 “Ship integration evaluation” [3].

Table 127. Action 8C - Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Pre5	Proposal for requirements of surface materials in ro-ro spaces, with reference to suitable test method and material property performance criteria	Investment	N/A	N/A	N/A	N/A	N/A	N/A
		Operation	N/A	N/A	N/A	N/A	N/A	N/A
		Maintance	N/A	N/A	N/A	N/A	N/A	N/A
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed

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

Main author of the chapter: Vito Radolovic, FLOW

This chapter presents an overview of the life cycle cost assessment for the solutions proposed by Action 9-A, i.e., means for detection on weather deck. Two RCMs were proposed by WP06 and one RCO selected (Ref. D04.6 "Cost-effectiveness assessment report" [2]) and assessed within this report:

- RCM Det1 - Flame wavelength detectors
- RCM Det8 - Thermal imaging (infrared) cameras
- RCO10 - Fire detection on weather decks

For the description of the RCM's please refer to Deliverable D04.9 "Preliminary impact of solutions and related testing and demonstrations plan" [1], for the description of the RCO please refer to Deliverable D04.6, [2].

14.1 Life cycle cost assessment

An installation cost assessment for two different system solutions was made:

- **System#01** – flame wavelength detectors (RCM Det1)
- **System#02** – thermal imaging (infrared) cameras (RCM Det8)
- **System#03** - Fire detection on weather decks (RCO10)

The cost assessment was made for reference ships selected by the project, Magnolia Seaways the generic ro-ro cargo ship operated by DFDS Seaways, and Stena Flavia, the generic ro-pax ship. The cost assessment was made for both newbuilding and existing ships.

The LASH FIRE generic vehicle carrier (Torrens) does not have any ro-ro space on the weather deck, so cost assessment was not performed.

14.1.1 Description of the developed solution

Main author of the chapter: Davood Zeinali, FRN

14.1.1.1 System#01 – flame wavelength detectors (RCM Det1)

The system of flame wavelength detectors comprises of a few detector units as shown in Figure 8, and a cable connecting each detector back to the ship's fire control panel for receiving and processing the alarm signals provided by the detectors. The mounting of the detectors is also done using a bracket attached to the ship, while a junction box may be used for better interface and maintenance. Each flame detector may also be accompanied by an optical camera (at an extra cost) to store footage of the area where fire is detected (e.g., 1-minute pre-event and 3 minutes post-event).

The detection range for optical devices such as flame detectors follows the square law between distance and area of detection as long as the distance is high compared to the characteristic length of the object to be detected, such that detection at twice the distance requires nearly four times the area (or fire size), as illustrated in Figure 9. Accordingly, if a flame detector is able to detect a 40-kW fire at 30 m, detection at 60 m is expected to require a 160 kW fire.

The detection range of flame detectors also depends on their sensitivity settings, where low sensitivity settings may be used for close-range detection, while high sensitivity settings may be used for long-range detection. Correspondingly, the sensitivity settings may be fixed according to the application, desired detection time, and acceptable frequency of nuisance alarms. For instance, a 0.3

m x 0.3 m heptane pool fire may be detected at 15 m in nearly 1 s with low sensitivity settings, whereas the same fire may be detected from 60 m in nearly 3 s with high sensitivity settings, albeit more nuisance alarms may be triggered with the latter settings.

Figure 8: Example flame detector unit installed on board Hollandia Seaways for testing. The orange cable connects the detector to the fire control panel where the alarm signal is received and processed.

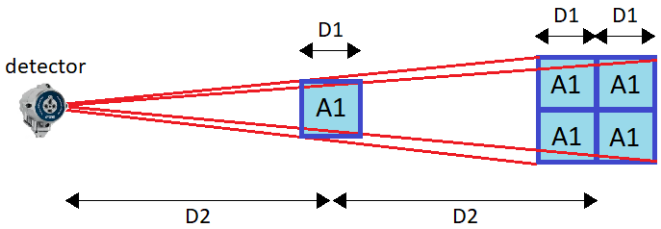

Figure 9: Square law between distance and area of detection (applicable when D2 >> D1): if an object that has an area of A1 is detectable at the distance of D2, detection at a distance of 2 x D2 requires nearly an area of 4 x A1.

Most flame detectors provide a single output signal indicating the presence/absence of flames within the field of view, i.e., no X/Y coordinates are provided. However, array-type flame detectors have their field of view divided into several sectors, enabling them to detect in which part of their field of view the fire is located. Even with such type of detectors, however, often several detectors are needed in the detection system to ensure adequate coverage of the desired area based on the working range and acceptable sensitivity of the flame detectors.

14.1.1.1.1 Ro-ro cargo integration description

The weather deck on the reference ship, Magnolia Seaways, extends forward and aft of the superstructure, therefore 4 flame detectors are arranged in the aft part of the deck and 6 flame detectors in the fore part of the deck as shown in Figure 10. The shown flame detectors have low sensitivity settings with effective detection range of nearly 35 m at 90° horizontal angle and 75° vertical angle. The detectors shall be arranged above the cargo and therefore appropriate stands shall be arranged. For 4 detectors, supports may be arranged at the superstructure, where for 6 detectors stands made of DN100 piping with tensioners are considered. Approximately 700 m of cabling for the detection system is estimated.

Integrated examples of a flame detection system for the weather deck are shown on Figure 10 and Figure 11 for the generic LASH FIRE ships of Magnolia Seaways (ro-ro cargo) and Stena Flavia (ro-pax).

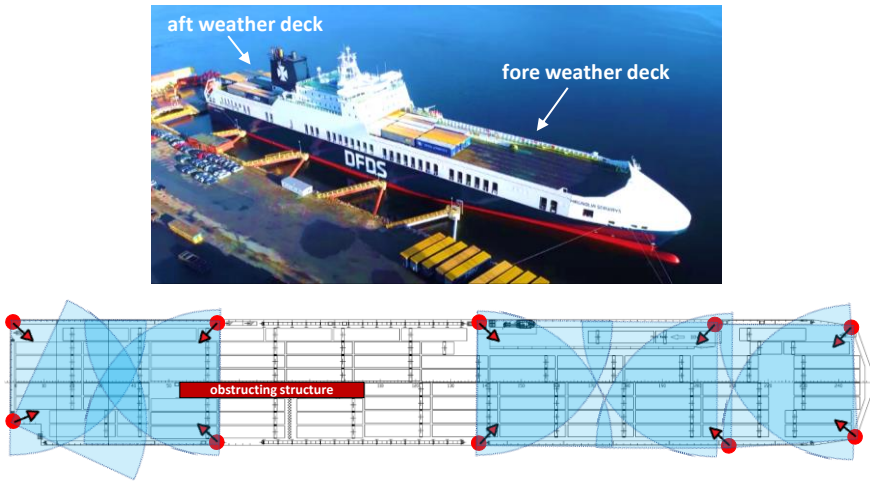

Figure 10: Integrated example of a flame detection system for the weather deck of Magnolia Seaways (ro-ro cargo ship shown above)

14.1.1.1.2 Ro-pax integration description

The weather decks on the reference ship, Stena Flavia extends aft of the superstructure at Deck 4 and Deck 5 as shown on Figure 11. Five flame detectors are arranged at Deck 5 and two at Deck 4. The shown flame detectors have low sensitivity settings with effective detection range of nearly 35 m at 90° horizontal angle and 75° vertical angle. The detectors shall be arranged above the cargo and therefore appropriate stands shall be arranged. For one detector, support may be arranged at the superstructure, while for six detectors stands made of DN100 piping with tensioners are considered. Approximately 500 m of cabling for the detection system is estimated.

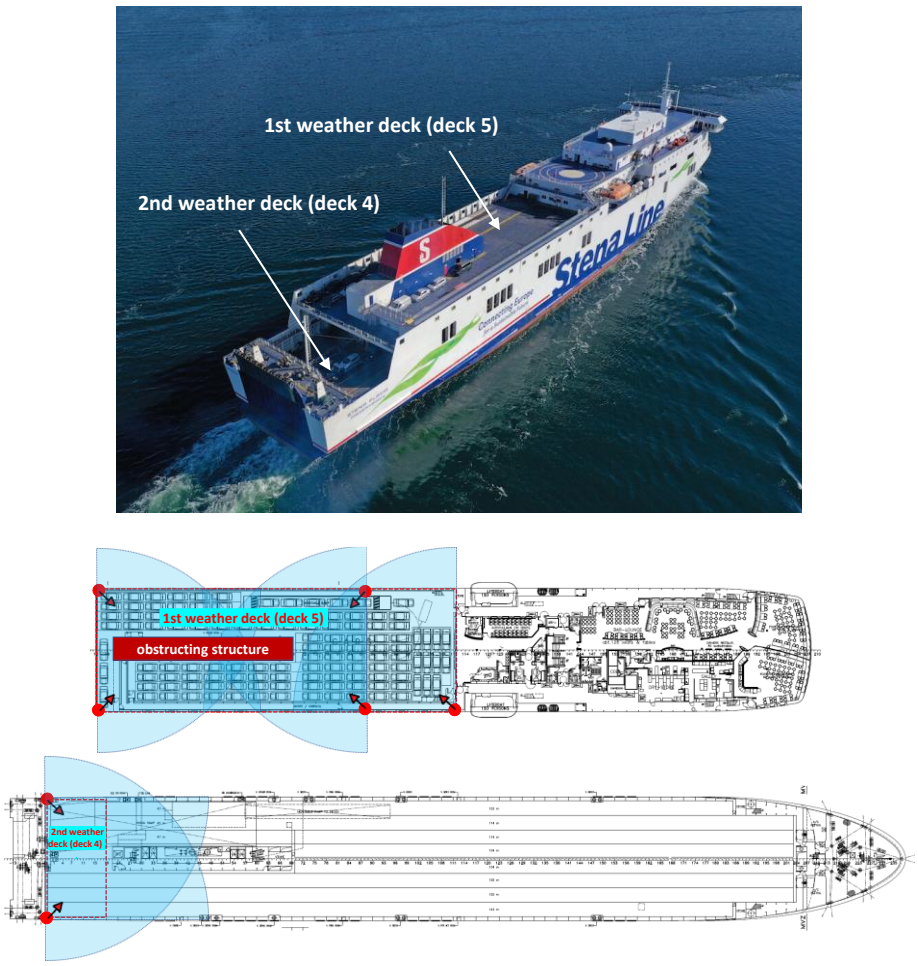

Figure 11: Integrated example of a flame detection system for the weather decks of Stena Flavia (ro-pax ship shown above), with 5 flame detectors on deck 5 and 2 flame detectors on deck 4.

14.1.1.2 System#02 – thermal imaging (infrared) cameras (RCM Det8)

The detection system based on thermal imaging is made up of a few infrared cameras (example shown in Figure 12), as well as some cables connecting the cameras back to the ship's fire control panel and computer with the software required to receive and process the alarm signals and thermal images provided by the infrared cameras.

Figure 12: Example thermal imaging (infrared) camera installed on board Hollandia Seaways for testing.

Infrared cameras are sensitive to hot surfaces, so they can detect areas that are hotter than other surfaces nearby. This can be used to detect potential ignition sources before any flame or smoke is released, but this may cause false alarms if the hot surface is not a real fire hazard. As a result, pre-registering areas with known hot objects at specific temperatures in the detection system can be an option for eliminating false alarms generated by those sources of heat. Correspondingly, the proper commissioning of the thermal imaging fire detection system must consider the hot areas that are expected in normal operations. Moreover, the effectiveness of the thermal imaging cameras may be affected when their lens is covered by dirt, saltwater film or ice, so they require some general maintenance. The cameras also require free line of sight to the fire zone to trigger an alarm.

The detection range of infrared cameras may be as long as 250 m for objects as big as a human, but the detection depends also on the sensitivity settings of the camera, where low sensitivity settings may be used for close-range detection, while high sensitivity settings may be used for long-range detection. As infrared cameras are optical devices, their detection range also follows the square law between distance and area of detection illustrated in Figure 9, such that detection at twice the distance requires nearly four times the area (or fire size). Correspondingly, the location of the cameras and their sensitivity settings may be fixed according to the application, desired detection time, and acceptable frequency of nuisance alarms. Often several cameras are used to ensure adequate coverage of the desired area based on the working range and acceptable sensitivity of the cameras.

In addition to triggering fire alarms, infrared cameras can also identify the location of the fire and can provide this information in terms of X/Y coordinates that are useful for fire suppression using autonomous systems.

14.1.1.2.1 Ro-ro cargo integration description

A fire detection system for the weather deck of Magnolia Seaways consisting of two infrared cameras in the aft part of the deck and two infrared cameras in the fore part of the deck as shown on Figure 13 and Figure 14. The cameras in this example have medium sensitivity settings allowing effective detection range of nearly 100 m at 25° horizontal angle and 20° vertical angle. The cameras shall be arranged above the cargo and therefore appropriate stands shall be arranged. For two cameras, support may be arranged at the superstructure, while for other two stands made of DN100 piping with tensioners are considered. Approximately 350 m of cabling for the detection system is estimated.

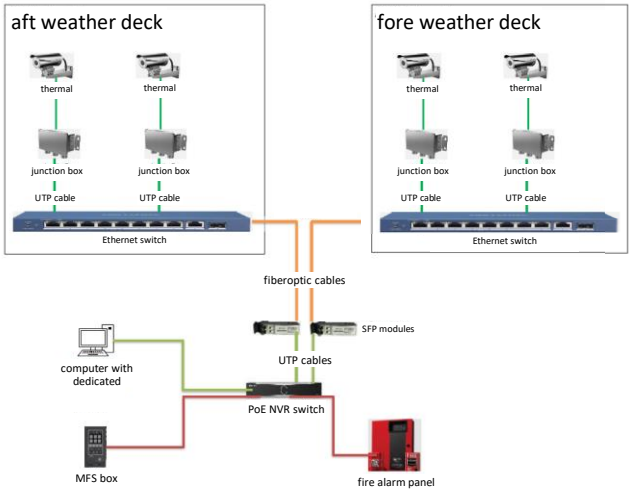

Figure 13: Concept of a detection system based on thermal imaging (infrared) cameras for Magnolia Seaways.

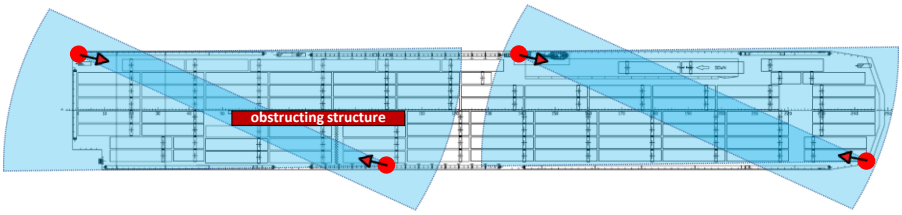

Figure 14: Integrated example of a fire detection system for the weather deck of Magnolia Seaways

14.1.1.2.2 Ro-pax integration description

A fire detection system for the weather decks of Stena Flavia consisting of three infrared cameras on deck 5, and one infrared camera on deck 4, is shown on Figure 15. In this example, different cameras and sensitivity settings are used with effective detection ranges as follows: 100 m at 25° horizontal angle and 20° vertical angle (2 cameras on deck 5), 45 m at 53° horizontal angle and 40° vertical angle (1 camera on deck 5), 30 m at 80° horizontal angle and 56° vertical angle (1 camera on deck 4).

For three cameras, support may be arranged at the superstructure and engine casing, where for one camera a stand made of DN100 piping with tensioners was considered. Approximately 180 m of cabling for the detection system is estimated.

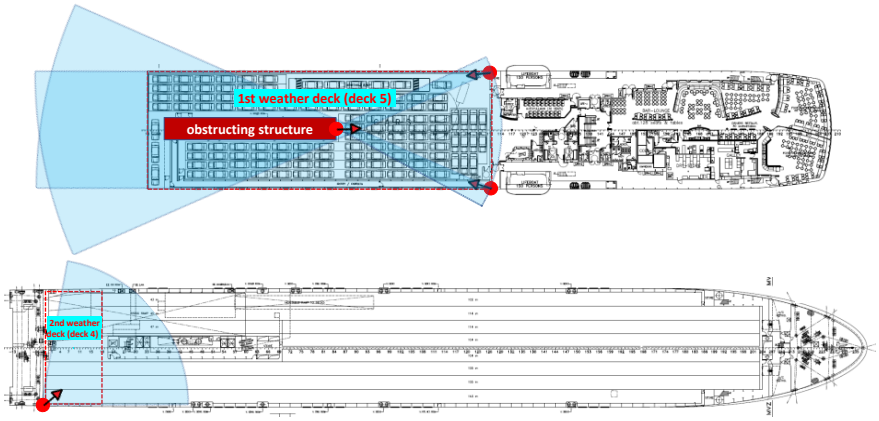

Figure 15: Integrated example of a fire detection system for the weather decks of Stena Flavia

14.1.1.3 System#03: Fire detection on weather decks (RCO10)

System #3 (RCO10) is considering both System#1(RCM Det1) and System#2(RCM Det8). For the cost assessment purposes, average cost from both systems integration was considered. For the description of the RCO please refer to Deliverable D04.6, [2].

14.1.2 Life cycle cost model

14.1.2.1 Cost items description and assumptions

Independent of the system, ship type, newbuilding or existing ship, the following costs were considered:

- Investment cost,
- inspections, testing, and maintenance, and
- end of life cost.

The expected lifetime for a new built ship was assumed to be 43 years for the ro-pax and 40.3 years for the ro-ro cargo. The expected lifetime for existing ships was assumed to be 22.8 years for the ro-pax and 22.9 years for the ro-ro cargo. Further, it was assumed that all system solutions will be serviceable during the entire time if properly maintained.

14.1.2.1.1 Investment cost

14.1.2.1.1.1 System#01 – flame wavelength detectors (RCM Det1)

The following items are considered:

- Detectors, mounting brackets, computer workstation for video monitoring and recording, MFS alarm panel,
- the material purchasing cost (piping, cables)m
- stands for detectors and tensionersm
- the labour cost for the engineering, shipyard administrationm
- the labour cost for the installation work and commissioning:
    - installation of detection system,

    - production and installation of stands.
- document, certification, and other administration costs (considered for existing ships only, while for new buildings no additional cost was assumed), and
- operator training.

14.1.2.1.1.2 System#02 – thermal imaging (infrared) cameras (RCM Det8)

The following items are considered:

- Cameras, junction boxes, mounting brackets, PoE switches, PoE NVR switches, SFP modules, HDD memory, computer workstation for video monitoring and recording, MFS alarm panel,
- the material purchasing cost (piping, cables),
- stands for detectors and tensioners,
- the labour cost for the engineering, shipyard administration,
- the labour cost for the installation work and commissioning:
    - installation of detection system,
    - production and installation of stands,
- document, certification, and other administration costs (considered for existing ships only, while for new buildings no additional cost was assumed), and
- operator training.

14.1.2.1.1.3 Investment cost assessment assumptions

The purchasing costs for each component were estimated based on figures from system component suppliers.

The estimated cost provided for the production, installation, and commissioning was based on a Croatian shipyards standard where the average cost per weight or length was estimated. Production and installation of steel structures such as monitor stands, 2.5 EUR/kg for production and 1.5 EUR/kg for installation was assumed where an increase of 10% for retrofitting was estimated. A cabling installation cost of 25 EUR/m was assumed for newbuilding and 30 EUR/m for retrofit.

It is to be noted that significant cost differences may occur depending on the business area, i.e., shipyard location. However, the cost estimates can easily be adjusted to a specific business area.

14.1.2.1.2 Cost for inspections, testing, and maintenance

For each cost component, the average was considered based on figures from the suppliers.

14.1.2.1.3 End of life cost

The recycling and resale of the system may be doable but the suppliers themselves recognize no residual value for the system after the ship's lifetime. Therefore, no end-of-life cost was considered.

14.1.2.2 Life cycle cost component for ro-ro cargo newbuilding

14.1.2.2.1 Investment cost

The estimated cost for the installation of the two system solutions, respectively, on a ro-ro cargo new building is summarized in

Table 128.

Table 128 Action 9A- The estimated cost for the installation of the two system solutions, respectively, on a ro-ro cargo new building

		System#01	System#02	System#03
System Number				
System Name		Det1: Flame detector	Det8: IR heat camera	RCO10
Investment cost				
Purchasing cost	EUR	60 590.00	49 098.00	54 844.00
Insurance cost	EUR	-	-	-
Integration design & validation cost	EUR	5 000.00	5 000.00	5 000.00
Disassemble and modify the old system or structure	EUR	-	-	-
Road transporter cost	EUR	-	-	-
Ship transporter cost	EUR	-	-	-
Assembly/Installation cost	EUR	33 900.00	18 750.00	26 325.00
Comissioning cost	EUR	500.00	500.00	500.00
Document, certification and other administration costs	EUR	-	-	-
Loss of hire costs	EUR	-	-	-
Operator traning cost	EUR	500.00	500.00	500.00
Other cost	EUR	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total cost	EUR	100 490.00	73 848.00	87 169.00

14.1.2.2.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and energy consumption is negligible and therefore not considered.

14.1.2.2.3 Maintenance cost

It is concluded that the estimated cost for inspections, testing, and maintenance of the two selected solutions are fairly similar. The estimated cost for the two system solutions on a ro-ro cargo new building is summarized in Table 129.

Table 129. Action 9A- The estimated cost for the inspection, testing and maintenance of the two system solutions for a ro-ro cargo newbuilding

		System#01	System#02	System#03
System Number				
System Name		Det1: Flame detector	Det8: IR heat camera	RCO10
Maintenance cost				
Annual maintenance				
Annual system maintenance cost	EUR/year	5 000.00	5 000.00	5 000.00
Loss due to vessel downtime during maintenance	EUR/year	-	-	-
Other annual maintenance cost	EUR/year	-	-	-
		-	-	-
Total annual maintenance cost	EUR/year	5 000.00	5 000.00	5 000.00

14.1.2.2.4 End of life cost

No end-of-life cost was considered applicable.

14.1.2.3 Life cycle cost component for ro-ro cargo existing ship

14.1.2.3.1 Investment cost

The estimated cost for the installation of the two system solutions on a ro-ro cargo existing ship are summarized in Table 130.

Table 130 Action 9A- The estimated cost for the installation of the two system solutions on a ro-ro cargo existing ship

System Number		System#01	System#02	System#03
System Name		Det1: Flame detector	Det8: IR heat camera	RCO10
Investment cost				
Purchasing cost	EUR	60 590.00	49 098.00	54 844.00
Insurance cost	EUR	-	-	-
Integration design & validation cost	EUR	8 000.00	8 000.00	8 000.00
Disassemble and modify the old system or structure	EUR	-	-	-
Road transporter cost	EUR	-	-	-
Ship transporter cost	EUR	-	-	-
Assembly/Installation cost	EUR	38 440.00	20 900.00	29 670.00
Comissioning cost	EUR	1 000.00	1 000.00	1 000.00
Document, certification and other administration costs	EUR	12 000.00	12 000.00	12 000.00
Loss of hire costs	EUR	-	-	-
Operator traning cost	EUR	500.00	500.00	500.00
Other cost	EUR	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total cost	EUR	120 530.00	91 498.00	106 014.00

14.1.2.3.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and the energy consumption is negligible and therefore not considered.

14.1.2.3.3 Maintenance cost

It was assumed that the maintenance cost is similar to a newbuilding, refer to the cost figures listed in Table 129.

14.1.2.3.4 End of life cost

No end-of-life cost was considered applicable.

14.1.2.4 Life cycle cost component for ro-pax newbuilding

14.1.2.4.1 Investment cost

The estimated cost for the installation of the two system solutions, respectively, on a ro-pax new building is summarized in Table 131.

Table 131 Action 9A- The estimated cost for the installation of the two system solutions, respectively, on a ro-pax new building

System Number		System#01	System#02	System#03
System Name		Det1: Flame detector	Det8: IR heat camera	RCO10
Investment cost				
Purchasing cost	EUR	40 938.00	46 048.00	43 493.00
Insurance cost	EUR	-	-	-
Integration design & validation cost	EUR	5 000.00	5 000.00	5 000.00
Disassemble and modify the old system or structure	EUR	-	-	-
Road transporter cost	EUR	-	-	-
Ship transporter cost	EUR	-	-	-
Assembly/Installation cost	EUR	21 980.00	12 500.00	17 240.00
Comissioning cost	EUR	500.00	500.00	500.00
Document, certification and other administration costs	EUR	-	-	-
Loss of hire costs	EUR	-	-	-
Operator traning cost	EUR	500.00	500.00	500.00
Other cost	EUR	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total cost	EUR	68 918.00	64 548.00	66 733.00

14.1.2.4.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and energy consumption is negligible and therefore not considered.

14.1.2.4.3 Maintenance cost

It was assumed that the maintenance cost is similar to a ro-ro cargo newbuilding, refer to the cost figures listed in Table 129.

14.1.2.4.4 End of life cost

No end-of-life cost was considered applicable.

14.1.2.5 Life cycle cost component for ro-pax existing ship

14.1.2.5.1 Investment cost

The estimated cost for the installation of the two system solutions on a ro-pax existing ship are summarized in

Table 132.

Table 132 Action 9A- The estimated cost for the installation of the two system solutions on a ro-pax existing ship

System Number		System#01	System#02	System#03
System Name		Det1: Flame detector	Det8: IR heat camera	RCO10
Investment cost				
Purchasing cost	EUR	40 938.00	46 048.00	43 493.00
Insurance cost	EUR	-	-	-
Integration design & validation cost	EUR	8 000.00	8 000.00	8 000.00
Disassemble and modify the old system or structure	EUR	-	-	-
Road transporter cost	EUR	-	-	-
Ship transporter cost	EUR	-	-	-
Assembly/Installation cost	EUR	24 828.00	13 600.00	19 214.00
Comissioning cost	EUR	1 000.00	1 000.00	1 000.00
Document, certification and other administration costs	EUR	12 000.00	12 000.00	12 000.00
Loss of hire costs	EUR	-	-	-
Operator traning cost	EUR	500.00	500.00	500.00
Other cost	EUR	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total cost	EUR	87 266.00	81 148.00	84 207.00

14.1.2.5.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and the energy consumption is negligible and therefore not considered.

14.1.2.5.3 Maintenance cost

It was assumed that the maintenance cost is similar to a ro-ro cargo newbuilding, refer to the cost figures listed in Table 129.

14.1.2.5.4 End of life cost

No end-of-life cost was considered applicable.

14.1.3 LCC Result

The LCC results for a ro-ro cargo new building is shown in Table 133.

Table 133. Action 9A- The LCC results for a ro-ro cargo new building

System Number		System#01	System#02	System#03
System Name		Det1: Flame detectors	Det8: IR heat cameras	RCO10
Unit		**Per Ship**		
Total Investment cost	EUR	100 490.00 €	73 848.00 €	87 169.00 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	113 277.64 €	113 277.64 €	113 277.64 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	213 767.64 €	187 125.64 €	200 446.64 €
Unit		**Per Lane meter**		
Total Investment cost	EUR	26.23 €	19.28 €	22.75 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	29.57 €	29.57 €	29.57 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	55.80 €	48.85 €	52.32 €

The LCC results for a ro-ro cargo retrofit is shown in Table 134.

Table 134. Action 9A- The LCC results for a ro-ro cargo existing ship

System Number		System#01	System#02	System#03
System Name		Det1: Flame detectors	Det8: IR heat cameras	RCO10
Unit		**Per Ship**		
Total Investment cost	EUR	120 530.00 €	91 498.00 €	106 014.00 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	80 835.62 €	80 835.62 €	80 835.62 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	201 365.62 €	172 333.62 €	186 849.62 €
Unit		**Per Lane meter**		
Total Investment cost	EUR	31.46 €	23.88 €	27.67 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	21.10 €	21.10 €	21.10 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	52.56 €	44.98 €	48.77 €

The LCC results for a ro-pax new building is shown in Table 135.

Table 135. Action 9A- The LCC results for a ro-pax new building.

System Number		System#01	System#02	System#03
System Name		Det1: Flame detectors	Det8: IR heat cameras	RCO10
Unit		**Per Ship**		
Total Investment cost	EUR	68 918.00 €	64 548.00 €	66 733.00 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	117 743.36 €	117 743.36 €	117 743.36 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	186 661.36 €	182 291.36 €	184 476.36 €

The LCC results for a ro-pax existing ship is shown in Table 136.

Table 136. Action 9A- The LCC results for a ro-pax existing ship

System Number		System#01	System#02	System#03
System Name		Det1: Flame detectors	Det8: IR heat cameras	RCO10
Unit		**Per Ship**		
Total Investment cost	EUR	87 266.00 €	81 148.00 €	84 207.00 €
Total Operation cost	EUR	- €	- €	- €
Total Maintenance cost	EUR	80 835.62 €	80 835.62 €	80 835.62 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	168 101.62 €	161 983.62 €	165 042.62 €

LCC results have not been given per cargo unit for a ro-pax ship as the large weather deck is intended for passenger cars only.

Results summary is shown in Table 137.

Table 137. Action 9A - Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Det1	Flame wavelength detectors	Investment	68 918.00 €	87 266.00 €	100 490.00 €	120 530.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	117 743.36 €	80 835.62 €	113 277.64 €	80 835.62 €	N/A	N/A
		TOTAL	**186 661.36 €**	**168 101.62 €**	**213 767.64 €**	**201 365.62 €**	**N/A**	**N/A**
Det8	Thermal imaging (infrared) cameras	Investment	64 548.00 €	81 148.00 €	73 848.00 €	91 498.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	117 743.36 €	80 835.62 €	113 277.64 €	80 835.62 €	N/A	N/A
		TOTAL	**182 291.36 €**	**161 983.62 €**	**187 125.64 €**	**172 333.62 €**	**N/A**	**N/A**
RCO10	Fire detection on weather decks	Investment	66 733.00 €	84 207.00 €	87 169.00 €	106 014.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	117 743.36 €	80 835.62 €	113 277.64 €	80 835.62 €	N/A	N/A
		TOTAL	**184 476.36 €**	**165 042.62 €**	**200 446.64 €**	**186 849.62 €**	**N/A**	**N/A**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed

14.2 Conclusion

An assessment of the installation cost and the cost for inspection, testing, and maintenance of two weather deck detection system solutions proposed by Action 9-A was performed. Further, the assessment was performed for two ship types, the selected generic ro-ro cargo, and ro-pax ships that were used for integration and LCC assessment.

The performed cost assessment for ro-ro cargo ships showed that the total lifecycle cost is about 15% higher in case of flame detectors application, exclusively due to higher installation costs (more pieces of equipment and cabling needed, higher installation costs). Regarding ro-pax ships, the comparison of two systems is again in favour of IR thermal camera implementation, although, the relative difference shows only a few percent of difference.

It needs to be emphasized that the installation cost is dependent on the weather deck arrangement. Specifically, obstructions arrangements such as engine casing and deckhouses as well as deck area size and shape, have an impact on the number of detection units to be installed, which represent the majority of the installation and maintenance cost. Both the ro-ro cargo and ro-pax generic ships considered for the cost estimation have arranged obstructions in way of central casing, and so the cost assessment may be considered conservative regarding the applicability to the ro-ro world fleet.

Finally, it is difficult to scale the cost per ship type, lane meters, or deck area, where the cost shall be calculated on a case-by-case basis.

Further, significant cost differences may occur depending on the business area, i.e., shipyard location, particularly the installation cost. However, the cost estimates can easily be adjusted to a specific business area.

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

Main author of the chapter: Vito Radolovic, FLOW

This chapter presents an overview of the life cycle cost assessment for the solutions proposed by Action 9-B i.e. New means for fire detection in closed and open ro-ro spaces. Three RCMs were proposed by WP09 and one RCO selected (Ref. D04.6 "Cost-effectiveness assessment report" [2]) and assessed within this report:

- RCM Det3 - Video detection
- RCM Det4 - Adaptive detection threshold settings
- RCM Det7 - Fibre optic linear heat detection
- RCO11 - Fire detection in closed ro-ro spaces & open ro-ro spaces

For the description of the RCM's please refer to Deliverable D04.9 "Preliminary impact of solutions and related testing and demonstrations plan" [1], for the description of the RCO please refer to Deliverable D04.6, [2].

15.1 Life cycle cost assessment

An installation cost assessment for two different system solutions was made:

- **System#01** – video fire detection (Det3)
- **System#02** – fibreoptic linear heat detection (Det7)

Cost assessment for the RCO11 was found to be same as for System#2, RCM Det7.

The RCM Det4 was found to be integrable for new buildings with no additional cost where the integration potential on existing ships highly depends on the system installed onboard, and in general not acceptable from the ship operators due to potential high cost, Ref D05.7, [3]. Finally, the RCM Det 4 was not considered for the LCC assessment.

The cost assessment was made for reference ships selected by the project, Magnolia Seaways the generic ro-ro cargo ship operated by DFDS Seaways, Stena Flavia, the generic ro-pax ship and Torrens, the generic vehicle carrier. The cost assessment was made for both newbuilding and existing ships.

15.1.1 Description of the developed solution

Main author of the chapter: Davood Zeinali, FRN

15.1.1.1 System#01 – video fire detection (RCM Det3)

It is firstly notable that fire detection based on video analytics is recommended only for closed ro-ro spaces because such a detection system is sensitive to changing light conditions which trigger false alarms. Therefore, the cost assessment made here for video fire detection systems only focuses on closed ro-ro spaces.

The detection system based on video analytics, mainly comprises several video cameras and an algorithm that performs Video Flame Detection (VFD) and/or Video Smoke Detection (VSD). The cameras can be either regular CCTV cameras, attached to a computer with the required video analytics software, or dedicated cameras that come with the required detection software as a package. Accordingly, flame or smoke characteristics are interpreted in the field of view to identify

visual features of flame or smoke. One advantage for this optical detection system is that each camera can cover a large area. However, the use of cameras below the deckhead of ro-ro spaces limits their possible mounting positions to the free height above the cargo. Correspondingly, if a tall vehicle is loaded directly in front of the camera, the field of view will be greatly limited.

Like flame detectors and thermal imaging cameras, regular cameras used for video detection rely on optical technology and will require a free line of sight to the flame or smoke. Moreover, the detection range for the cameras follows the square law between distance and area of detection as long as the distance is high compared to the characteristic length of the object to be detected, such that detection at twice the distance requires nearly four times the area, as illustrated in Figure 16. Moreover, the area is proportional to the fire size in terms of radiant heat output (RHO). Therefore, if a flame detector is able to detect a fire with an RHO of 40 kW at 30 m, detection at 60 m is expected to require a fire with an RHO of 160 kW.

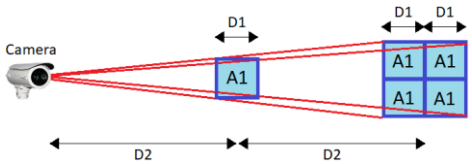

Figure 16: Square law between distance and area of detection (applicable when D2 >> D1): if an object that has an area of A1 is detectable at the distance of D2, detection at a distance of 2 x D2 requires nearly an area of 4 x A1.

15.1.1.1.1 Ro-ro cargo integration description

Integrated example of a video fire detection system for the closed ro-ro spaces on Magnolia Seaways consists of 11 cameras for the main deck and 4 cameras for the tank top as illustrated on Figure 7. The cameras in this example have medium sensitivity settings allowing effective detection range of nearly 40 m at 54° horizontal angle and 40° vertical angle. Total of 930 m of power and signal cables is estimated.

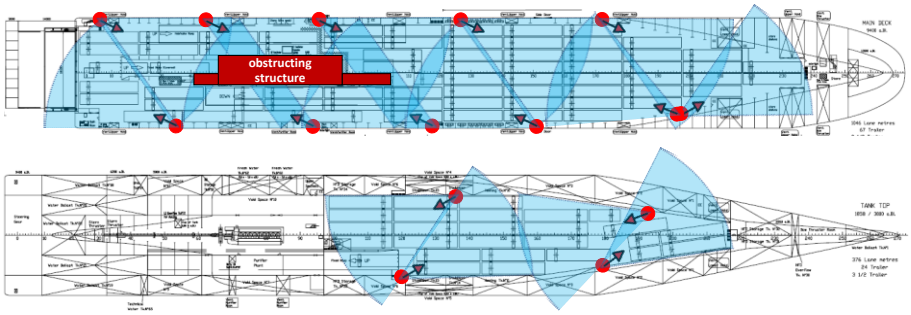

Figure 17: Integrated example of a video fire detection system for the closed ro-ro spaces on Magnolia Seaways.

15.1.1.1.2 Ro-pax integration description

Integrated example of a video fire detection system for the closed ro-ro spaces on Stena Flavia consists of 8 cameras for Deck 3, 3 cameras for deck 2, 3 cameras for deck 1, as illustrated on Figure

18. The cameras in this example have medium sensitivity settings allowing effective detection range of nearly 40 m at 54° horizontal angle and 40° vertical angle. Total of 800 m of power and signal cables is estimated.

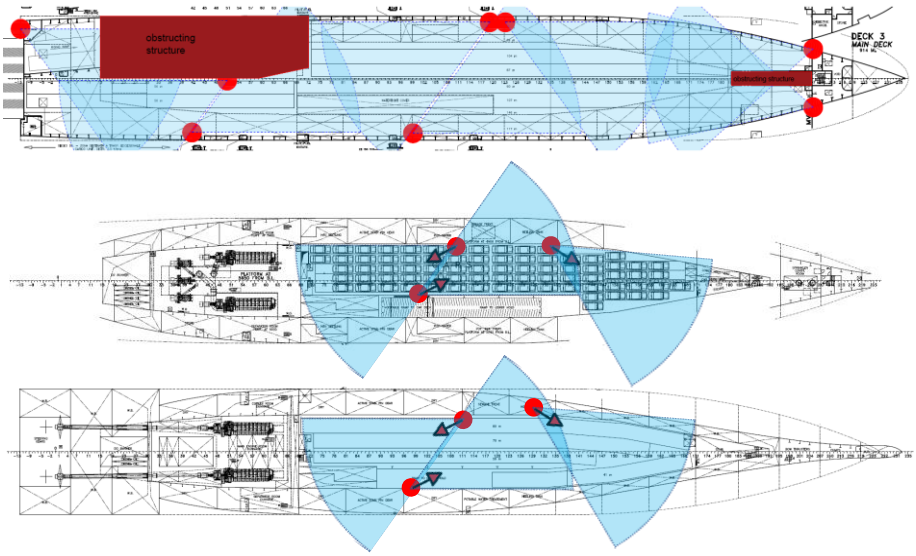

Figure 18: Integrated example of a video fire detection system for the closed ro-ro spaces on Stena Flavia

15.1.1.1.3 Vehicle carrier integration description

Integrated example of a video fire detection system for the closed ro-ro spaces on Torrens consists of 129 cameras: decks 12 to 5 are similar and each require 12 cameras, while deck 4 requires 10 cameras, deck 3 requires 7 cameras, deck 2 requires 7 cameras, and deck 1 requires 5 cameras, as illustrated on Figure 19. The long-range cameras in this example have medium sensitivity settings allowing effective detection range of nearly 40 m at 54° horizontal angle and 40° vertical angle, while the low-range cameras (used in decks 12 to 5) have a wider lens allowing effective detection range of nearly 20 m at 85° horizontal angle and 63° vertical angle. Total of 8800 m of power and signal cables is estimated.

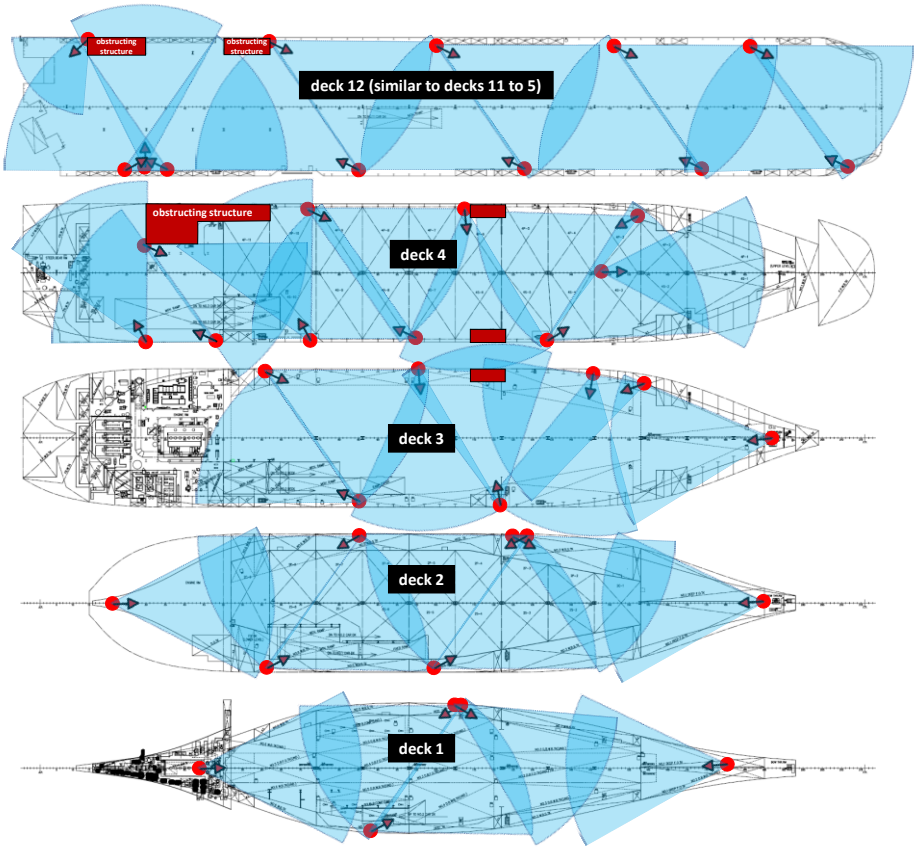

Figure 19: Integrated example of a video fire detection system for the closed ro-ro spaces on Torrens.

15.1.1.2 System#02 – fibreoptic linear heat detection (RCM Det7)

The system of fibreoptic linear heat detection comprises mainly of a fibreoptic cable, while all the electronics and signal processing are done in the central unit, where the laser pulses are generated, transmitted to the fibreoptic cable, and the reflections are analysed and processed for alarm evaluations. This means that the required maintenance of the system can be done centrally. Moreover, in case the fibreoptic cable is damaged, the system can identify the location of the damage. The sensing cable can also be connected as a loop and connected to the central unit at both ends to provide redundancy against one cable breach per loop.

The fibreoptic cable needs to be fixed on the ceiling along the deckhead of the ro-ro space, whereby continuous temperature recordings are made along the cable. As the longitudinal and transversal girders on the deckhead create many compartments along the ceiling, the ideal configuration for fire detection is achieved when the fibreoptic cable goes through all the compartments.

One of the main challenges with the installation of the linear heat detection systems is the regulatory requirement for cable fixings at regular intervals (see Table 138). In addition, when cables are not

laid on top of horizontal cable trays or supports, it is required to add metallic cable clips or saddles at regular distances (e.g. 1 m to 2 m) to retain the cable during a fire. This requirement increases the time and cost of installation for the linear heat detection systems because the cable cannot be in direct contact with any cool/hot surfaces which might interfere with the functioning of the heat sensing cable. An example fixing which allows isolating the heat sensing cable is shown in Figure 20. Hoistable decks may also pose some challenges for the implementation of linear systems, as the wires on the hoistable decks need to partly go along the sides of the ship to be joined with the rest of the decks.

Table 138 Spacing of fixing points for cables not carried in pipes (DNV rules for classification of ships, Part 4, Chapter 8)

External diameter of cables		Non-armoured or unbraided cables [mm]	Armoured or braided cables [mm]
Exceeding [mm]	Not exceeding [mm]		
-	8	200	250
8	13	250	300
13	20	300	350
20	30	350	400
30	-	400	450

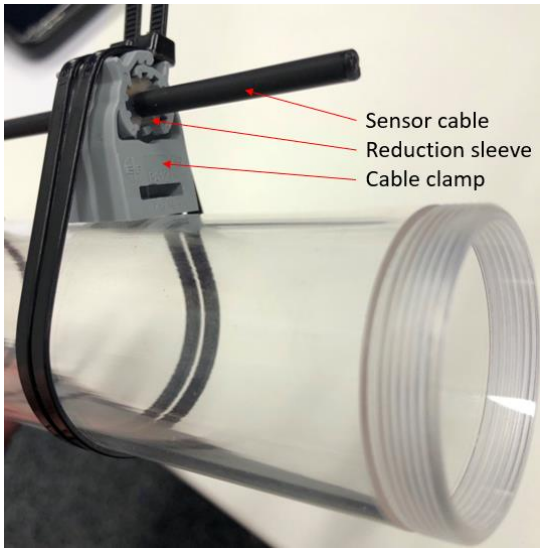

Figure 20: Example fixing of a heat sensing cable on a pipe: the cable is isolated from the pipe using spacers.

15.1.1.2.1 Integration description

Integration of the system on the ro-ro cargo is illustrated in Figure 21. The figure shows an integrated example of the fibreoptic linear heat detection system for the largest open ro-ro space of Magnolia Seaways. For the largest open ro-ro space of Magnolia Seaways which offers 1137 lane meters, the full coverage requires approximately 1672 m of cables, offering a measurement resolution of 2 m with redundancy. Converting this proportional to the lane meters for other decks, it can be estimated

that the entire ship will require 4675 m of cables. Similarly, a total of 2375 m of fibreoptic cables is needed for Stena Flavia (see Figure 22), and 11200 m of fibreoptic cables is needed for Torrens (see Figure 23).

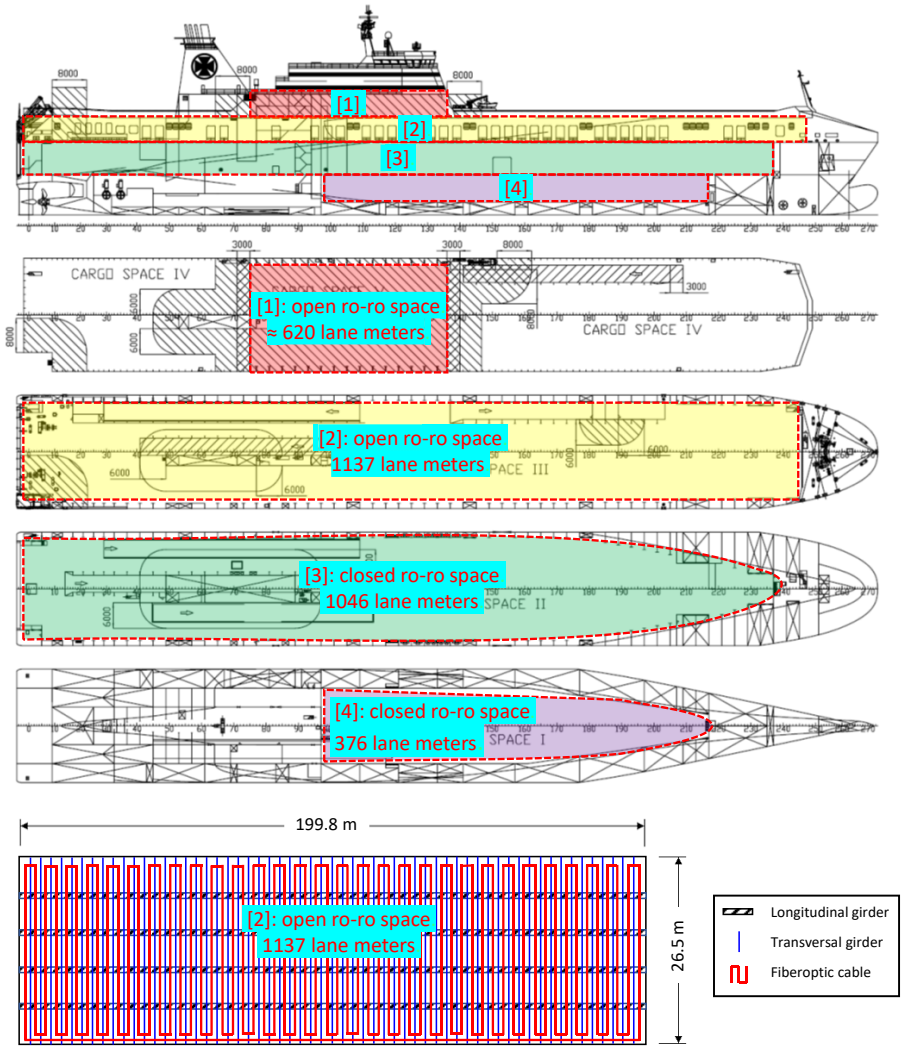

Figure 21: Integrated example of a fibreoptic linear heat detection system for Magnolia Seaways: the different ro-ro spaces are shown above, while the example detection system is shown at the bottom for the largest ro-ro space (requiring approximately 1137 m of fibreoptic cable).

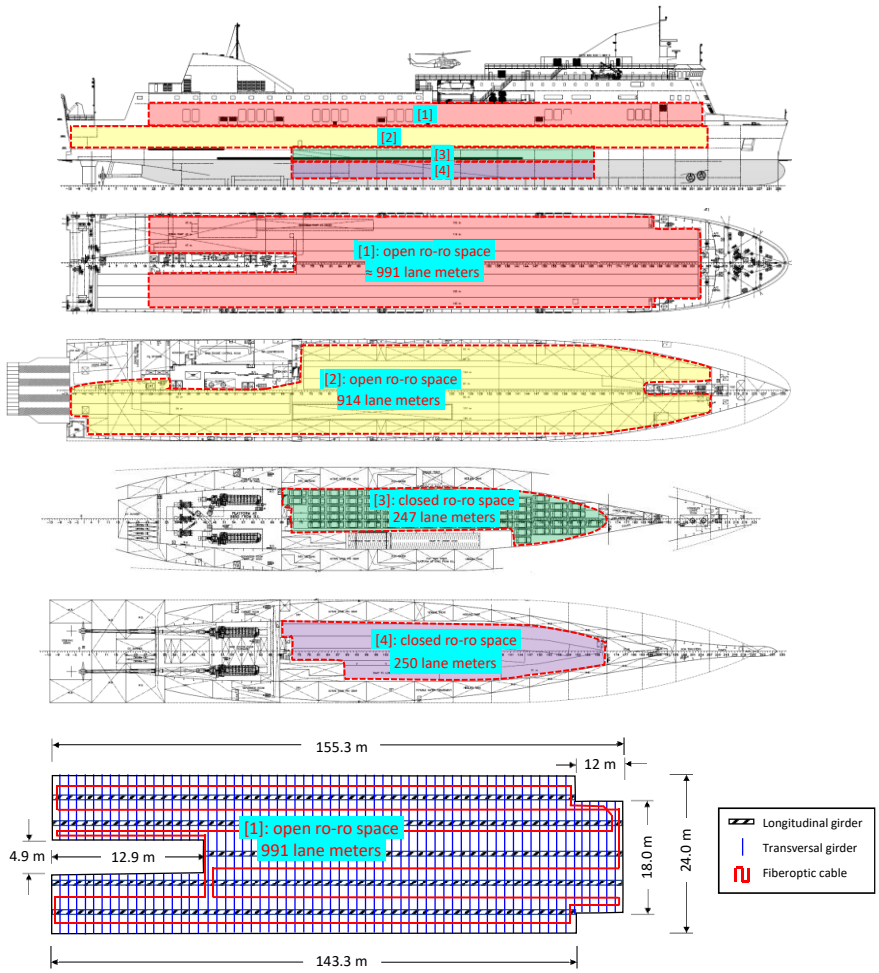

Figure 22: Integrated example of a fiberoptic linear heat detection system for Stena Flavia: the different ro-ro spaces are shown above, while the example detection system is shown at the bottom for the largest ro-ro space (requiring approximately 980 m of fiberoptic cable).

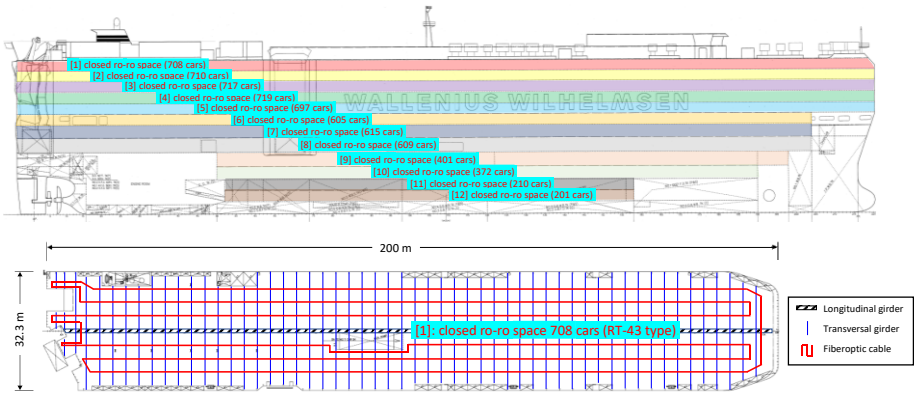

Figure 23: Integrated example of a fiberoptic linear heat detection system for Torrens: the different ro-ro spaces are shown above, while the example detection system is shown at the bottom for the uppermost ro-ro space (requiring approximately 1205 m of fiberoptic cable).

15.1.2 Life cycle cost model

15.1.2.1 Cost items description and assumptions

Independent of the system, ship type, newbuilding or existing ship, the following costs were considered:

- Investment cost,
- inspections, testing, and maintenance, and
- end of life cost.

It was assumed that all system solutions will be serviceable during the entire time if properly maintained.

15.1.2.1.1 Investment cost

15.1.2.1.1.1 System#01 — video fire detection (RCMDet3)

The following items are considered:

- Cameras, junction boxes, mounting brackets, PoE switches, PoE NVR switches, SFP modules, HDD memory, computer workstation for video monitoring and recording, MFS alarm panel,
- the material purchasing cost (cables),
- the labour cost for the engineering, shipyard administration
- the labour cost for the installation work and commissioning:
    - installation of detection system,
- document, certification, and other administration costs. considered for existing ships only, where for new buildings no additional cost was assumed, and
- operator training.

15.1.2.1.1.2 System#02 – fibreoptic linear heat detection (RCM Det7)

The following items are considered:

- Cable with sensors and field wiring,
- cable fixing,
- the labour cost for the engineering, shipyard administration,
- the labour cost for the installation work and commissioning,
    - installation of detection system,
- document, certification, and other administration costs. Considered for existing ships only, where for new buildings no additional cost was assumed,
- operator training.

15.1.2.1.1.3 Investment cost assessment assumptions

The purchasing costs for each component were estimated based on figures from system component suppliers. The estimated cost provided for the production, installation, and commissioning was based on a Croatian shipyards standard where the average cost per weight or length was estimated. A cabling installation cost of 25 EUR/m was assumed for newbuilding and 30 EUR/m for existing ship.

It is to be noted that significant cost differences may occur depending on the business area i.e. shipyard location. However, the cost estimates can easily be adjusted to a specific business area.

15.1.2.1.2 Cost for inspections, testing, and maintenance

For each cost component, the average was considered based on figures from the suppliers.

15.1.2.1.3 End of life cost

The recycling and resale of the system may be doable but the suppliers themselves recognize no residual value for the system after the ship's lifetime. Therefore, no end-of-life cost was considered.

15.1.2.2 Life cycle cost component for ro-ro cargo newbuilding

15.1.2.2.1 Investment cost

The estimated cost for the installation of the two system solutions, respectively, on a ro-ro cargo new building is summarized in

Table 139.

Table 139 Action 9B- The estimated cost for the installation of the two system solutions, respectively, on a ro-ro cargo new building

System Number		System#01	System#02
System Name		Det3: Video fire dete	Det7: Fibreoptic line
Investment cost			
Purchasing cost	EUR	114 840.00	103 194.00
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	5 000.00	20 000.00
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	29 250.00	150 250.00
Comissioning cost	EUR	500.00	10 000.00
Document, certification and other administration costs	EUR	-	-
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	500.00	5 000.00
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	150 090.00	288 444.00

15.1.2.2.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and energy consumption is negligible and therefore not considered.

15.1.2.2.3 Maintenance cost

The estimated cost for the two system solutions on a ro-ro cargo new building is summarized in Table 140.

Table 140. Action 9B- The estimated cost for the inspection, testing, and maintenance of the two system solutions for a ro-ro cargo newbuilding

System Number		System#01	System#02
System Name		Det3: Video fire dete	Det7: Fibreoptic line
Maintenance cost			
Annual maintenance			
Annual system maintenance cost	EUR/year	3 000.00	8 600.00
Loss due to vessel downtime during maintenance	EUR/year	-	-
Other annual maintenance cost	EUR/year	-	-
		-	-
Total annual maintenance cost	EUR/year	3 000.00	8 600.00

15.1.3 End of life cost

No end-of-life cost was considered.

15.1.3.1 Life cycle cost component for ro-ro cargo existing ship

15.1.3.1.1 Investment cost

The estimated cost for the installation of the two system solutions on a ro-ro cargo existing ship are summarized in Table 141.

Table 141 Action 9B- The estimated cost for the installation of the two system solutions on a ro-ro cargo existing ship

System Number		System#01	System#02
System Name		Det3: Video fire dete	Det7: Fibreoptic line
Investment cost			
Purchasing cost	EUR	114 840.00	103 194.00
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	8 000.00	35 000.00
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	33 900.00	199 000.00
Comissioning cost	EUR	1 000.00	15 000.00
Document, certification and other administration costs	EUR	8 000.00	15 000.00
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	500.00	5 000.00
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	166 240.00	372 194.00

15.1.3.1.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and the energy consumption is negligible and therefore not considered.

15.1.3.1.3 Maintenance cost

It was assumed that the maintenance cost is similar to a newbuilding, refer to the cost figures listed in Table 140.

15.1.3.1.4 End of life cost

No end-of-life cost was considered applicable.

15.1.3.2 Life cycle cost component for ro-pax newbuilding

15.1.3.2.1 Investment cost

The estimated cost for the installation of the two system solutions, respectively, on a ro-pax new building is summarized in

Table 142.

Table 142 Action 9B- The estimated cost for the installation of the two system solutions, respectively, on a ro-pax new building

System Number		System#01	System#02
System Name		Det3: Video fire dete	Det7: Fibreoptic line
Investment cost			
Purchasing cost	EUR	107 547.00	95 719.00
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	5 000.00	20 000.00
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	26 000.00	78 750.00
Comissioning cost	EUR	500.00	10 000.00
Document, certification and other administration costs	EUR	-	-
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	500.00	5 000.00
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	139 547.00	209 469.00

15.1.3.2.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and energy consumption is negligible and therefore not considered.

15.1.3.2.3 Maintenance cost

The estimated cost for the two system solutions on a ro-ro cargo new building is summarized in Table 143.

Table 143. Action 9B- The estimated cost for the inspection, testing and maintenance of the two system solutions for a ro-pax newbuilding

System Number		System#01	System#02
System Name		Det3: Video fire dete	Det7: Fibreoptic line
Maintenance cost			
Annual maintenance			
Annual system maintenance cost	EUR/year	3 000.00	8 600.00
Loss due to vessel downtime during maintenance	EUR/year	-	-
Other annual maintenance cost	EUR/year	-	-
		-	-
Total annual maintenance cost	EUR/year	3 000.00	8 600.00

15.1.3.2.4 End of life cost

No end-of-life is cost considered.

15.1.3.3 Life cycle cost component for ro-pax existing ship

15.1.3.3.1 Investment cost

The estimated cost for the installation of the two system solutions, respectively, on a ro-pax existing ship is summarized in Table 144.

Table 144 Action 9B- The estimated cost for the installation of the two system solutions, respectively, on a ro-pax existing ship

System Number		System#01	System#02
System Name		Det3: Video fire dete	Det7: Fibreoptic line
Investment cost			
Purchasing cost	EUR	107 547.00	95 719.00
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	8 000.00	35 000.00
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	30 000.00	104 000.00
Comissioning cost	EUR	1 000.00	15 000.00
Document, certification and other administration costs	EUR	8 000.00	15 000.00
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	500.00	5 000.00
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	155 047.00	269 719.00

15.1.3.3.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and energy consumption is negligible and therefore not considered.

15.1.3.3.3 Maintenance cost

It was assumed that the maintenance cost is similar to a newbuilding, refer to the cost figures listed in Table 6.

15.1.3.3.4 End of life cost

No end-of-life is cost considered applicable.

15.1.3.4 Life cycle cost component for vehicle carrier newbuilding

15.1.3.4.1 Investment cost

The estimated cost for the installation of the two system solutions on a vehicle carrier newbuilding are summarized in

Table 145.

Table 145 Action 9B- The estimated cost for the installation of the two system solutions on a vehicle carrier newbuilding

System Number		System#01	System#02
System Name		Det3: Video fire dete	Det7: Fibreoptic line
Investment cost			
Purchasing cost	EUR	951 762.00	168 400.00
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	10 000.00	35 000.00
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	260 000.00	361 000.00
Comissioning cost	EUR	5 000.00	20 000.00
Document, certification and other administration costs	EUR	-	-
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	500.00	5 000.00
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	1 227 262.00	589 400.00

15.1.3.4.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and the energy consumption is negligible and therefore not considered.

15.1.3.4.3 Maintenance cost

The estimated cost for the two system solutions on a vehicle carrier new building is summarized in Table 146.

Table 146. Action 9B- The estimated cost for the inspection, testing, and maintenance of the two system solutions for a vehicle carrier newbuilding

System Number		System#01	System#02
System Name		Det3: Video fire dete	Det7: Fibreoptic line
Maintenance cost			
Annual maintenance			
Annual system maintenance cost	EUR/year	6 000.00	12 900.00
Loss due to vessel downtime during maintenance	EUR/year	-	-
Other annual maintenance cost	EUR/year	-	-
		-	-
Total annual maintenance cost	EUR/year	6 000.00	12 900.00

15.1.3.4.4 End of life cost

No end-of-life is cost considered.

15.1.3.5 Life cycle cost component for vehicle carrier existing ship

15.1.3.5.1 Investment cost

The estimated cost for the installation of the two system solutions on a vehicle carrier existing ship are summarized in Table 147.

Table 147 Action 9B- The estimated cost for the installation of the two system solutions on a vehicle carrier existing ship

System Number		System#01	System#02
System Name		Det3: Video fire dete	Det7: Fibreoptic line
Investment cost			
Purchasing cost	EUR	951 762.00	168 400.00
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	16 000.00	55 000.00
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	304 000.00	478 000.00
Comissioning cost	EUR	5 000.00	30 000.00
Document, certification and other administration costs	EUR	8 000.00	15 000.00
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	500.00	5 000.00
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	1 285 262.00	751 400.00

15.1.3.5.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and the energy consumption is negligible and therefore not considered.

15.1.3.5.3 Maintenance cost

It was assumed that the maintenance cost is similar to a newbuilding, refer to the cost figures listed in Table 146.

15.1.3.5.4 End of life cost

No end-of-life cost was considered applicable.

15.1.4 LCC Result

The LCC results for a ro-ro cargo new building is shown in Table 148.

Table 148. Action 9B- The LCC results for a ro-ro cargo new building

System Number		System#01	System#02
System Name		)et3: Video fire detectio	Fibreoptic linear heat dete
Unit		**Per Ship**	
Total Investment cost	EUR	150 090.00 €	288 444.00 €
Total Operation cost	EUR	- €	- €
Total Maintenance cost	EUR	67 966.58 €	194 837.54 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	218 056.58 €	483 281.54 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	39.18 €	75.29 €
Total Operation cost	EUR	- €	- €
Total Maintenance cost	EUR	17.74 €	50.86 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	56.92 €	126.15 €

The LCC results for a ro-ro cargo existing ship is shown in Table 149.

Table 149. Action 9B- The LCC results for a ro-ro cargo existing ship

System Number		System#01	System#02
System Name		)et3: Video fire detectio	Fibreoptic linear heat dete
Unit		**Per Ship**	
Total Investment cost	EUR	166 240.00 €	372 194.00 €
Total Operation cost	EUR	- €	- €
Total Maintenance cost	EUR	48 501.37 €	139 037.27 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	214 741.37 €	511 231.27 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	43.39 €	97.15 €
Total Operation cost	EUR	- €	- €
Total Maintenance cost	EUR	12.66 €	36.29 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	56.05 €	133.45 €

The LCC results for a ro-pax new building is shown in Table 150.

Table 150. Action 9B- The LCC results for a ro-pax new building.

System Number		System#01	System#02
System Name		)et3: Video fire detectio	Fibreoptic linear heat dete
Unit		**Per Ship**	
Total Investment cost	EUR	139 547.00 €	209 469.00 €
Total Operation cost	EUR	- €	- €
Total Maintenance cost	EUR	70 646.01 €	202 518.58 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	210 193.01 €	411 987.58 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	63.43 €	95.21 €
Total Operation cost	EUR	- €	- €
Total Maintenance cost	EUR	32.11 €	92.05 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	95.54 €	187.27 €

The LCC results for a ro-pax existing ship is shown in Table 151.

Table 151. Action 9B- The LCC results for a ro-pax existing ship

System Number		System#01	System#02
System Name		)et3: Video fire detectio	Fibreoptic linear heat dete
Unit		**Per Ship**	
Total Investment cost	EUR	155 047.00 €	269 719.00 €
Total Operation cost	EUR	- €	- €
Total Maintenance cost	EUR	48 501.37 €	139 037.27 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	203 548.37 €	408 756.27 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	70.48 €	122.60 €
Total Operation cost	EUR	- €	- €
Total Maintenance cost	EUR	22.05 €	63.20 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	92.52 €	185.80 €

The LCC results for a vehicle carrier new building is shown in Table 152.

Table 152. Action 9B- The LCC results for a vehicle carrier new building

System Number		System#01	System#02
System Name		)et3: Video fire detectio	Fibreoptic linear heat dete
Unit		**Per Ship**	
Total Investment cost	EUR	1 227 262.00 €	589 400.00 €
Total Operation cost	EUR	- €	- €
Total Maintenance cost	EUR	112 002.11 €	240 804.54 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	1 339 264.11 €	830 204.54 €
Unit		**Per CEU**	
Total Investment cost	EUR	193.27 €	92.82 €
Total Operation cost	EUR	- €	- €
Total Maintenance cost	EUR	17.64 €	37.92 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	210.91 €	130.74 €

The LCC results for a vehicle carrier existing ship is shown in Table 153.

Table 153. Action 9B- The LCC results for a vehicle carrier existing ship

System Number		System#01	System#02
System Name		)et3: Video fire detectio	Fibreoptic linear heat dete
Unit		**Per Ship**	
Total Investment cost	EUR	1 285 262.00 €	751 400.00 €
Total Operation cost	EUR	- €	- €
Total Maintenance cost	EUR	78 564.70 €	168 914.11 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	1 363 826.70 €	920 314.11 €
Unit		**Per CEU**	
Total Investment cost	EUR	202.40 €	118.33 €
Total Operation cost	EUR	- €	- €
Total Maintenance cost	EUR	12.37 €	26.60 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	214.78 €	144.93 €

Results summary is shown in Table 154.

Table 154. Action 9B - Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Det3	Video fire detection	Investment	139 547.00 €	155 047.00 €	150 090.00 €	166 240.00 €	1 227 262.00 €	1 285 262.00 €
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		Maintance	70 646.01 €	48 501.37 €	67 966.58 €	48 501.37 €	112 002.11 €	78 564.70 €
		TOTAL	**210 193.01 €**	**203 548.37 €**	**218 056.58 €**	**214 741.37 €**	**1 339 264.11 €**	**1 363 826.70 €**
Det4	Adaptive threshold settings for detection	Investment	N/A	N/A	N/A	N/A	N/A	N/A
		Operation	N/A	N/A	N/A	N/A	N/A	N/A
		Maintance	N/A	N/A	N/A	N/A	N/A	N/A
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Det7	Fibre optic linear heat detection	Investment	209 469.00 €	269 719.00 €	288 444.00 €	372 194.00 €	589 400.00 €	751 400.00 €
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		Maintance	202 518.58 €	139 037.27 €	194 837.54 €	139 037.27 €	240 804.54 €	168 914.11 €
		TOTAL	**411 987.58 €**	**408 756.27 €**	**483 281.54 €**	**511 231.27 €**	**830 204.54 €**	**920 314.11 €**
RCO11	Fire detection in closed ro-ro spaces & open ro-ro spaces	Investment	209 469.00 €	269 719.00 €	288 444.00 €	372 194.00 €	589 400.00 €	751 400.00 €
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		Maintance	202 518.58 €	139 037.27 €	194 837.54 €	139 037.27 €	240 804.54 €	168 914.11 €
		TOTAL	**411 987.58 €**	**408 756.27 €**	**483 281.54 €**	**511 231.27 €**	**830 204.54 €**	**920 314.11 €**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed

15.2 Conclusion

An Life cycle cost assessment for two detection system RCM's and one selected RCO for open and close ro-ro spaces, proposed by Action 9-B was performed. Further, the assessment was performed for three ship types, the selected generic ro-ro cargo, ro-pax and vehicle carrier that were used for integration and LCC assessment.

In case of ro-ro cargo ships, the results shows that System#2 (RCM Det7, RCO11) the fibreoptics linear heat detection system is much more expensive than System#1 (RCM Det3), video fire detection system, mainly due to assembly/installation costs. Regarding ro-pax vessels, the results are very similar, showing that the cost of system#02 is almost double that of system#01, both for new buildings and existing ships. As opposed to LCC for forementioned ships, the costs for vehicle carriers shows that system #01 is much more expensive than fibreoptics solution, predominantly due to the equipment purchasing cost, both for existing and new build ship.

It needs to be emphasized that the installation cost is dependent on the ro-ro space arrangement. Specifically, obstructions arrangements such as engine casing, staircases as well as deck area size and shape, have an impact on the number of detection units to be installed, which represent the majority of the installation and maintenance cost.

Finally, for system #1 it is difficult to scale the cost per ship type, lane meters, or deck area, where the cost shall be calculated on a case-by-case basis. Further, the cost for System#2 (RCM Det7, RCO11) may be scaled per deck area with an acceptable accuracy.

Further, significant cost differences may occur depending on the business area, i.e., shipyard location, particularly the installation cost. However, the cost estimates can easily be adjusted to a specific business area.

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

Main author of the chapter: Vito Radolovic, FLOW

This chapter presents an overview of the life cycle cost assessment for the solutions proposed by Action 9-C i.e. Means for automatic fire confirmation, localization and assessment. Two RCMs were proposed by WP09 and one RCO selected (Ref. D04.6 "Cost-effectiveness assessment report" [2]) and assessed within this report:

- RCM Det5 - Video fire detection
- RCM Det6 - Thermal imaging (infrared) cameras
- RCO12 - Visual system for fire confirmation and localization

For the description of the RCM's please refer to Deliverable D04.9 "Preliminary impact of solutions and related testing and demonstrations plan" [1], for the description of the RCO please refer to Deliverable D04.6, [2].

16.1 Life cycle cost assessment

An installation cost assessment for two different system solutions was made:

- **System#01** – Video fire detection (Det5)
- **System#02** – Thermal imaging (infrared) cameras (Det6)
- **System#03** – Visual system for fire confirmation and localization (RCO12)

The cost assessment was made for reference ships selected by the project, Magnolia Seaways the generic ro-ro cargo ship operated by DFDS Seaways, Stena Flavia, the generic ro-pax ship and Torrens, the generic vehicle carrier. The cost assessment was made for both newbuilding and existing ships.

16.1.1 Description of the developed solution

Main author of the chapter: Davood Zeinali, FRN

16.1.1.1 System#01 – video fire detection (RCM Det5)

The video fire detection system (RCM Det5) considered at Action 9-C is similar as the video fire detection system (RCM Det3) considered at Action 9-B. Further, the only difference includes operational training through fire drills. Thus, for the system description as well as integration definition on generic ships (ro-ro cargo, ro-pax, vehicle carrier) please refer to Chapter 15.

16.1.1.2 System#02 – thermal imaging (infrared) cameras (RCM Det6)

The thermal imaging (infrared) cameras detection system (RCM Det6) considered at Action 9-C is similar as the thermal imaging (infrared) cameras system (RCM Det8) considered at Action 9-A. Further, the only difference includes operational training through fire drills. Thus, for the system description as well as integration definition on generic ships (ro-ro cargo, ro-pax) please refer to Chapter 14.

16.1.1.3 System#03 – Visual system for fire confirmation and localization (RCO12)

The visual system for fire confirmation and localization (RCO12) considered is a combination of the two RCMs; the RCM Det5 and RCM Det6 according to the ro-ro space type. For the closed ro-ro spaces and average integration cost of RCM Det5 and RCM det6 was considered. Further, for the Weather deck and open ro-ro space integration cost of RCM Det6 was considered.

16.1.1.3.1 Ro-ro cargo integration description

Integrated example of the thermal imaging cameras (RCM Det6) for the Weather decks on Magnolia Seaways is described in Chapter 14.1.1.2. Integrated example of a video fire detection system (RCM Det5) for the closed ro-ro spaces on Magnolia Seaways is described in Chapter 15.1.1.1. Integrated example of the thermal imaging cameras (RCM Det6) for the closed ro-ro spaces and open ro-ro spaces on Magnolia Seaways consists of 2 cameras on the tank top, 4 cameras for the main deck and 4 cameras for Upper deck and 2 camera below the superstructure on the weather deck. Different cameras and sensitivity settings are used with effective detection ranges as follows: 100 m at 25° horizontal angle and 20° vertical angle, as well as 45 m at 53° horizontal angle and 40° vertical angle. Total of 400 m of power and signal cables is estimated for RCM Det 6 integration in closed ro-ro spaces and 360 m in open ro-ro spaces.

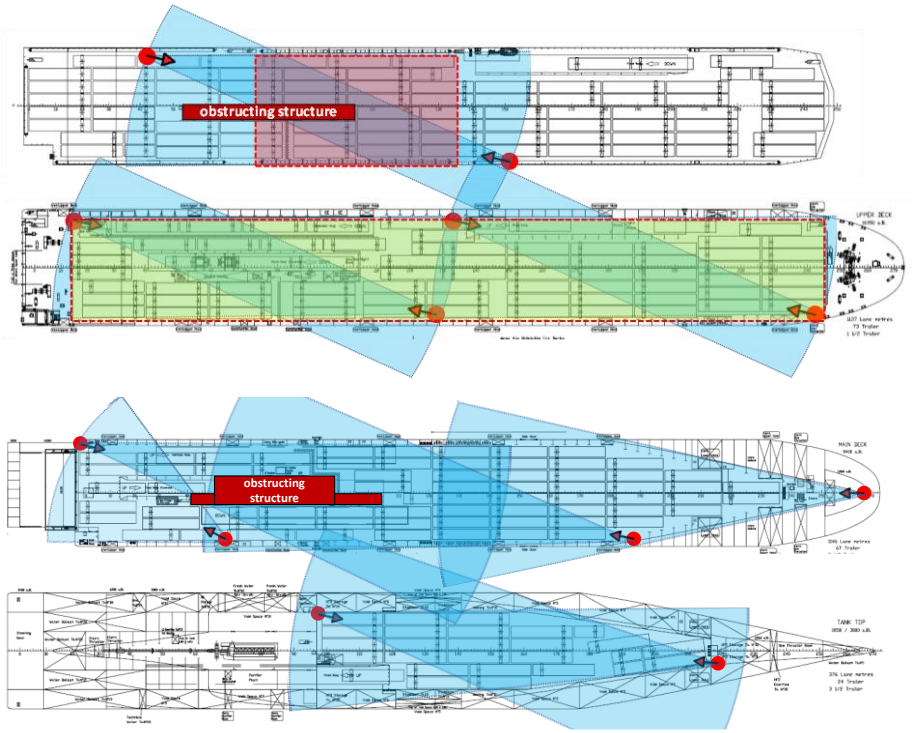

Figure 24: Integrated example of a Thermal imaging camera detection system for open and close ro-ro spaces on Magnolia Seaways

16.1.1.3.2 Ro-pax integration description

Integrated example of the thermal imaging cameras (RCM Det6) for the Weather decks on Stena Flavia is described in Chapter 14.1.1.2. Integrated example of a video fire detection system (RCM Det5) for the closed ro-ro spaces on Stena Flavia is described in Chapter 15.1.1.1. Integrated example of the thermal imaging cameras (RCM Det6) for the closed ro-ro spaces and open ro-ro spaces on Stena Flavia consists of 1 camera for the tank top, 1 camera for Deck 2, 3 cameras for the main deck and 3 cameras for Deck4. Different cameras and sensitivity settings are used with effective detection ranges as follows: 100 m at 25° horizontal angle and 20° vertical angle, as well as 45 m at

53° horizontal angle and 40° vertical angle. Total of 400 m of power and signal cables is estimated for RCM Det 6 integration in closed ro-ro spaces and 150 m in open ro-ro spaces.

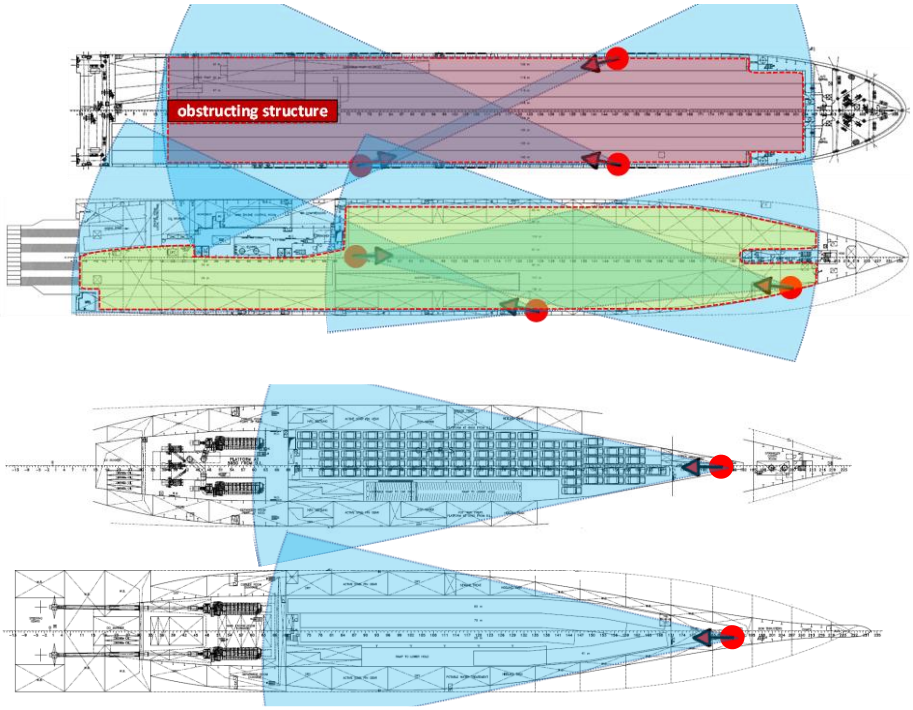

Figure 25: Integrated example of a Thermal imaging camera detection system for open and close ro-ro spaces on Stena Flavia

16.1.1.3.3 Vehicle carrier integration description

Integrated example of the thermal imaging cameras (RCM Det6) for the closed ro-ro spaces on Torrens consists of 52 cameras. Decks 5 to 12 are similar, and each require 5 cameras, while deck 4 requires 4 cameras, deck 3 requires 3 cameras, deck 2 requires 3 cameras, and deck 1 requires 2 cameras. The long-range cameras in this example have medium sensitivity settings allowing effective detection range of nearly 100 m at 25° horizontal angle and 20° vertical angle, while the low-range cameras used in decks 12 to 5 have a wider lens allowing effective detection range of nearly 30 m at 80° horizontal angle and 56° vertical angle, and those on deck 4, 2, and 1 have an effective detection range of nearly 45 m at 53° horizontal angle and 40° vertical angle. Total of 3400 m of power and signal cables is estimated for RCM Det 6 integration on all decks.

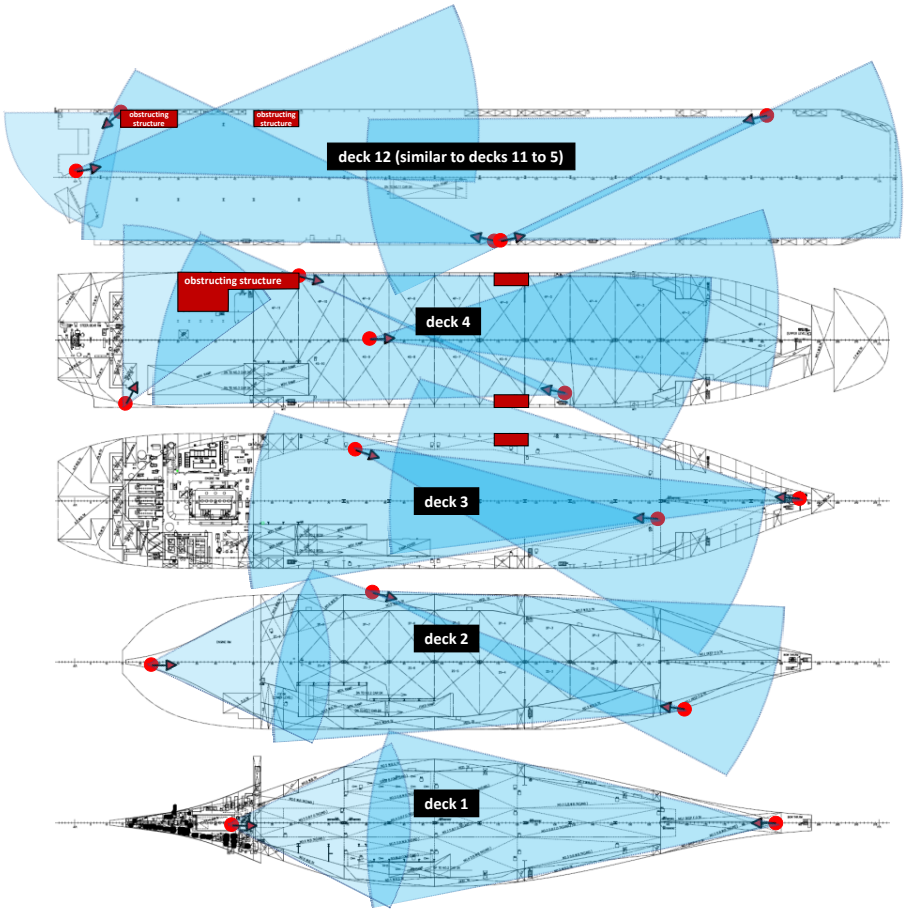

Figure 26: Integrated example of a Thermal imaging camera detection system for the closed ro-ro spaces on Torrens

16.1.2 Life cycle cost model

16.1.2.1 Cost items description and assumptions

Independent of the system, ship type, newbuilding or existing ship, the following costs were considered:

- Investment cost,
- inspections, testing, and maintenance,
- operational cost, and
- end of life cost.

It was assumed that all system solutions will be serviceable during the entire time if properly maintained.

16.1.2.1.1 Investment cost

16.1.2.1.1.1 System#01 – video fire detection (RCM Det5)

It was assumed that the investment cost is similar to the cost of RCM Det3 (refer to the cost figures listed within internal Chapter 15).

16.1.2.1.1.2 System#02 – thermal imaging (infrared) cameras (RCM Det6)

It was assumed that the investment cost is similar to the cost of RCM Det8 (refer to the cost figures listed within Chapter 14).

16.1.2.1.1.3 System#03– Visual system for fire confirmation and localization (RCO12)

It was assumed that the investment cost is similar to the cost of RCM Det3 for the Video fire detection system (refer to the cost figures listed within internal Chapter 15) and is similar to the cost of RCM Det8 for the thermal imaging camera detection system (refer to the cost figures listed within Chapter 14).

16.1.2.1.2 Cost for inspections, testing, and maintenance

For each cost component, the average was considered based on figures from the suppliers.

16.1.2.1.3 End of life cost

The recycling and resale of the system may be doable but the suppliers themselves recognize no residual value for the system after the ship's lifetime. Therefore, no end-of-life cost was considered.

16.1.2.2 Life cycle cost component

Life cycle cost component for the considered ship types as well as new buildings and existing ships is summarized in this section.

16.1.2.2.1 Investment cost

It was assumed that the investment cost for System#1 is similar to the cost of solution Det3 (refer to the cost figures listed within Chapter 15).

It was assumed that the investment cost for System#2 is similar to the cost of solution Det8 (refer to the cost figures listed within internal within Chapter 14).

The estimated cost for the installation of the System#3(RCO12) on a ro-pax new building is summarized in

Table 155.

Table 155 Action 9C- The estimated cost for the installation of the system#3 (RCO12) on a ro-pax newbuilding

System Number		System#03
System Name		RCO12
Investment cost		
Purchasing cost	EUR	134 627.00
Insurance cost	EUR	-
Integration design & validation cost	EUR	11 000.00
Disassemble and modify the old system or structure	EUR	-
Road transporter cost	EUR	-
Ship transporter cost	EUR	-
Assembly/Installation cost	EUR	37 250.00
Comissioning cost	EUR	1 500.00
Document, certification and other administration costs	EUR	-
Loss of hire costs	EUR	-
Operator traning cost	EUR	500.00
Other cost	EUR	-
		-
		-
		-
		-
		-
		-
Total cost	EUR	184 877.00

The estimated cost for the installation of the System#3(RCO12) on a ro-pax existing ship is summarized in Table 156.

Table 156 Action 9C- The estimated cost for the installation of the system#3 (RCO12) on a ro-pax existing ship

System Number		System#03
System Name		RCO12
Investment cost		
Purchasing cost	EUR	134 627.00
Insurance cost	EUR	-
Integration design & validation cost	EUR	18 000.00
Disassemble and modify the old system or structure	EUR	-
Road transporter cost	EUR	-
Ship transporter cost	EUR	-
Assembly/Installation cost	EUR	42 100.00
Comissioning cost	EUR	3 000.00
Document, certification and other administration costs	EUR	22 000.00
Loss of hire costs	EUR	-
Operator traning cost	EUR	500.00
Other cost	EUR	-
		-
		-
		-
		-
		-
		-
Total cost	EUR	220 227.00

The estimated cost for the installation of the System#3(RCO12) on a ro-ro cargo new building is summarized in Table 157.

Table 157 Action 9C- The estimated cost for the installation of the system#3 (RCO12) on a ro-ro cargo newbuilding

System Number		System#03
System Name		RCO12
Investment cost		
Purchasing cost	EUR	194 389.00
Insurance cost	EUR	-
Integration design & validation cost	EUR	13 000.00
Disassemble and modify the old system or structure	EUR	-
Road transporter cost	EUR	-
Ship transporter cost	EUR	-
Assembly/Installation cost	EUR	56 375.00
Comissioning cost	EUR	1 500.00
Document, certification and other administration costs	EUR	-
Loss of hire costs	EUR	-
Operator traning cost	EUR	500.00
Other cost	EUR	-
		-
		-
		-
		-
		-
		-
Total cost	EUR	265 764.00

The estimated cost for the installation of the System#3(RCO12) on a ro-ro cargo existing ship is summarized in Table 158.

Table 158 Action 9C- The estimated cost for the installation of the system#3 (RCO12) on a ro-ro cargo existing ship

System Number		System#03
System Name		RCO12
Investment cost		
Purchasing cost	EUR	194 389.00
Insurance cost	EUR	-
Integration design & validation cost	EUR	21 000.00
Disassemble and modify the old system or structure	EUR	-
Road transporter cost	EUR	-
Ship transporter cost	EUR	-
Assembly/Installation cost	EUR	63 650.00
Comissioning cost	EUR	3 000.00
Document, certification and other administration costs	EUR	22 000.00
Loss of hire costs	EUR	-
Operator traning cost	EUR	500.00
Other cost	EUR	-
		-
		-
		-
		-
		-
		-
Total cost	EUR	304 539.00

The estimated cost for the installation of the System#3(RCO12) on a vehicle carrier new building is summarized in Table 159.

Table 159 Action 9C- The estimated cost for the installation of the system#3 (RCO12) on a vehicle carrier newbuilding

System Number		System#03
System Name		RCO12
Investment cost		
Purchasing cost	EUR	737 039.00
Insurance cost	EUR	-
Integration design & validation cost	EUR	10 000.00
Disassemble and modify the old system or structure	EUR	-
Road transporter cost	EUR	-
Ship transporter cost	EUR	-
Assembly/Installation cost	EUR	182 500.00
Comissioning cost	EUR	5 000.00
Document, certification and other administration costs	EUR	-
Loss of hire costs	EUR	-
Operator traning cost	EUR	500.00
Other cost	EUR	-
		-
		-
		-
		-
		-
		-
Total cost	EUR	935 039.00

The estimated cost for the installation of the System#3(RCO12) on a vehicle carrier existing ship is summarized in Table 160.

Table 160 Action 9C- The estimated cost for the installation of the system#3 (RCO12) on a vehicle carrier existing ship

System Number		System#03
System Name		RCO12
Investment cost		
Purchasing cost	EUR	737 039.00
Insurance cost	EUR	-
Integration design & validation cost	EUR	16 000.00
Disassemble and modify the old system or structure	EUR	-
Road transporter cost	EUR	-
Ship transporter cost	EUR	-
Assembly/Installation cost	EUR	213 000.00
Comissioning cost	EUR	5 000.00
Document, certification and other administration costs	EUR	10 000.00
Loss of hire costs	EUR	-
Operator traning cost	EUR	500.00
Other cost	EUR	-
		-
		-
		-
		-
		-
		-
Total cost	EUR	981 539.00

16.1.2.2.2 Operation cost

The following items are considered:

- Additional crew training through fire drills

Influence on the operational cost by adding additional weight of the added system and steel weight was considered negligible and therefore not considered.

The estimated operation cost for the system solutions is summarized in Table 161.

Table 161 Action 9C- The estimated operation cost for the system solutions on ro-ro cargo, ro-pax and vehicle carrier new building and existing ships

System Number		System#01	System#02	System#03
System Name		Det5: Video fire dete	Det6: IR heat camera	RCO12
Operation cost				
Additional Energy consumption	kWh/year	-	-	-
Additional Fuel Consumption	t/year	-	-	-
Reduce Fuel Consumption	t/year	-	-	-
Operator cost	EUR/year	1 000.00	1 000.00	1 000.00
Insurance, taxes, and other fees cost	EUR/year	-	-	-
Loss of cargo/loss revenue	EUR/year	-	-	-
Additional of cargo/profit revenue	EUR/year	-	-	-
Other operation cost	EUR/year	-	-	-

16.1.2.2.3 Maintenance cost

It was assumed that the maintenance cost for System#1 is similar the cost at solution Det3, refer to the cost figures listed within Chapter 15.

It was assumed that the maintenance cost for System#2 is similar the cost at solution Det8, refer to the cost figures listed within Chapter 14.

It was assumed that the maintenance cost for System#2 is similar to the cost of RCM Det3 for the Video fire detection system (refer to the cost figures listed within internal Chapter 15) and is similar to the cost of RCM Det8 for the thermal imaging camera detection system (refer to the cost figures listed within Chapter 14).

16.1.2.2.4 End of life cost

No end-of-life cost was considered applicable.

16.1.3 LCC Result

The LCC results for a ro-ro cargo new building is shown in Table 162.

Table 162. Action 9C- The LCC results for a ro-ro cargo new building

System Number		System#01	System#02	System#03
System Name		Det5: Video fire detectio	Det6: IR heat cameras	RCO12
Unit		**Per Ship**		
Total Investment cost	EUR	150 090.00 €	73 848.00 €	265 764.00 €
Total Operation cost	EUR	22 655.53 €	22 655.53 €	22 655.53 €
Total Maintenance cost	EUR	67 966.58 €	113 277.64 €	271 866.33 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	240 712.11 €	209 781.17 €	560 285.86 €
Unit		**Per Lane meter**		
Total Investment cost	EUR	39.18 €	19.28 €	69.37 €
Total Operation cost	EUR	5.91 €	5.91 €	5.91 €
Total Maintenance cost	EUR	17.74 €	29.57 €	70.96 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	62.83 €	54.76 €	146.25 €

The LCC results for a ro-ro cargo existing ship is shown in Table 163.

Table 163. Action 9C- The LCC results for a ro-ro cargo existing ship

System Number		System#01	System#02	System#03
System Name		Det5: Video fire detectio	Det6: IR heat cameras	RCO12
Unit		**Per Ship**		
Total Investment cost	EUR	166 240.00 €	91 498.00 €	304 539.00 €
Total Operation cost	EUR	16 167.12 €	16 167.12 €	16 167.12 €
Total Maintenance cost	EUR	48 501.37 €	80 835.62 €	194 005.50 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	230 908.50 €	188 500.75 €	514 711.62 €
Unit		**Per Lane meter**		
Total Investment cost	EUR	43.39 €	23.88 €	79.49 €
Total Operation cost	EUR	4.22 €	4.22 €	4.22 €
Total Maintenance cost	EUR	12.66 €	21.10 €	50.64 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	60.27 €	49.20 €	134.35 €

The LCC results for a ro-pax new building is shown in Table 164.

Table 164. Action 9C- The LCC results for a ro-pax new building.

System Number		System#01	System#02	System#03
System Name		)et5: Video fire detectio	Det6: IR heat cameras	RCO12
Unit		**Per Ship**		
Total Investment cost	EUR	139 547.00 €	64 548.00 €	184 877.00 €
Total Operation cost	EUR	23 548.67 €	23 548.67 €	23 548.67 €
Total Maintenance cost	EUR	70 646.01 €	117 743.36 €	117 743.36 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	233 741.69 €	205 840.03 €	326 169.03 €
Unit		**Per Lane meter**		
Total Investment cost	EUR	63.43 €	29.34 €	84.04 €
Total Operation cost	EUR	10.70 €	10.70 €	10.70 €
Total Maintenance cost	EUR	32.11 €	53.52 €	53.52 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	106.25 €	93.56 €	148.26 €

The LCC results for a ro-pax existing ship is shown in Table 165.

Table 165. Action 9C- The LCC results for a ro-pax existing ship

System Number		System#01	System#02	System#03
System Name		)et5: Video fire detectio	Det6: IR heat cameras	RCO12
Unit		**Per Ship**		
Total Investment cost	EUR	155 047.00 €	81 148.00 €	220 227.00 €
Total Operation cost	EUR	16 167.12 €	16 167.12 €	16 167.12 €
Total Maintenance cost	EUR	48 501.37 €	80 835.62 €	194 005.50 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	219 715.50 €	178 150.75 €	430 399.62 €
Unit		**Per Lane meter**		
Total Investment cost	EUR	70.48 €	36.89 €	100.10 €
Total Operation cost	EUR	7.35 €	7.35 €	7.35 €
Total Maintenance cost	EUR	22.05 €	36.74 €	88.18 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	99.87 €	80.98 €	195.64 €

The LCC results for a vehicle carrier new building is shown in Table 166.

Table 166. Action 9C- The LCC results for a vehicle carrier new building

System Number		System#01	System#02	System#03
System Name		Det5: Video fire detectio	Det6: IR heat cameras	RCO12
Unit		**Per Ship**		
Total Investment cost	EUR	1 227 262.00 €	- €	935 039.00 €
Total Operation cost	EUR	18 667.02 €	- €	18 667.02 €
Total Maintenance cost	EUR	112 002.11 €	- €	102 668.60 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	1 357 931.13 €	- €	1 056 374.62 €
Unit		**Per CEU**		
Total Investment cost	EUR	193.27 €	- €	147.25 €
Total Operation cost	EUR	2.94 €	- €	2.94 €
Total Maintenance cost	EUR	17.64 €	- €	16.17 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	213.85 €	- €	166.36 €

The LCC results for a vehicle carrier existing ship is shown in Table 167.

Table 167. Action 9C- The LCC results for a vehicle carrier existing ship

System Number		System#01	System#02	System#03
System Name		Det5: Video fire detectio	Det6: IR heat cameras	RCO12
Unit		**Per Ship**		
Total Investment cost	EUR	1 285 262.00 €	- €	981 539.00 €
Total Operation cost	EUR	13 094.12 €	- €	13 094.12 €
Total Maintenance cost	EUR	78 564.70 €	- €	72 017.64 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	1 376 920.82 €	- €	1 066 650.76 €
Unit		**Per CEU**		
Total Investment cost	EUR	202.40 €	- €	154.57 €
Total Operation cost	EUR	2.06 €	- €	2.06 €
Total Maintenance cost	EUR	12.37 €	- €	11.34 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	216.84 €	- €	167.98 €

Results summary is shown in Table 168.

Table 168. Action 9C - Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Det5	Video fire detection	Investment	139 547.00 €	155 047.00 €	150 090.00 €	166 240.00 €	1 227 262.00 €	1 285 262.00 €
		Operation	23 548.67 €	16 167.12 €	22 655.53 €	16 167.12 €	18 667.02 €	13 094.12 €
		Maintance	70 646.01 €	48 501.37 €	67 966.58 €	48 501.37 €	112 002.11 €	78 564.70 €
		TOTAL	**233 741.68 €**	**219 715.49 €**	**240 712.11 €**	**230 908.49 €**	**1 357 931.13 €**	**1 376 920.82 €**
Det6	Thermal imaging (infrared) cameras	Investment	64 548.00 €	81 148.00 €	73 848.00 €	91 498.00 €	N/A	N/A
		Operation	23 548.67 €	16 167.12 €	22 655.53 €	16 167.12 €	N/A	N/A
		Maintance	117 743.36 €	80 835.62 €	113 277.64 €	80 835.62 €	N/A	N/A
		TOTAL	**205 840.03 €**	**178 150.74 €**	**209 781.17 €**	**188 500.74 €**	**N/A**	**N/A**
RCO12	Visual system for fire confirmation and localization	Investment	184 877.00 €	220 227.00 €	265 764.00 €	304 539.00 €	935 039.00 €	981 539.00 €
		Operation	23 548.67 €	16 167.12 €	22 655.53 €	16 167.12 €	18 667.02 €	13 094.12 €
		Maintance	117 743.36 €	194 005.50 €	271 866.33 €	194 005.50 €	102 668.60 €	72 017.64 €
		TOTAL	**326 169.03 €**	**430 399.62 €**	**560 285.86 €**	**514 711.62 €**	**1 056 374.62 €**	**1 066 650.76 €**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed

16.2 Conclusion

An assessment of the installation cost and the cost for inspection, testing, and maintenance of two detection system solutions for open and close ro-ro spaces, proposed by Action 9-C was performed. Further, the assessment was performed for three ship types, the selected generic ro-ro cargo, ro-pax and vehicle carrier that were used for integration and LCC assessment.

The cost of Action 9-C solutions is similar to those of solutions 9-A and 9-B, with the only difference being in the operational cost where crew training through fire drills is additionally considered for 9-C solutions.

A direct comparison between proposed and assessed solutions is not feasible for ro-pax and ro-ro cargo ships, as they are applicable for different ro-ro space types, i.e. RCM Det5 for closed ro-ro spaces only, RCM Det6 for weather decks only and RCO12 for all ro-ro spaces. For vehicle carriers with only closed ro-ro spaces arranged, the results showed that the Video fire detection system (RCM Det5) is considerably more expensive than the Thermal imaging camera system considered within RCO12.

Further, significant cost differences may occur depending on the business area, i.e., shipyard location, particularly the installation cost. However, the cost estimates can easily be adjusted to a specific business area.

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

Main author of the chapter: Urban Lishajko, WAL

This chapter presents an overview of the life cycle cost assessment for the solutions proposed by Action 10-A i.e., Local application fire-extinguishing systems. Three RCMs were proposed by WP10 and one RCO selected (Ref. D04.6, [2]) and assessed within this report:

- RCM Ext1a - A dry pipe sprinkler system. Note: This is per definition an automatic system
- RCM Ext1b - An automatic deluge water spray system utilizing open nozzles
- RCM Ext2 - A deluge system using rotating CAFS nozzles
- RCO13 - Local application fire-extinguishing systems

For the description of the RCM's please refer to Deliverable D04.9, [1], and D10.1 [9], for the description of the RCO please refer to Deliverable D04.6, [2].

17.1 Life cycle cost assessment

An installation cost assessment for three different system solutions was made:

- **System#01**- A dry-pipe sprinkler system utilizing automatic sprinklers (RCM Ext1a)
- **System#02**- A deluge water spray system (RCM Ext1b)
- **System#03**- A deluge system using rotating CAFS nozzles (RCM Ext2).

Cost assessment for the RCO13 was found to be same as for System#1, RCM Ext1a.

17.1.1 Description of the developed solution

Main author of the chapter: Magnus Arvidson, RISE

17.1.1.1 General

For the System#01, individual sprinklers installed at the ceiling are activated by the heat from the fire, the latter systems (System#02 and System#03) require a fire detection system for detection and activation.

All three system require a water pump that is connected to the freshwater tanks of the ship and supplied by the main power supply. Dry-pipe or deluge valves are located either outside the protected space or inside separate cabinets inside the protected space. As water is discharged inside the protected spaces, means for water drainage is required.

It is judged that the systems can be installed without or with minimal influence on the cargo capacity in the terms of space. However, all systems add weight to the total weight of the ship, which will influence the cargo capacity in terms of weight load and/or the fuel consumption.

The differences between the system solutions are discussed below.

17.1.1.2 System#01 - Automatic dry-pipe sprinkler system (RCM Ext1a)

A dry-pipe sprinkler system uses automatic sprinklers that are attached to a piping system containing air or nitrogen under pressure. When one or more sprinklers (installed at the ceiling of the protected space) operates by the heat from the fire, the pressure drop opens a dry-pipe valve, and the water flows into the piping system and out the opened sprinklers. There is typically a delay time in the order of 45 s to 60 s from the activation of the first sprinklers to the discharge of water. The system

needs to be hydraulically designed for a certain area of operation; the maximum area over which the sprinklers are expected to operate in a fire. This area contains about twelve to fifteen sprinklers.

The total water demand is the lowest of the three studied system solutions, which results in the lowest pump demand, the lowest required power demand, and the least water drainage demand of the three studied systems.

17.1.1.3 System#02 - Automatic deluge water spray system (RCM Ext1b)

A deluge water spray system has a fixed pipe system connected to a water supply and is equipped with water spray nozzles designed to provide a specific water discharge and distribution over the protected surfaces or area. Automatic activation requires a separate fire detection system that is installed in the deluge section protection areas. Manual activation is possible and is made by physical operation of the deluge valve but may be electronically remote controlled from another location. There is a time delay from the operation of the deluge valve until water is discharged from the water spray nozzles.

Deluge systems should be designed for the simultaneous activation of the two (or four) adjacent deluge sections with the greatest hydraulic demand at the minimum water discharge density. This results in a total water demand that is the highest of the three studied system solutions. Another drawback compared to a dry-pipe system is that a large number of deluge valves are required.

17.1.1.4 System#03 - Automatic Compressed Air Foam system -CAFS (RCM Ext2)

A Compressed Air Foam System (CAFS) is designed similar to a deluge water spray system but uses open foam discharge devices for the extinguishment of a fire or for the protection of unaffected adjacent areas. System components of CAFS are typically a water source, a centrifugal pump, a foam concentrate tank, a foam proportioning and injection component, a mixing chamber or device, an air compressor, and a control system ensuring suitable mixing of the water, foam concentrate and air.

The total water demand is between a deluge water spray system and a dry-pipe sprinkler system.

17.1.2 Life cycle cost model

Main author of the chapter: Magnus Arvidson, RISE

Cost assessments were performed for the vehicle carrier newbuilding and retrofit, described in relevant chapters below. All cost assessments were based on a system installation on MS Torrens, the generic vehicle carrier of the LASH FIRE project. For more detailed description of the lifecycle cost assessment performed and used input data and assumptions, please refer to report D10.1, [9] chapters 15 and 16.

17.1.2.1 Life cycle cost component for a vehicle carrier new Building

17.1.2.1.1 Investment cost

Independent of the system, the installation cost assessment was divided into three parts with associated costs:

1. The cost for components as the pump, air compressor (if used), Nitrogen generator (if used) the valves, control panels and the sprinklers or nozzles.
2. The cost for the piping, couplings, and hangers.
3. The labour cost for the engineering, shipyard administration, installation work as well commissioning and training.

The costs for each part were estimated based on figures from system component suppliers and sprinkler system installers. Sprinkler system contractors have knowledge, for example, of the number of work hours that it normally takes to install a valve or the pipework for a certain number of sprinklers. For the automatic deluge water spray and CAF systems, a fire detection and control system are required. The cost for this installation was estimated by a fire detection system supplier. Table 169 summarizes the estimated cost for the installation of the three system solutions on a new building.

Table 169. Action 10-A - The estimated cost for the installation of the three system solutions on a vehicle carrier new building.

System Number		System#01	System#02	System#03
System Name		Ext1a	Ext1b	Ext2
Investment cost				
Purchasing cost	EUR	843 893.07	1 101 880.00	1 311 952.00
Insurance cost	EUR	-	-	-
Integration design & validation cost	EUR	100 000.00	150 000.00	125 000.00
Disassemble and modify the old system or structure	EUR	-	-	-
Road transporter cost	EUR	-	-	-
Ship transporter cost	EUR	-	-	-
Assembly/Installation cost	EUR	343 225.00	489 228.00	489 228.00
Comissioning cost	EUR	3 000.00	3 000.00	3 000.00
Document, certification and other administration costs	EUR	-	-	-
Loss of hire costs	EUR	-	-	-
Operator traning cost	EUR	3 000.00	3 000.00	3 000.00
Other cost	EUR	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total cost	EUR	1 293 118.07	1 747 108.00	1 932 180.00

It was assumed that all three system solutions will be serviceable during the entire time, if properly maintained.

17.1.2.1.2 Operation cost

Based on the estimated total weight of the three system solutions (about 100 tons) the additional fuel consumption was estimated. It was judged that improved fire protection would not result in any reduced insurance premiums. Although a dry-pipe system is the least heavy (about 100 tons) and CAFS (about 110 tons) the heaviest system of the three system solutions, the same additional fuel consumption figure was applied. Table 170 shows the estimated operation costs.

Table 170. Action 10-A - The estimated operation costs due to the installation of the three system solutions.

System Number		System#01	System#02	System#03
System Name		Ext1a	Ext1b	Ext2
Operation cost				
Additional Energy consumption	kWh/year	-	-	-
Additional Fuel Consumption	t/year	72.00	72.00	72.00
Reduce Fuel Consumption	t/year	-	-	-
Operator cost	EUR/year	-	-	-
Insurance, taxes, and other fees cost	EUR/year	-	-	-
Loss of cargo/loss revenue	EUR/year	-	-	-
Additional of cargo/profit revenue	EUR/year	-	-	-
Other operation cost	EUR/year	-	-	-

17.1.2.1.3 Maintenance cost

Inspections, testing, and maintenance of fire protection systems and appliances are required in accordance with SOLAS Chapter II-2/14.2.2. Classification societies typically considers MSC.1/Circ. 1432 and MSC.1/Circ. 1516 as the minimum guidelines on which such inspections are to be based. These guidelines may be used as a basis for the ship's onboard maintenance plan required by SOLAS regulation II-2/14 and the detailed requirements were used as the baseline for the cost assessment. The second document includes amendments to MSC.1/Circ. 1432.

For each of the three systems, an assessment of the cost for the inspections, testing and maintenance over a 10 year period was made. Based on that, an average annual cost was calculated. It was assumed that most of the actions (the least complicated) are undertaken by competent crew members. The more complex actions, like internal inspection of control/section valves and testing of foam proportioners and specific system service, repair work and maintenance, external competence is needed.

Finally, some actions require laboratory testing, as the control test of foam concentrate. This service is available at several different fire test laboratories, which provided input on the cost including an estimated freight cost for the shipment of the foam sample.

The large number of deluge valves associated with the automatic deluge water spray system and CAFS substantially increase the total labor time for these systems. As an example, every month it should be verified that that all control and section valves are in the proper open or closed position, and every fifth year an internal inspection of all these valves should be made. The use of foam in the CAFS will also add additional measures to be taken. The fact that a deluge system also necessitates a separate fire detection system require extensive time for inspection and testing.

Some maintenance and repair work require a vessel downtime and an estimated cost figure was provided by Wallenius Marine AB.

Table 171 summarizes the outcome of the maintenance cost assessment.

Table 171. Action 10-A - The estimated cost for the inspection, testing and maintenance of the three system solutions.

System Number		System#01	System#02	System#03
System Name		Ext1a	Ext1b	Ext2
Maintenance cost				
Annual maintenance				
Annual system maintenance cost	EUR/year	9 828.00	26 850.00	27 896.00
Loss due to vessel downtime during maintenance	EUR/year	-	-	-
Other annual maintenance cost	EUR/year	-	-	-
		-	-	-
Total annual maintenance cost	EUR/year	9 828.00	26 850.00	27 896.00
Periodic maintenance				
Spare part cost	EUR	675.00	1 350.00	2 025.00
Service repair cost	EUR	2 700.00	5 400.00	8 100.00
Loss due to vessel downtime during repair	EUR	-	-	-
Other periodic maintenance cost	EUR	-	-	-
		-	-	-
Inspection				
Periodic inspection and certification cost	EUR	5 400.00	5 400.00	5 400.00
Other cost	EUR	-	-	-
		-	-	-
		-	-	-

From this assessment, it can be concluded that the annual cost is more than a factor of two higher for the two deluge systems as compared to the dry-pipe sprinkler system. The reason is that the deluge systems are more complex and include more components, resulting in more extensive inspection, testing and maintenance and higher costs for spare parts. The use of foam and the equipment related to the generation of will make the CAFS the most expensive system to maintain serviceable.

17.1.2.1.4 End of Life cost

No end of life cost considered.

17.1.2.2 Life cycle cost component for existing ship

17.1.2.2.1 Investment cost

Table 172 summarises the estimated cost for the installation of the three system solutions on an existing ship. As there is no existing water-based fire protection system there is no cost for any disassembly or modification of an old system. However, it was assumed that the labor cost for the installation ('Assembly/Installation cost') is higher for an installation on an existing ship as any installation obstacles need to be resolved onsite and not during the design phase.

Table 172. Action 10-A - The estimated cost for the installation of the three system solutions on a vehicle carrier existing ship.

System Number		System#01	System#02	System#03
System Name		Ext1a	Ext1b	Ext2
Investment cost				
Purchasing cost	EUR	843 893.07	1 101 880.00	1 311 952.00
Insurance cost	EUR	-	-	-
Integration design & validation cost	EUR	100 000.00	150 000.00	125 000.00
Disassemble and modify the old system or structure	EUR	-	-	-
Road transporter cost	EUR	-	-	-
Ship transporter cost	EUR	-	-	-
Assembly/Installation cost	EUR	411 870.00	587 073.60	587 073.60
Comissioning cost	EUR	3 000.00	3 000.00	3 000.00
Document, certification and other administration costs	EUR	-	-	-
Loss of hire costs	EUR	280 000.00	280 000.00	280 000.00
Operator traning cost	EUR	3 000.00	3 000.00	3 000.00
Other cost	EUR	-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
		-	-	-
Total cost	EUR	1 641 763.07	2 124 953.60	2 310 025.60

It was assumed that all three system solutions will be serviceable during the entire time, if properly maintained.

17.1.2.2.2 Operation cost

It was assumed that the operation cost is similar to a new building, refer to the cost figures listed in

Table 170 above.

17.1.2.2.3 Maintenance cost

It was assumed that the maintenance cost is similar to a new building, refer to the cost figures listed in

Table 171 above.

17.1.2.2.4 End of Life cost

No end of life cost considered.

17.1.3 LCC Result

The LCC results for a vehicle carrier new building is summarised in Table 173.

Table 173. Action 10A - The LCC results for a vehicle carrier new building.

System Number		System#01	System#02	System#03
System Name		Ext1a	Ext1b	Ext2
Unit		**Per Ship**		
Total Investment cost	EUR	1 293 118.07 €	1 747 108.00 €	1 932 180.00 €
Total Operation cost	EUR	480 587.73 €	480 587.73 €	480 587.73 €
Total Maintenance cost	EUR	249 627.67 €	627 003.85 €	706 155.74 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	2 023 333.47 €	2 854 699.58 €	3 118 923.47 €
Unit		**Per CEU**		
Total Investment cost	EUR	203.64 €	275.14 €	304.28 €
Total Operation cost	EUR	75.68 €	75.68 €	75.68 €
Total Maintenance cost	EUR	39.31 €	98.74 €	111.21 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	318.64 €	449.56 €	491.17 €

The LCC results for a vehicle carrier existing ship is summarised in Table 174.

Table 174. Action 10-A - The LCC results for a vehicle carrier existing ship.

System Number		System#01	System#02	System#03
System Name		Ext1a	Ext1b	Ext2
Unit		**Per Ship**		
Total Investment cost	EUR	1 641 763.07 €	2 124 953.60 €	2 310 025.60 €
Total Operation cost	EUR	296 992.54 €	296 992.54 €	296 992.54 €
Total Maintenance cost	EUR	173 334.79 €	437 040.49 €	491 554.58 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	2 112 090.39 €	2 858 986.62 €	3 098 572.71 €
Unit		**Per CEU**		
Total Investment cost	EUR	258.55 €	334.64 €	363.78 €
Total Operation cost	EUR	46.77 €	46.77 €	46.77 €
Total Maintenance cost	EUR	27.30 €	68.83 €	77.41 €
Total End of Life cost	EUR	- €	- €	- €
Total Life Cycle Cost	EUR	332.61 €	450.23 €	487.96 €

Results summary is shown in Table 175.

Table 175. Action 10-A - Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Ext1a	Dry pipe sprinkler system for ro-ro spaces on vehicle carriers	Investment	N/A	N/A	N/A	N/A	1 293 118.07 €	1 641 763.07 €
		Operation	N/A	N/A	N/A	N/A	480 587.73 €	296 992.54 €
		Maintance	N/A	N/A	N/A	N/A	249 627.67 €	173 334.79 €
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**2 023 333.47 €**	**2 112 090.39 €**
Ext1b	Automatic deluge water spray system utilizing open nozzles	Investment	N/A	N/A	N/A	N/A	1 747 108.00 €	2 124 953.60 €
		Operation	N/A	N/A	N/A	N/A	480 587.73 €	296 992.54 €
		Maintance	N/A	N/A	N/A	N/A	627 003.85 €	437 040.49 €
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**2 854 699.58 €**	**2 858 986.62 €**
Ext2	Deluge system using rotating CAFS nozzles on vehicle carriers	Investment	N/A	N/A	N/A	N/A	193 180.00 €	2 310 025.60 €
		Operation	N/A	N/A	N/A	N/A	480 587.73 €	296 992.54 €
		Maintance	N/A	N/A	N/A	N/A	706 155.74 €	491 554.58 €
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**1 379 923.47 €**	**3 098 572.71 €**
RCO13	Dry-pipe sprinkler system for vehicle carriers	Investment	N/A	N/A	N/A	N/A	1 293 118.07 €	1 641 763.07 €
		Operation	N/A	N/A	N/A	N/A	480 587.73 €	296 992.54 €
		Maintance	N/A	N/A	N/A	N/A	249 627.67 €	173 334.79 €
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**2 023 333.47 €**	**2 112 090.39 €**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed.

17.2 Conclusion

An assessment of the installation cost and the cost for inspection, testing and maintenance of three water-based fire protection system solutions for Ro-Ro spaces on vehicle carriers were made. The systems were a dry-pipe sprinkler system utilizing automatic sprinklers, a deluge water spray system and a deluge system using rotating CAFS nozzles. The first (dry-pipe sprinkler system utilizing automatic sprinklers) of the three listed systems is the least expensive to install and maintain serviceable, the third system (deluge system using rotating CAFS nozzle) the most expensive.

It is concluded that the Life cycle cost for a new building is higher than for an existing ship, despite the fact that the investment cost in the existing ship is higher. The main reason is that the newbuilt ship was assumed to have a longer (29 years) expected lifetime than that of an existing ship (17 years).

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

Main author of the chapter: Vito Radolovic, FLOW

This chapter presents an overview of the life cycle cost and environmental assessment for the solutions proposed by Action 10-B i.e., Weather deck fixed fire-extinguishing systems. Four RCMs were proposed by WP10 and two RCO's selected (Ref. D04.6 "Cost-effectiveness assessment report" [2]) and assessed within this report:

- RCM Ext3 - Autonomous fire monitor (water only) system for the protection of weather decks
- RCM Ext4 - Remotely-controlled Compressed Air Foam fire monitor system for the protection of weather deck
- RCM Ext3a - Remotely-controlled fire monitor (water only) system for the protection of weather decks
- RCM Ext4a - Autonomous Compressed Air Foam fire monitor system for the protection of weather deck
- RCO14 - Fixed remotely-controlled fire monitor system using water for weather decks
- RCO15 - Fixed autonomous fire monitor system using water for weather decks

For the description of the RCM's please refer to Deliverable D04.9 "Preliminary impact of solutions and related testing and demonstrations plan" [1], and D10.1 "Description of the development of local application fire-extinguishing systems and selected solutions" [9], for the description of the RCO please refer to Deliverable D04.6, [2].

18.1 Life cycle cost assessment

An installation cost assessment for three different system solutions was made:

- **System#01**- Autonomous fire monitor (water only) system for the protection of weather decks (RCM Ext3)
- **System#02**- Remotely-controlled Compressed Air Foam fire monitor system for the protection of weather deck (RCM Ext4)
- **System#03**- Remotely-controlled fire monitor (water only) system for the protection of weather decks (RCM Ext3a).
- **System#04**- Autonomous Compressed Air Foam fire monitor system for the protection of weather deck (RCM Ext4a).

Cost assessment for the RCO14 was found to be same as for System#03, RCM Ext3a. Cost assessment for the RCO15 was found to be same as for System#01, RCM Ext3.

The cost assessment was made for reference ships selected by the project, Magnolia Seaways the generic ro-ro cargo ship operated by DFDS Seaways, and Stena Flavia, the generic ro-pax ship. The cost assessment was made for both newbuilding and existing ships.

18.1.1 Description of the developed solution

18.1.1.1 System#01/#03 - fire monitor systems (RCM Ext3, RCM Ext3a)

The system was assumed to be comprised of fire monitors units including an adjustable jet/spray firefighting monitor nozzle tip, a programmable logic controller (PLC), an electric valve and actuator, a joystick, joystick cable and a fire monitor cable kit.

The fire monitors are also assumed to require a pump that provides at least 2 500 l/min of flow at 10 bars of pressure. Each fire monitor will need to be mounted on stable support with tensioners where relevant. The entire system will need to be supplied with piping running from the pump to each of the monitors (DN150 piping considered). Note that a common distribution pipe for monitors along each side, respectively, of the ship can be arranged.

In addition to the fire monitor equipment, a fully autonomous fire monitor system (System#01)) will additionally require two fire detectors for each fire monitor, cables from those detectors, as well as specialized electronic hardware and software to achieve the autonomous function.

It is anticipated that the cost of the components necessary for fully autonomous functionality (i.e., fire detectors and electronic hardware and software) will significantly decrease over time and the overall cost of an autonomous system is expected to be comparable to the overall cost a system using remote control fire monitor system that do not have autonomous functionality.

18.1.1.2 System#02/#04 - Fire monitor systems using CAF (RCM Ext4, RCM Ext4a)

The additional cost for a CAF fire monitor system, is mainly related to the CAF generating unit. This includes the mixing chamber, a foam concentrate dosing system, and controls to manage the water to air ratio. The arrangement of the additional CAFS equipment was assumed within typical service and/or machinery spaces for new buildings, where an additional deckhouse was considered for retrofit. It was assumed that the capacity of the water pump should be at least 2 500 l/min, to ensure similar fire-fighting capacity to a water only system in the case the CAFS runs out of foam. This way the water pump is always capable to provide enough water to create the CAF. The CAFS should be large enough to supply foam to at least two fire monitors simultaneously. The fire monitors were assumed to be of a smooth bore type nozzle or straight piece of pipe, to maintain the quality of the foam that is discharging through the nozzle. For a remote-controlled CAFS, a fire detection system is not required for the functionality of the system.

18.1.1.3 Ro-ro cargo integration description

The weather deck on the reference ship extends below a superstructure where the position of fire monitors is not possible. However, this area is protected by a deluge water spray (‘Drencher’) system as Section 1. The system is manually activated by starting the two fire pumps and opening the deluge valve. A fire may occur such that simultaneous operation of the ‘Drencher’ system under the superstructure and the intended fire monitor system is required. Therefore, a dedicated water pump for the fire monitor system was supposed to be required. Three fire monitors are necessary to cover the weather deck area aft of the superstructure and two fire monitors to cover the forward weather deck area, and approximately 300 m piping and 300 m of cabling for the detection system (Ext3, Ext4a only). Figure 27 shows the layout of an autonomous fire monitor system on the weather deck on Magnolia Seaways, with the positions of the monitors and the fire detectors. The CAFS monitors would have the same position as the fire monitors.

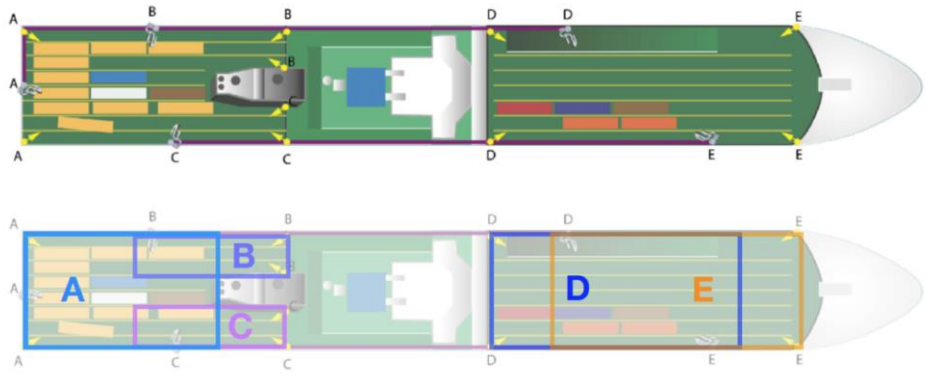

Figure 27. The layout of an autonomous fire monitor systems on the weather deck on Magnolia Seaways, with the positions of the monitors and the fire detectors.

18.1.1.4 Ro-pax integration description

There are two weather decks arranged on the Stena Flavia reference ship. A relatively small weather deck is arranged on the Starboard side at Deck 3 and a weather deck on Deck 5 is arranged aft of the superstructure. A dedicated water pump for the fire monitor system was considered. Four fire monitors are necessary to cover the weather decks area and approximately 120 m piping and 400 m of cabling for the detection system (Ext3, Ext4a only) is required. Figure 28 shows the layout of an autonomous fire monitor system on the weather deck on Stena Flavia, with the positions of the monitors and the fire detectors. A CAFS would have the same position as the fire monitors. The fire detection system for the Ro-Pax was estimated based on the detailed assessment for the ro-ro cargo.

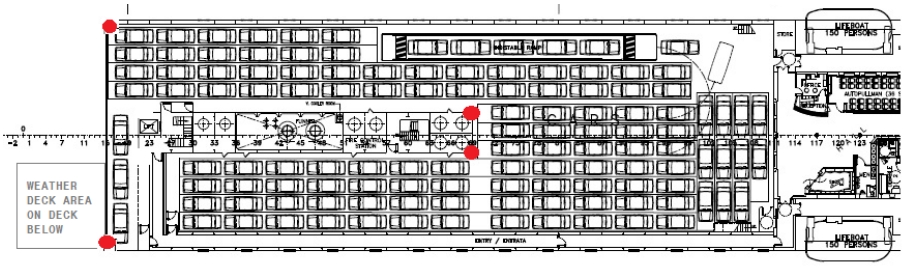

Figure 28. The layout of fire monitor systems on the weather decks on Stena Flavia

18.1.2 Life cycle cost model

18.1.2.1 Cost items description and assumptions

Independent of the system, ship type, newbuilding or existing ship, the following costs were considered:

- Investment cost,
- inspections, testing, and maintenance, and,
- end of life cost.

It was assumed that all system solutions will be serviceable during the entire time if properly maintained.

18.1.2.1.1 Investment cost

The following items are considered:

- The cost for system components as the fire monitor units, the water pump, air compressor (CAFS), foam mixing chamber (CAFS), the valves, control panels, detection system (if used), etc.,
- the purchasing cost of piping, flanges, and hangers,
- stands for fire monitors and tensioners,
- construction steel for deckhouse (CAFS),
- software and licence costs (autonomous system),
- the labour cost for the engineering, shipyard administration, installation work as well commissioning and training,
- the labour cost for the installation work as well commissioning and training:
    - installation of pump unit,
    - production and installation of piping,
    - production and installation of stands,
    - fire detection system installation cost (if used),
- document, certification, and other administration costs. Considered for existing ships only, where for new buildings no additional cost was assumed.

18.1.2.1.1.1 Investment cost assessment assumptions

For each of the systems, the cost for purchasing, production and installation was considered.

The purchasing costs for each component were estimated based on figures from system component suppliers. Further, average component cost of available detection technologies was considered for the detection system, if used.

The estimated cost provided for the production, installation, and commissioning was based on a Croatian shipyards standard where the average cost per weight or length was estimated. For piping, 4.25 EUR/t for production, 5.0 EUR/t for installation (newbuilding) and 6.0 EUR/t for retrofit was assumed. Production and installation of steel structures such as monitor stands, deckhouse, 2.5 EUR/t and 1.5 EUR/t, respectively, was assumed where an increase of 10% for retrofitting was estimated. A cabling installation cost of 25 EUR/m was assumed for newbuilding and 30 EUR/m for retrofit.

18.1.2.1.2 Cost for inspections, testing, and maintenance

Inspections, testing, and maintenance of fire protection systems and appliances are required in accordance with SOLAS Chapter II-2/14.2.2. Surveyors are required to approve that inspections, testing, and maintenance are carried out as part of the safety equipment survey, in accordance with

the maintenance plan on the ship. Classification societies typically consider MSC.1/Circ. 1432 and MSC.1/Circ. 1516, as minimum guidelines on which such inspections are to be based. The first document superseded MSC/Circ. 850, recognizing the need to include maintenance and inspection guidelines for the latest advancements in fire protection systems and appliances. It applies to all ships and provides the minimum recommended level. The guidelines may be used as a basis for the ship's onboard maintenance plan required by SOLAS regulation II-2/14. The second document includes amendments to MSC.1/Circ. 1432.

Table 176 provides an overview of the requirements in MSC.1/Circ. 1432 and MSC.1/Circ. 1516 for fixed foam fire-extinguishing, water mist, water spray and sprinkler systems.

Table 176. Overview of inspections, testing and maintenance of main fire-fighting systems based on MSC.1/Circ. 1432 and MSC.1/Circ. 1516 as amended.

Equipment	Time interval	Requirement	Guideline
Fixed foam fire-extinguishing systems	Monthly	Verification of valves and gauges, etc.	MSC.1/Circ. 1432, paragraph 5.3
	Quarterly	Verification of quantity of foam concentrate	MSC.1/Circ. 1432, paragraph 6.2
	Annually	Functional test, and foam sample testing, etc.	MSC.1/Circ. 1432, paragraph 7.4
	5-yearly	Inspection of each part	MSC.1/Circ. 1432, paragraph 9.2
Water mist, water spray and sprinkler systems	Weekly	Visual inspection, etc.	MSC.1/Circ. 1432, paragraph 4.7
	Monthly	Verification of valves and gauges, etc.	MSC.1/Circ. 1432, paragraph 5.4
	Quarterly	Assessment of system water quality	MSC.1/Circ. 1516, paragraph 6.5
	Annually	Blowing air, blowing water test, etc.	MSC.1/Circ. 1516, paragraph 7.5
	5-yearly	Internal inspection of all control/section valves, etc.	MSC.1/Circ. 1516, paragraph 9.3
	10-yearly	Hydrostatic test for gas and water pressure cylinders	MSC.1/Circ. 1432, paragraph 10.2

As fire monitor systems are currently not required to be installed on ships, similar guidelines do not exist for such systems. However, the guidance given above was used as a starting point for estimating the actions needed and to undertake a cost assessment.

Certain inspection and maintenance procedures may be performed by competent crew members, while others should be performed by trained external personnel. The onboard maintenance plan should indicate which parts that are to be completed by trained personnel. Records of inspections must be carried on board the ship and may be computer-based. In cases where the inspections and maintenance are carried out by external parties, inspection reports must be provided at the completion of the testing. In addition, manufacturer's inspection, control, and maintenance recommendations must be followed.

18.1.2.1.2.1 Inspections, testing, and maintenance cost assessment assumptions

For each of the three systems, an assessment of the cost for the inspections, testing and maintenance over a 10 year period was made. Based on that, an average annual cost was calculated. It was assumed that most of the actions (the least complicated) are undertaken by competent crew members. For these actions, the estimated labor time was multiplied by the internal cost for a crew member. Based on input from Wallenius Marine AB, the cost was set to 22 EUR per work hour.

The more complex actions, like internal inspection of fire monitors and testing of foam proportioners and specific system service and maintenance, external competence is needed. The cost of labor varies depending on the part of the world in which the work was performed. Based on input from Wallenius Marine AB, service engineers in the European Union for original equipment suppliers is between 120 EUR to 150 EUR per work hour. For this cost assessment, 135 EUR per work hour was used.

Finally, some actions require laboratory testing, as the periodical control test of foam concentrate. This service is available at several different fire test laboratories, which provided input on the cost including an estimated freight cost for the shipment of the foam sample.

The required time for some of the measures was purely estimated. As an example, it was judged that the weekly inspections would require no more than one working hour irrespective of the type of system.

The cost for an annual service to fulfill the manufacturer's recommendation for inspection, control, and maintenance recommendations was added. The cost for spare parts as gaskets for valves, filters, and foam was estimated to be 25% of the estimated cost for the annual system service.

18.1.2.2 Life cycle cost component for ro-ro cargo newbuilding

18.1.2.2.1 Investment cost

The estimated cost for the installation of the system solutions, respectively, on a ro-ro cargo new building is summarized in Table 177.

Table 177 Action 10-B- The estimated cost for the installation of the system solutions, respectively, on a ro-ro cargo new building

System Number		System#01	System#02	System#03	System#04
System Name		Ext3: An autonomous	Ext4: A remote-cont	Ext3a: A remote-con	Ext4a: An autonomo
Investment cost					
Purchasing cost	EUR	166 590.00	271 690.00	132 690.00	305 590.00
Insurance cost	EUR	-	-	-	-
Integration design & validation cost	EUR	15 000.00	15 000.00	15 000.00	15 000.00
Disassemble and modify the old system or structure	EUR	-	-	-	-
Road transporter cost	EUR	-	-	-	-
Ship transporter cost	EUR	-	-	-	-
Assembly/Installation cost	EUR	81 100.00	78 600.00	73 600.00	86 100.00
Comissioning cost	EUR	3 000.00	3 000.00	3 000.00	3 000.00
Document, certification and other administration costs	EUR	-	-	-	-
Loss of hire costs	EUR	-	-	-	-
Operator traning cost	EUR	1 000.00	1 000.00	1 000.00	1 000.00
Other cost	EUR	-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
Total cost	EUR	266 690.00	369 290.00	225 290.00	410 690.00

18.1.2.2.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and energy consumption is negligible and therefore not considered.

18.1.2.2.3 Maintenance cost

It is concluded that the estimated cost for inspections, testing, and maintenance of the two selected solutions are fairly similar. It is recognized (although not documented here) that the use of a fire detection system required for an autonomous system and the use of foam and associated equipment for a remote-controlled CAFS have a certain influence on the cost. The estimated cost for the system solutions on a ro-ro cargo new building is summarized in Table 178.

Table 178. Action 10-B- The estimated cost for the inspection, testing and maintenance of the system solutions for a ro-ro cargo newbuilding

System Number		System#01	System#02	System#03	System#04
System Name		Ext3: An autonomous	Ext4: A remote-cont	Ext3a: A remote-con	Ext4a: An autonomo
Maintenance cost					
Annual maintenance					
Annual system maintenance cost	EUR/year	7 000.00	7 000.00	6 000.00	8 000.00
Loss due to vessel downtime during maintenance	EUR/year	-	-	-	-
Other annual maintenance cost	EUR/year	-	-	-	-
		-	-	-	-
Total annual maintenance cost	EUR/year	7 000.00	7 000.00	6 000.00	8 000.00

18.1.2.3 Life cycle cost component for ro-ro existing ships

18.1.2.3.1 Investment cost

The estimated cost for the installation of the system solutions on a ro-ro cargo retrofit are summarized in Table 179.

Table 179 Action 10-B- The estimated cost for the installation of the two system solutions on a ro-ro cargo existing ship

System Number		System#01	System#02	System#03	System#04
System Name		Ext3: An autonomous	Ext4: A remote-cont	Ext3a: A remote-con	Ext4a: An autonomo
Investment cost					
Purchasing cost	EUR	166 590.00	278 690.00	132 690.00	312 590.00
Insurance cost	EUR	-	-	-	-
Integration design & validation cost	EUR	20 000.00	20 000.00	20 000.00	20 000.00
Disassemble and modify the old system or structure	EUR	-	-	-	-
Road transporter cost	EUR	-	-	-	-
Ship transporter cost	EUR	-	-	-	-
Assembly/Installation cost	EUR	90 280.00	99 280.00	81 280.00	108 280.00
Comissioning cost	EUR	3 000.00	3 000.00	3 000.00	3 000.00
Document, certification and other administration costs	EUR	12 000.00	12 000.00	12 000.00	12 000.00
Loss of hire costs	EUR	-	-	-	-
Operator traning cost	EUR	1 000.00	1 000.00	1 000.00	1 000.00
Other cost	EUR	-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
Total cost	EUR	292 870.00	413 970.00	249 970.00	456 870.00

18.1.2.3.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and the energy consumption is negligible and therefore not considered.

18.1.2.3.3 Maintenance cost

It was assumed that the maintenance cost is similar to a newbuilding, refer to the cost figures listed in Table 178.

18.1.2.4 Life cycle cost component for ro-pax newbuilding

18.1.2.4.1 Investment cost

The estimated cost for the installation of the system solutions on a ro-pax newbuilding is summarized in Table 180.

Table 180 Action 10-B- The estimated cost for the installation of the system solutions on a ro-pax newbuilding

System Number		System#01	System#02	System#03	System#04
System Name		Ext3: An autonomous	Ext4: A remote-cont	Ext3a: A remote-con	Ext4a: An autonomo
Investment cost					
Purchasing cost	EUR	130 915.00	243 015.00	104 015.00	269 915.00
Insurance cost	EUR	-	-	-	-
Integration design & validation cost	EUR	15 000.00	15 000.00	15 000.00	15 000.00
Disassemble and modify the old system or structure	EUR	-	-	-	-
Road transporter cost	EUR	-	-	-	-
Ship transporter cost	EUR	-	-	-	-
Assembly/Installation cost	EUR	35 720.00	30 720.00	25 720.00	40 720.00
Comissioning cost	EUR	3 000.00	3 000.00	3 000.00	3 000.00
Document, certification and other administration costs	EUR	-	-	-	-
Loss of hire costs	EUR	-	-	-	-
Operator traning cost	EUR	1 000.00	1 000.00	1 000.00	1 000.00
Other cost	EUR	-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
Total cost	EUR	185 635.00	292 735.00	148 735.00	329 635.00

18.1.2.4.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and the energy consumption is negligible and therefore not considered.

18.1.2.4.3 Maintenance cost

It is concluded that the estimated cost for inspections, testing, and maintenance of the two selected solutions are fairly similar. It is recognized (although not documented here) that the use of a fire detection system required for an autonomous system and the use of foam and associated equipment for a remote-controlled CAFS have a certain influence on the cost. The estimated cost for the system solutions on a ro-pax newbuilding is summarized in

Table 181.

Table 181. Action 10-B- The estimated cost for the inspection, testing and maintenance of the system solutions for a ro-pax newbuilding

System Number		System#01	System#02	System#03	System#04
System Name		Ext3: An autonomous	Ext4: A remote-cont	Ext3a: A remote-con	Ext4a: An autonomo
Maintenance cost					
Annual maintenance					
Annual system maintenance cost	EUR/year	5 600.00	5 600.00	4 800.00	6 400.00
Loss due to vessel downtime during maintenance	EUR/year	-	-	-	-
Other annual maintenance cost	EUR/year	-	-	-	-
		-	-	-	-
Total annual maintenance cost	EUR/year	5 600.00	5 600.00	4 800.00	6 400.00

18.1.2.5 Life cycle cost component for ro-pax existing ship

18.1.2.5.1 Investment cost

The estimated cost for the installation of the system solutions on a ro-pax existing ship is summarized in Table 182.

Table 182 Action 10-B- The estimated cost for the installation of the two system solutions on a ro-pax existing ship

System Number		System#01	System#02	System#03	System#04
System Name		Ext3: An autonomous	Ext4: A remote-cont	Ext3a: A remote-con	Ext4a: An autonomo
Investment cost					
Purchasing cost	EUR	130 915.00	250 015.00	104 015.00	276 915.00
Insurance cost	EUR	-	-	-	-
Integration design & validation cost	EUR	20 000.00	20 000.00	20 000.00	20 000.00
Disassemble and modify the old system or structure	EUR	-	-	-	-
Road transporter cost	EUR	-	-	-	-
Ship transporter cost	EUR	-	-	-	-
Assembly/Installation cost	EUR	40 360.00	46 360.00	28 360.00	58 360.00
Comissioning cost	EUR	3 000.00	3 000.00	3 000.00	3 000.00
Document, certification and other administration costs	EUR	12 000.00	12 000.00	12 000.00	12 000.00
Loss of hire costs	EUR	-	-	-	-
Operator traning cost	EUR	1 000.00	1 000.00	1 000.00	1 000.00
Other cost	EUR	-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
Total cost	EUR	207 275.00	332 375.00	168 375.00	371 275.00

18.1.2.5.2 Operation cost

It was assumed that the impact on the operational cost due to additional system weight and the energy consumption is negligible and therefore not considered.

18.1.2.5.3 Maintenance cost

It was assumed that the maintenance cost is similar to a new building, refer to the cost figures listed in Table 181.

18.1.3 LCC Result

The LCC results for a ro-ro cargo new building is shown in

Table 183.

Table 183. Action 10-B- The LCC results for a ro-ro cargo new building

System Number		System#01	System#02	System#03	System#04
System Name		Ext3	Ext4	Ext3a	Ext4a
Unit		**Per Ship**			
Total Investment cost	EUR	266 690.00 €	369 290.00 €	225 290.00 €	410 690.00 €
Total Operation cost	EUR	- €	- €	- €	- €
Total Maintenance cost	EUR	158 588.69 €	158 588.69 €	135 933.17 €	181 244.22 €
Total End of Life cost	EUR	- €	- €	- €	- €
Total Life Cycle Cost	EUR	425 278.69 €	527 878.69 €	361 223.17 €	591 934.22 €
Unit		**Per Lane meter**			
Total Investment cost	EUR	69.61 €	96.40 €	58.81 €	107.20 €
Total Operation cost	EUR	- €	- €	- €	- €
Total Maintenance cost	EUR	41.40 €	41.40 €	35.48 €	47.31 €
Total End of Life cost	EUR	- €	- €	- €	- €
Total Life Cycle Cost	EUR	111.01 €	137.79 €	94.29 €	154.51 €

The LCC results for a ro-ro cargo existing ship is shown in Table 184.

Table 184. Action 10-B- The LCC results for a ro-ro cargo existing ship

System Number		System#01	System#02	System#03	System#04
System Name		Ext3	Ext4	Ext3a	Ext4a
Unit		**Per Ship**			
Total Investment cost	EUR	292 870.00 €	413 970.00 €	249 970.00 €	456 870.00 €
Total Operation cost	EUR	- €	- €	- €	- €
Total Maintenance cost	EUR	113 169.87 €	113 169.87 €	97 002.75 €	129 337.00 €
Total End of Life cost	EUR	- €	- €	- €	- €
Total Life Cycle Cost	EUR	406 039.87 €	527 139.87 €	346 972.75 €	586 207.00 €
Unit		**Per Lane meter**			
Total Investment cost	EUR	76.45 €	108.06 €	65.25 €	119.26 €
Total Operation cost	EUR	- €	- €	- €	- €
Total Maintenance cost	EUR	29.54 €	29.54 €	25.32 €	33.76 €
Total End of Life cost	EUR	- €	- €	- €	- €
Total Life Cycle Cost	EUR	105.99 €	137.60 €	90.57 €	153.02 €

The LCC results for a ro-pax new building is shown in Table 185

Table 185. Action 10-B- The LCC results for a ro-pax new building.

System Number		System#01	System#02	System#03	System#04
System Name		Ext3	Ext4	Ext3a	Ext4a
Unit		**Per Ship**			
Total Investment cost	EUR	185 635.00 €	292 735.00 €	148 735.00 €	329 635.00 €
Total Operation cost	EUR	- €	- €	- €	- €
Total Maintenance cost	EUR	131 872.56 €	131 872.56 €	113 033.62 €	150 711.50 €
Total End of Life cost	EUR	- €	- €	- €	- €
Total Life Cycle Cost	EUR	317 507.56 €	424 607.56 €	261 768.62 €	480 346.50 €

The LCC results for a ro-pax existing ship is shown in

Table 186.

Table 186. Action 10-B- The LCC results for a ro-pax existing ship

System Number / System Name		System#01 Ext3	System#02 Ext4	System#03 Ext3a	System#04 Ext4a
Unit		**Per Ship**			
Total Investment cost	EUR	207 275.00 €	332 375.00 €	168 375.00 €	371 275.00 €
Total Operation cost	EUR	- €	- €	- €	- €
Total Maintenance cost	EUR	90 535.90 €	90 535.90 €	77 602.20 €	103 469.60 €
Total End of Life cost	EUR	- €	- €	- €	- €
Total Life Cycle Cost	EUR	297 810.90 €	422 910.90 €	245 977.20 €	474 744.60 €

LCC results have not been given per cargo unit for a ro-pax ship as the large weather deck is intended for passenger cars only.

Results summary is shown in Table 187.

Table 187. Action 10B - Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Ext3	Autonomous fire monitor (water only) system for the protection of weather decks	Investment	185 635.00 €	207 275.00 €	266 690.00 €	292 870.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	131 872.56 €	90 535.90 €	158 588.69 €	113 169.87 €	N/A	N/A
		TOTAL	**317 507.56 €**	**297 810.90 €**	**425 278.69 €**	**406 039.87 €**	**N/A**	**N/A**
Ext3a	Remotely-controlled fire monitor (water only) system for the protection of weather decks	Investment	292 735.00 €	332 375.00 €	369 290.00 €	413 970.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	131 872.56 €	90 535.90 €	158 588.69 €	113 169.87 €	N/A	N/A
		TOTAL	**424 607.56 €**	**422 910.90 €**	**527 878.69 €**	**527 139.87 €**	**N/A**	**N/A**
Ext4	Remotely-controlled Compressed Air Foam fire monitor system for the protection of weather deck	Investment	148 735.00 €	168 375.00 €	225 290.00 €	249 970.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	113 033.62 €	77 602.20 €	135 933.17 €	97 002.75 €	N/A	N/A
		TOTAL	**261 768.62 €**	**245 977.20 €**	**361 223.17 €**	**346 972.75 €**	**N/A**	**N/A**
Ext4a	Autonomous Compressed Air Foam fire monitor system for the protection of weather deck	Investment	329 635.00 €	371 275.00 €	410 690.00 €	456 870.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	150 711.50 €	103 469.60 €	181 244.22 €	129 337.00 €	N/A	N/A
		TOTAL	**480 346.50 €**	**474 744.60 €**	**591 934.22 €**	**586 207.00 €**	**N/A**	**N/A**
RCO14	Fixed remotely-controlled fire monitor system using water for weather decks	Investment	185 635.00 €	207 275.00 €	266 690.00 €	292 870.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	131 872.56 €	90 535.90 €	158 588.69 €	113 169.87 €	N/A	N/A
		TOTAL	**317 507.56 €**	**297 810.90 €**	**425 278.69 €**	**406 039.87 €**	**N/A**	**N/A**
RCO15	Fixed autonomous fire monitor system using water for weather decks	Investment	292 735.00 €	332 375.00 €	369 290.00 €	413 970.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	131 872.56 €	90 535.90 €	158 588.69 €	113 169.87 €	N/A	N/A
		TOTAL	**424 607.56 €**	**422 910.90 €**	**527 878.69 €**	**527 139.87 €**	**N/A**	**N/A**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed.

18.2 Environmental assessment

Main author of the chapter: Francine Amon, RISE

LCA is utilized to estimate the environmental impact of the weather deck fire protection solutions developed in Action 10-B of the LASH FIRE project, see IR05.65 for the full LCA report. The LCAs include assessments of the environmental impact of commercially producing, using, and disposing of a fixed weather deck fire protection system consisting of five fire monitors that use water only and 1) are operated remotely by humans from a safe position on board the ship, and 2) operate autonomously using fire detectors to direct the water flow toward the fire and thereafter (if considered necessary) operated by humans. Both systems are compared with a REF case in which no weather deck fire protection system exists.

18.2.1 Approach

The difference between the two fire protection systems is that additional fire detectors are needed to provide early fire detection and to direct the fire monitors of the autonomous system to the fire. The fire suppressant delivery system is otherwise the same and consists of a water pump, piping, and five monitors for applying water to the fore and aft weather decks. For the design ro-ro cargo ship used in this analysis (the Magnolia Seaways) there are two monitors on the fore weather deck and three monitors on the aft weather deck. An example of the integration of a fixed fire protection system is described and illustrated in Section 18.1.1. It was assumed that two monitors will be activated to respond to a fire from opposing angles. The fundamental differences between the two fire protection systems are the activation time, which was assumed to be faster for the autonomous system than for the remotely operated system, the additional equipment needed for the autonomous system, and differences in the total amount of water used by each system (as the fire suppression performance is expected to be improved by applying water at an early stage).

Fire tests were conducted to determine the performance of the two fire protection systems. A set of assumptions (common to both systems and the REF case), see Section 18.2.2, was made to compare their fire suppression performance. These assumptions were based on availability of information and experience regarding the fuel type and quantity, fire growth and spread rates, and fire effluent production.

The overall system boundaries include an entire ro-ro cargo ship, the Magnolia Seaways, shown in Figure 29 with a load of freight truck cargo trailers on the fore and aft weather decks. The fire was assumed to start on the aft weather deck and the drencher system located in the superstructure that separates the fore and aft weather decks was assumed to prevent the fire from spreading beyond the aft weather deck. The effluents to surface water and the atmosphere from a fire and from testing/maintenance of the fire protection systems are included in the LCA models.

In a comparative LCA, conditions and processes that are the same for all systems being compared can drop out of the analysis, as their contributions are equal for each system. This reduces the system boundaries to the two fire protection systems and their fire suppression performance, and the reference case in which there is no fire protection system for the weather deck. The reason for this approach is to allow flexibility in the LCA models in case unforeseen alterations to the ship are needed to accommodate the fire protection systems.

Figure 29: Magnolia Seaways, the reference ship used for the Action 10-B LCAs.

The REF case is included in the comparison to provide context to the environmental impact results of the fire protection systems. It represents the current fire protection situation on most ro-ro cargo ships, as there is no IMO requirement for a fixed fire protection system for weather decks, although some ships may be equipped with fire protection systems anyway. It was assumed that the fire spreads to all the cargo on the aft weather deck, which is completely consumed in the fire. The number of cargo containers on the aft weather deck was assumed to be 22, which was obtained by scaling distances from a diagram of the aft weather deck.

18.2.2 Assumptions

It was necessary to make assumptions when sufficient resources and/or information were not available to support the LCA models, particularly regarding the fire model. If the same conditions and challenges are used for both fire protection systems for the comparison, then their relative fire performance can be preserved; however, it is not recommended to generalise these results to other systems or conditions. The assumptions regarding the fire model and general assumptions regarding other aspects of the LCA models are listed in Table 188.

Table 188: Assumptions required to complete the LCA analysis.

Focus	Assumption description
Fire model assumptions	According to WP04 the ship service life is 40 years (newbuilding) and there are 1,32E-04 fires per year. This results in 5,28E-03 "serious" fires during the lifetime of the ship.
	A fire starts in a truck or cargo container on the aft weather deck and does not spread beyond the aft weather deck.
	The fire tests adequately represent the fire conditions on the weather deck. This is a major assumption because the fire tests were fuel limited and the fire conditions in a cargo container will likely be oxygen limited at least until the walls of the container are breached.
	The results of the LASH FIRE fire tests are adequately represented by the FM Global fire model to estimate the effluents emitted to the atmosphere and surface water.
	Two monitors are activated to respond to the fire from opposing angles.
	The autonomous system has a shorter activation time than the remote system (30 s vs 300 s) as measured from the time visible flames (i.e., flames possible to detect by flame detectors) extending above the cargo container are observed.
	Less water is needed for the autonomous system because it activates when the fire is relatively smaller than for the remotely operated system (30 min of flow vs 60 min).
	The fire can spread to the contents of an adjacent container if the temperature inside the wall of the container exceeds 350 ˚C.
	The activation of the fire protection system prevents the total energy of the fire from increasing further.
	The autonomous system contains the fire within the original cargo container and prevents it from spreading to any other cargo.
	The remotely operated system allows the fire to spread to the two cargo containers adjacent to the original burning container, but not beyond.
	For the REF case the fire spreads to all the cargo on the aft weather deck, which is estimated to consist of 22 cargo containers.
	The cargo is comprised of a mix of materials commonly found in a furnished room, for example, sofas, chairs, tables, electronic equipment, books, carpet, etc.
	Each cargo container contains 10 times the weight of materials commonly found in a furnished room.
General assumptions	The installation is on a newbuilding ship rather than a retrofit on an existing ship.
	The fire protection system has the same service life as the ship.
	Data provided by UNF was assumed to be representative of the manufacturing processes (energy use, waste streams, etc) of both fire protection systems.
	The existing freshwater tank is capable of supplying the fixed fire protection system with sufficient water during the initial stage of a fire, even if the drencher system is activated, and that sea water thereafter is used.
	The system maintenance was assumed to follow the recommendations provided in D10.3.

18.2.3 Results

In Figure 30 it is evident that the REF case has much less impacts in all four categories due to the very low probability of a serious fire during the lifetime of the ship. The impacts of a fire (smoke, fire water run-off, replacement of damaged cargo) are barely visible in most categories. Of the fire-related impacts, the impact of replacing damaged cargo is higher than the smoke and fire water run-off impacts.

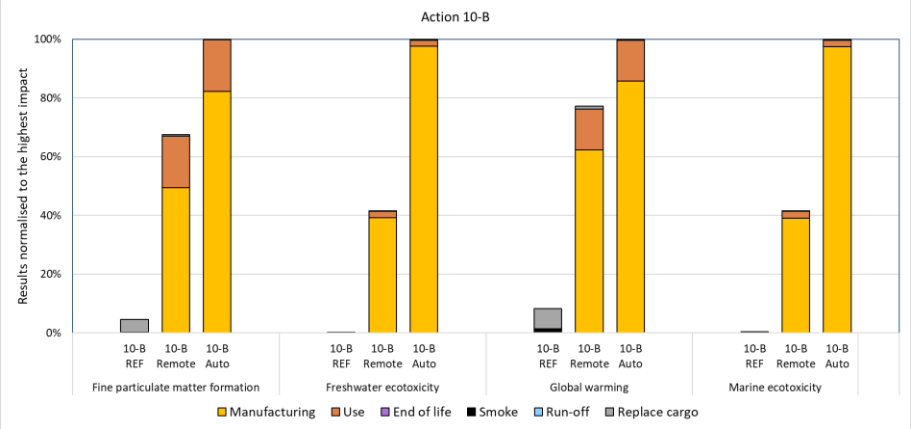

Figure 30: Detailed results for remotely operated and autonomous fixed fire protection systems, compared with the REF case with no fire protection.

The manufacturing phase of the autonomous system has a higher contribution than the remotely operated system due to the inclusion of fire detectors. There is more to manufacture for the autonomous system.

18.2.4 Discussion

From an environmental perspective, there are too few fires on ro-ro cargo ship weather decks to justify installation of a fixed fire protection system, at least those fire monitor systems described in this report. The impacts of manufacturing, using, and disposing of either an autonomous or remotely controlled fire protection system are higher than the impacts of fire if there are only 5,28E-03 fires during the lifetime of the ship[1].

If the number of fires on the Magnolia Seaways were increased by a factor of ca 450, shown in Figure 31 with 2,4 serious fires during the lifetime of the ship, the environmental impacts from the fire (smoke, replacing cargo) become larger than the impacts of manufacturing, using, and disposing of the fixed fire protection system.

[1] This number of predicted fires came from WP04 and is specific to the weather deck of the Magnolia Seaways.

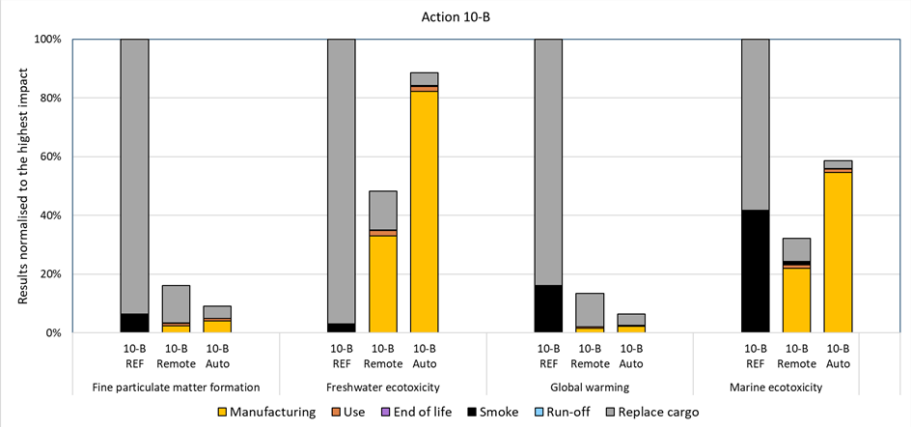

Figure 31: LCA results if there were 2.4 fires on the weather deck of the Magnolia Seaways during its lifetime.

18.3 Conclusion

A life cycle cost assessment of four weather deck fire monitor system solutions proposed by Action 10-B was performed. Further, the assessment was performed for two ship types, the selected generic ro-ro cargo, and ro-pax, ships that were used for the integration assessment. It needs to be emphasized that the installation cost is considerably dependent on the weather deck arrangement. Specifically, obstructions arrangements such as engine casing and deckhouses as well as deck area size and shape, have a significant impact on the number of fire monitors and fire detectors to be installed, which represent the majority of the installation and maintenance cost. Both the ro-ro cargo and ro-pax generic ships considered for the cost estimation have arranged obstructions in way of central casing, and so the cost assessment may be considered conservative regarding the applicability to the ro-ro world fleet. Finally, it is difficult to scale the cost per ship type, lane meters, or deck area, where the cost shall be calculated on a case-by-case basis.

18.3.1 LCA conclusion

The results of this comparative LCA indicate that the predicted number of serious fires likely to occur on the weather deck of a ship configured like the Magnolia Seaways is so low that the environmental impacts of producing, using, and disposing of a fixed water-based fire protection system outweigh the benefits.

The impacts of manufacturing and using the autonomous system are higher than the remotely operated system primarily due to the additional fire detection components.

It is, of course, a good thing that the probability of a serious fire is very low; hopefully this trend will continue to decrease over time as more fire safety measures are implemented. However, a low probability of serious fire does not mean that new fire safety measures should not be implemented. It is important to be prepared in case a fire does happen.

19 Updated performance of alternative fixed fire-fighting systems – Action 10-C

Main author of the chapter: Obrad Kuzmanovic, FLOW

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. Therefore, no cost assessment was performed.

Table 189. Action 10C - Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
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	Investment	N/A	N/A	N/A	N/A	N/A	N/A
		Operation	N/A	N/A	N/A	N/A	N/A	N/A
		Maintance	N/A	N/A	N/A	N/A	N/A	N/A
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed.

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

Main author of the chapter: Vito Radolovic, FLOW

This chapter presents an overview of the life cycle cost assessment for the solutions proposed by 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 RCM's please refer to Deliverables D04.9 ""Preliminary impact of solutions and related testing and demonstrations plan" [1].

20.1 Life cycle cost assessment

An installation cost assessment for four different system solutions was made:

1. **System#01** - A-30 fire insulation at decks separating ro-ro spaces (RCM Cont1b1)
2. **System#02** - Extinguishing system simultaneously activated above and below sub-dividing deck (RCM Cont1b2)
3. **System#03** - Solid curtain, transversal mounting, fully rolled down (RCM Cont3b)
4. **System#04** - Solid striped curtain, transversal mounting, fully/partly rolled down (RCM Cont3d)

The cost assessment was made for reference ships selected by the project with respect to the applicability of the solutions proposed; Magnolia Seaways the generic ro-ro cargo ship (System #3,#4) operated by DFDS Seaways, and Stena Flavia, the generic ro-pax ship (System #1,#2,#3,#4). The cost assessment was made for new buildings only.

20.1.1 Description of the developed solutions

20.1.1.1 System#01: A-30 fire insulation at decks separating ro-ro spaces (RCM Cont1b1)

The proposed risk control option is considering the arrangement of a A-30 thermal insulation at internal decks. The proposed RCO shall be applicable for ro-pax new buildings only. The integration on the Generic ship Stena Flavia considers application of insulation below Deck2, as illustrated on Figure 32. Total net deck and rampway area of 1000 m2 is to be protected.

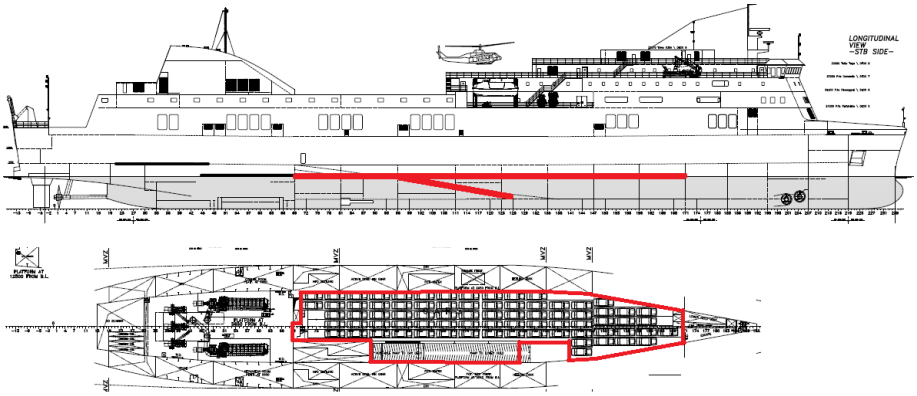

Figure 32. Horizontal subdivision - Stena Flavia

20.1.1.2 System#02: Extinguishing system simultaneously activated above and below sub-dividing deck (RCM Cont1b2)

The fixed fire-extinguishing system should comply with the requirements in SOLAS II-2/20.6.1 and cover the applicable area above and below the given deck. The activation above and below the deck should be simultaneous and automatic in the sense that activation occurs on both decks at the same time and that one part (above or below the deck) cannot be manually disconnected. Hence, the sprinkler areas above and below the given deck should belong to the same section of the extinguishing system. The proposed RCO shall be applicable for ro-pax new buildings only. The integration on the Generic ship Stena Flavia considers Deck2, as illustrated on Figure 32.

20.1.1.3 System#03 - Solid curtain, transversal mounting, fully rolled down (RCM Cont3b)

According to the RCO, the solid curtains are arranged to follow the drencher zones where the curtains shall divide each ro-ro space in two and additionally close the forward and aft opening of open ro-ro spaces towards the weather deck, where applicable. For the curtain operation, a clearance on deck in line with the curtain i.e a break in cargo stowage on deck is required. The curtain was assumed integrated in the ship structure to avoid interference with the clear height. Thus, local structural adjustments are considered.

The proposed RCO shall be applicable for ro-pax and ro-ro cargo new buildings.

The integration on the generic ro-pax ship Stena Flavia considers installation of the curtain system within ro-ro spaces at Deck1, Deck2, Deck3, Deck4 and Closure of aft openings at Deck3, as illustrated on Figure 33.

The aft opening is a large opening divided by a centre casing, thus requiring two closing devices. One of the devices will extend further down than the other due to the ramp that is positioned at a lower level than the normal Deck 4 level.

Total of 350 m of power cables and 650 m of signal cables are approximated.

Structural modification of Deck 2 structure, where the web height is lower than the required height for curtain installation, was considered manageable for new designs where ship height or reduction of

clear height (keeping same ship height) would be necessary with respect to the generic ship arrangement. **Further, this aspect has not been considered in the cost assessment.**

The integration on the generic ro-ro cargo ship Magnolia Seaways considers installation within ro-ro spaces at Tank top, Main deck, Upper deck and Closure of aft and forward openings at Weather deck, as illustrated on Figure 34. The arrangement of curtain at Main deck is in the area of movable decks, where specific arrangement in way of required clearance between movable deck panels was assumed manageable for new buildings. Total of 300 m of power cables and 400 m of signal cables are approximated.

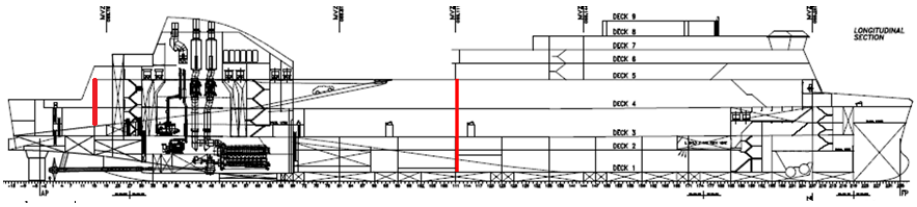

Figure 33. Vertical subdivision – Stena Flavia

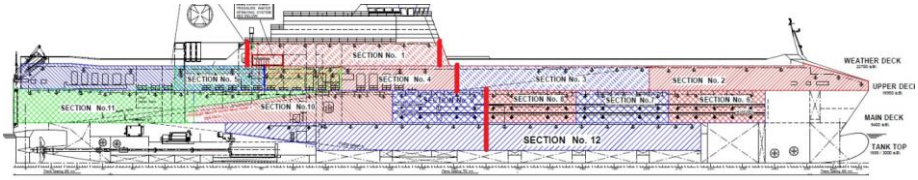

Figure 34. Vertical subdivision – Magnolia Seaways

20.1.1.4 System#04 - Solid striped curtain, transversal mounting, fully/partly rolled down (RCM Cont3d)

The proposed RCM shall be applicable for ro-pax and ro-ro cargo new buildings. The solid striped curtains arrangement is similar as for System#3 as illustrated on Figure 33 and Figure 34. For the striped curtain operation, a clearance on deck in line with the curtain i.e a break in cargo stowage on deck is not required as the curtain is lowered up to the cargo top. The curtain was assumed integrated in the ship structure to avoid interference with the clear height. Thus, local structural adjustments are considered.

Total of 750 m of power cables and 1800 m of signal cables are approximated for Stena Flavia, where total of 800 m of power cables and 1500 m of signal cables are approximated for Magnolia Seaways.

Structural modification of Deck 2 structure, where the web height is lower than the required height for curtain installation, was considered manageable for new designs where ship height or reduction of clear height (keeping same ship height) would be necessary with respect to the generic ship arrangement. **Further, this aspect has not been considered in the cost assessment.**

The arrangement of curtain at Magnolia Seaways's main deck is in the area of movable decks, where the installation of a striped curtain was found to be hardly manageable to avoid a break in the cargo

stowage. Further, 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.

Curtain Arrangement and operation, considered for the cost assessment, is to lower the curtain up to the cargo on the lowermost deck, leading to a break in the cargo stowage on the upper movable deck(s). This leads to an increased complexity of the deck arrangement, cargo loading/unloading operation and loss of revenue.

20.1.2 Life cycle cost model

20.1.2.1 Cost items description and assumptions

Independent of the system and ship type the following costs were considered:

- Investment cost,
- operation cost
- inspections, testing, and maintenance, and
- end of life cost.

The expected lifetime for a newly built ship was assumed to be 43 years for the ro-pax and 40.3 years for the ro-ro cargo. Further, it was assumed that all system solutions will be serviceable during the entire time and properly maintained.

20.1.2.1.1 System#1: A-30 fire insulation at decks separating ro-ro spaces (RCM Cont1b1)

20.1.2.1.1.1 Investment cost

The following items are considered:

- The purchasing cost for A30 fire insulation, and
- the labour cost for the installation work as well commissioning

For new buildings no additional cost was assumed for documentation, certification, and other administration activities.

The purchasing costs was estimated based on figures from system component suppliers at 8.2 EUR/m2. Total quantity of insulation is estimated 2.5 times the net deck area. This was based on the structural arrangement of Deck 2 (stiffeners, webs).

The estimated cost provided for the production, installation, and commissioning was based on a Croatian shipyard's standard where the average cost per area was estimated at 20.7 EUR/m2 (net deck area).

20.1.2.1.1.2 Operation cost

No operational cost considered. Influence on the operational cost by adding additional weight of the insulation was considered negligible.

20.1.2.1.1.3 Maintenance cost

Maintenance cost estimation was based on necessary local restoration of insulation due to damages caused by other system repairs and hot works during ship lifetime.

20.1.2.1.1.4 End of life cost

No end of life cost considered.

20.1.2.1.2 System#2: Extinguishing system simultaneously activated above and below sub-dividing deck (RCM Cont1b2)

20.1.2.1.2.1 Investment cost

The following items are considered:

- purchasing cost for the pump unit (increased capacity) due to higher capacity requirement (delta cost considered),
- purchasing cost of piping: additional piping lines and/or increased piping cross section (delta cost considered), and
- The labour cost for the piping installation work.

For new buildings no additional cost was assumed for documentation, certification, and other administration activities.

The purchasing costs was estimated based on figures from system component suppliers. The additional cost for the pump unit and piping was based on the required capacity increment of 10 %.

Additional piping of DN150, total 256 m estimated.

The estimated cost provided for the production, installation, and commissioning was based on a Croatian shipyard's standard. Cost for piping is estimated 4.25 EUR/t for production, 5.0 EUR/t for installation.

20.1.2.1.2.2 Operation cost

No operational cost considered.

20.1.2.1.2.3 Maintenance cost

No additional maintenance cost considered.

20.1.2.1.2.4 End of life cost

No end of life cost considered.

20.1.2.1.3 System#03 - Solid curtain, transversal mounting, fully rolled down (RCM Cont3b)

20.1.2.1.3.1 Investment cost

The following items are considered:

- The purchasing cost for solid curtain system (curtain cassette and sewing, el. Equipment, power and signal cables),
- additional construction steel (reduced web height),
- the labour cost for the engineering,
- the labour cost for the installation work as well commissioning:
    - Installation of solid curtain system,
    - installation of cabling, and
    - additional production and installation cost of steel structure(deck).

For new buildings no additional cost was assumed for documentation, certification, and other administration activities.

The purchasing costs was estimated based on figures from system component suppliers.

The estimated cost provided for the production, installation, and commissioning was based on a Croatian shipyard's standard where the average cost per weight or length was estimated. Production

and installation of steel structures is estimated, 2.5 EUR/t and 1.5 EUR/t, respectively. A cabling installation cost of 25 EUR/m was assumed.

20.1.2.1.3.2 Operation cost

The following items are considered:

- Additional crew operation during stowage,
- additional crew operation at movable ramps, and
- loss of revenue.

Influence on the operational cost by adding additional weight of the added system and steel weight was considered negligible.

Loss of revenue cost was based on the Stena and DFDS fleet statistics, where the average loss of revenue per lane meter of 12000 EUR/LM for ro-pax and 8000 EUR/LM for ro-ro cargo is estimated. Further, average loss in cargo area i.e. in lane meters of 3 meters for ro-pax and 6 m for ro-ro cargo is estimated at each solid curtain. A total of 32 lane meters loss for ro-pax and 41 lane meter loss for ro-ro cargo was considered.

20.1.2.1.3.3 Maintenance cost

Maintenance cost estimation was based on figures received from suppliers.

20.1.2.1.3.4 End of life cost

No end of life cost considered.

20.1.2.1.4 System#04 - Solid striped curtain, transversal mounting, fully/partly rolled down (RCM Cont3d)

20.1.2.1.4.1 Investment cost

The following items are considered:

- The purchasing cost for solid curtain system (curtain cassette and sewing, el. Equipment, power and signal cables),
- additional construction steel (reduced web height),
- the labour cost for the engineering,
- the labour cost for the installation work as well commissioning:
    - installation of solid curtain system,
    - installation of cabling, and
    - additional production and installation cost of steel structure(deck).

For new buildings no additional cost was assumed for documentation, certification, and other administration activities.

The purchasing costs was estimated based on figures from system component suppliers.

The estimated cost provided for the production, installation, and commissioning was based on a Croatian shipyard's standard where the average cost per weight or length was estimated. Production and installation of steel structures is estimated, 2.5 EUR/t and 1.5 EUR/t, respectively. A cabling installation cost of 25 EUR/m was assumed.

20.1.2.1.4.2 Operation cost

The following items are considered:

- Additional crew operation during stowage (movable decks only),
- additional crew operation at movable ramps (flaps, etc.), and
- loss of revenue.

Influence on the operational cost by adding additional weight of the added system and steel weight was considered negligible.

Loss of revenue cost was considered only for movable decks at generic ro-ro cargo ship, where a break in the cargo stowage was assumed according to considerations described in Chapter 20.1.1.4.

Loss of revenue cost was based on the Stena and DFDS fleet statistics, where the average loss of revenue per lane meter of 8000 EUR/LM for ro-ro cargo is estimated. Further, average loss in cargo area i.e. in lane meters of 2 meters for stowage on movable decks is estimated at each solid curtain. A total of 40 lane meters loss for ro-ro cargo was considered. Further, it was assumed that movable decks are used on 25% of the voyages.

20.1.2.1.4.3 Maintenance cost

Maintenance cost estimation was based on figures received from suppliers.

20.1.2.1.4.4 End of life cost

No end of life cost considered.

20.1.2.2 Life cycle cost component for ro-pax newbuilding

20.1.2.2.1 Investment cost

The estimated cost for the installation of the four system solutions, respectively, on a ro-pax new building is summarized in Table 190.

Table 190 Action 11A - The estimated cost for the installation of the four system solutions, respectively, on a ro-pax new building

System Number		System#01	System#02	System#03	System#04
System Name		Cont1b1: A-30 fire in	Cont1b2: Extinguish	Cont3b: Solid curtai	Cont3d: Solid stripe
Investment cost					
Purchasing cost	EUR	20 500.00	23 600.00	193 200.00	328 440.00
Insurance cost	EUR	-	-	-	-
Integration design & validation cost	EUR	400.00	-	3 000.00	3 000.00
Disassemble and modify the old system or structure	EUR	-	-	-	-
Road transporter cost	EUR	-	-	-	-
Ship transporter cost	EUR	-	-	-	-
Assembly/Installation cost	EUR	20 700.00	43 475.00	49 560.00	98 310.00
Comissioning cost	EUR	-	-	3 000.00	3 000.00
Document, certification and other administration costs	EUR	-	-	-	-
Loss of hire costs	EUR	-	-	-	-
Operator traning cost	EUR	1 000.00	-	-	-
Other cost	EUR	-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
Total cost	EUR	42 600.00	67 075.00	248 760.00	432 750.00

20.1.2.2.2 Operation cost

The operational cost for the installation of System#03, respectively, on a ro-pax new building was considered and summarized in Table 191. For other system solutions it was assumed that the impact on the operational cost is negligible and therefore not considered.

Table 191. Action 11A - The estimated operation cost for the installation of the four system solutions, respectively, on a ro-pax new building

System Number		System#01	System#02	System#03	System#04
System Name		Cont1b1: A-30 fire in	Cont1b2: Extinguish	Cont3b: Solid curtai	Cont3d: Solid stripe
Operation cost					
Additional Energy consumption	kWh/year	-	-	-	-
Additional Fuel Consumption	t/year	-	-	-	-
Reduce Fuel Consumption	t/year	-	-	-	-
Operator cost	EUR/year	-	-	4 000.00	-
Insurance, taxes, and other fees cost	EUR/year	-	-	-	-
Loss of cargo/loss revenue	EUR/year	-	-	1 152 000.00	-
Additional of cargo/profit revenue	EUR/year	-	-	-	-
Other operation cost	EUR/year	-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
Total operation cost exc. Energy cost	EUR/year	-	-	1 156 000.00	-

20.1.2.2.3 Maintenance cost

The estimated cost for inspections, testing, and maintenance for the four system solutions on a ro-pax new building is summarized inTable 192.

Table 192. Action 11A - The estimated cost for the inspection, testing and maintenance of the four system solutions for a ro-pax new building.

System Number		System#01	System#02	System#03	System#04
System Name		Cont1b1: A-30 fire in	Cont1b2: Extinguish	Cont3b: Solid curtai	Cont3d: Solid stripe
Maintenance cost					
Annual maintenance					
Annual system maintenance cost	EUR/year	1 000.00	-	2 000.00	6 000.00
Loss due to vessel downtime during maintenance	EUR/year	-	-	-	-
Other annual maintenance cost	EUR/year	-	-	-	-
		-	-	-	-
Total annual maintenance cost	EUR/year	1 000.00	-	2 000.00	6 000.00

20.1.2.2.4 End of life cost

No end of life cost considered.

20.1.2.3 Life cycle cost component for ro-ro cargo newbuilding

20.1.2.3.1 Investment cost

The estimated cost for the installation of the two system solutions, respectively, on a ro-ro cargo new building is summarized in Table 193.

Table 193 Action 11A - The estimated cost for the installation of the two system solutions, respectively, on a ro-ro cargo new building

System Number		System#01	System#02	System#03	System#04
System Name		Cont1b1: not aplicab	Cont1b2: not aplicat	Cont3b: Solid curtair	Cont3d: Solid stripe
Investment cost					
Purchasing cost	EUR	-	-	275 200.00	434 240.00
Insurance cost	EUR	-	-	-	-
Integration design & validation cost	EUR	-	-	3 000.00	3 000.00
Disassemble and modify the old system or structure	EUR	-	-	-	-
Road transporter cost	EUR	-	-	-	-
Ship transporter cost	EUR	-	-	-	-
Assembly/Installation cost	EUR	-	-	47 250.00	97 250.00
Comissioning cost	EUR	-	-	3 000.00	3 000.00
Document, certification and other administration costs	EUR	-	-	-	-
Loss of hire costs	EUR	-	-	-	-
Operator traning cost	EUR	-	-	-	-
Other cost	EUR	-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
Total cost	EUR	-	-	328 450.00	537 490.00

20.1.2.3.2 Operation cost

The operational cost for the installation of the two systems, respectively, on a ro-ro cargo new building was considered and summarized in Table 194.

Table 194. Action 11A - The estimated operation cost for the installation of the two system solutions, respectively, on a ro-ro cargo new building

System Number		System#01	System#02	System#03	System#04
System Name		Cont1b1: A-30 fire in	Cont1b2: Extinguish	Cont3b: Solid curtair	Cont3d: Solid stripe
Operation cost					
Additional Energy consumption	kWh/year	-	-	-	-
Additional Fuel Consumption	t/year	-	-	-	-
Reduce Fuel Consumption	t/year	-	-	-	-
Operator cost	EUR/year	-	-	5 000.00	2 000.00
Insurance, taxes, and other fees cost	EUR/year	-	-	-	-
Loss of cargo/loss revenue	EUR/year	-	-	1 968 000.00	80 000.00
Additional of cargo/profit revenue	EUR/year	-	-	-	-
Other operation cost	EUR/year	-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
		-	-	-	-
Total operation cost exc. Energy cost	EUR/year	-	-	1 973 000.00	82 000.00

20.1.2.3.3 Maintenance cost

The estimated cost for the two system solutions on a ro-ro cargo new building is summarized in Table 195.

Table 195. Action 11A - The estimated cost for the inspection, testing and maintenance of the two system solutions for a ro-ro cargo newbuilding

System Number		System#01	System#02	System#03	System#04
System Name		Cont1b1: A-30 fire in	Cont1b2: Extinguish	Cont3b: Solid curtai	Cont3d: Solid stripe
Maintenance cost					
Annual maintenance					
Annual system maintenance cost	EUR/year	-	-	2 000.00	6 000.00
Loss due to vessel downtime during maintenance	EUR/year	-	-	-	-
Other annual maintenance cost	EUR/year	-	-	-	-
		-	-	-	-
Total annual maintenance cost	EUR/year	-	-	2 000.00	6 000.00

20.1.2.3.4 End of life cost

No end of life cost considered

20.1.3 LCC Result

The LCC results for a ro-pax new building is shown in Table 196.

Table 196. Action 11A - The LCC results for a ro-pax new building

System Number		System#01	System#02	System#03	System#04
System Name		insulation at decks sepa	ultaneously activated ab	ain, transversal mounting,	n, transversal mounti
Life cycle cost result					
Unit		**Per Ship**			
Total Investment cost	EUR	42 600.00 €	67 075.00 €	248 760.00 €	432 750.00 €
Total Operation cost	EUR	- €	- €	27 222 264.38 €	- €
Total Maintenance cost	EUR	23 548.67 €	- €	47 097.34 €	141 292.03 €
Total End of Life cost	EUR	- €	- €	- €	- €
Total Life Cycle Cost	EUR	66 148.67 €	67 075.00 €	27 518 121.72 €	574 042.03 €
Unit		**Per Lane meter**			
Total Investment cost	EUR	19.36 €	30.49 €	113.07 €	196.70 €
Total Operation cost	EUR	- €	- €	12 373.76 €	- €
Total Maintenance cost	EUR	10.70 €	- €	21.41 €	64.22 €
Total End of Life cost	EUR	- €	- €	- €	- €
Total Life Cycle Cost	EUR	30.07 €	30.49 €	12 508.24 €	260.93 €

The LCC results for a ro-ro cargo newbuilding is shown in Table 197.

Table 197. Action 11A - The LCC results for a ro-ro cargo newbuilding

System Number		System#01	System#02	System#03	System#04
System Name		insulation at decks sepa	ultaneously activated ab	ain, transversal mounting,	n, transversal mounti
Life cycle cost result					
Unit		**Per Ship**			
Total Investment cost	EUR	- €	- €	328 450.00 €	537 490.00 €
Total Operation cost	EUR	- €	- €	44 699 355.84 €	1 857 753.26 €
Total Maintenance cost	EUR	- €	- €	45 311.06 €	135 933.17 €
Total End of Life cost	EUR	- €	- €	- €	- €
Total Life Cycle Cost	EUR	- €	- €	45 073 116.90 €	2 531 176.42 €
Unit		**Per Lane meter**			
Total Investment cost	EUR	- €	- €	85.73 €	140.30 €
Total Operation cost	EUR	- €	- €	11 667.80 €	484.93 €
Total Maintenance cost	EUR	- €	- €	11.83 €	35.48 €
Total End of Life cost	EUR	- €	- €	- €	- €
Total Life Cycle Cost	EUR	- €	- €	11 765.37 €	660.71 €

Results summary is shown in Table 198.

Table 198. Action 11A - Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Cont1b1	A-30 fire insulation	Investment	42 600.00 €	N/A	N/A	N/A	N/A	N/A
		Operation	0.00 €	N/A	N/A	N/A	N/A	N/A
		Maintance	23 548.60 €	N/A	N/A	N/A	N/A	N/A
		TOTAL	**66 148.60 €**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Cont1b2	Extinguishing system simultaneously activated above and below sub-dividing deck	Investment	67 075.00 €	N/A	N/A	N/A	N/A	N/A
		Operation	0.00 €	N/A	N/A	N/A	N/A	N/A
		Maintance	0.00 €	N/A	N/A	N/A	N/A	N/A
		TOTAL	**67 075.00 €**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Cont3b	Solid curtain, transversal mounting, fully rolled down	Investment	284 760.00 €	N/A	328 450.00 €	N/A	N/A	N/A
		Operation	27 222 264.38 €	N/A	44 699 355.84 €	N/A	N/A	N/A
		Maintance	47 097.34 €	N/A	45 311.06 €	N/A	N/A	N/A
		TOTAL	**27 554 121.72 €**	**N/A**	**45 073 116.90 €**	**N/A**	**N/A**	**N/A**
Cont3d	Solid striped curtain, transversal mounting, fully/partly rolled down	Investment	432 750.00 €	N/A	537 490.00 €	N/A	N/A	N/A
		Operation	0.00 €	N/A	1 857 753.26 €	N/A	N/A	N/A
		Maintance	141 292.03 €	N/A	135 933.17 €	N/A	N/A	N/A
		TOTAL	**574 042.03 €**	**N/A**	**2 531 176.43 €**	**N/A**	**N/A**	**N/A**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed

20.2 Conclusion

Main author of the chapter: Vito Radolovic, FLOW

An assessment of the lifecycle cost for the subdivision system solutions proposed by Action 11-A was performed. Further, the assessment was performed for two ship types, the selected generic ro-ro cargo, and ro-pax, ships that were used for integration and LCC assessment.

It needs to be emphasized that the installation and operational cost is dependent on the ro-ro space arrangement for all solutions. Specifically, cargo space size (area) and deck structural arrangement have a considerable impact.

For solutions systems #01 and #02, the cost estimates can easily be scaled per ship type and cargo deck area. However, for solutions systems #03 and #04 it is difficult to scale the cost per ship type, lane meters, or deck area, where the cost shall be calculated on a case-by-case basis.

Further, significant cost differences may occur depending on the business area i.e. shipyard location, particularly the installation cost. However, the cost estimates can easily be adjusted to a specific business area.

21 Ensuring safe evacuation – Action 11-B

Main author of the chapter: Vito Radolovic, FLOW

Solution proposed by Action 11-B i.e. Ensuring safe evacuation is:

- RCM Cont5 -Alternative disembarkation path based on slides

The proposed RCM was not assessed as the development was found to be not mature for ship integration and further assessments, Ref. D05.7 “Ship integration evaluation” [3].

Results summary is shown in Table 199.

Table 199. Action 11B- Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Cont5	Alternative disembarkation path based on slides	Investment	N/A	N/A	N/A	N/A	N/A	N/A
		Operation	N/A	N/A	N/A	N/A	N/A	N/A
		Maintance	N/A	N/A	N/A	N/A	N/A	N/A
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed

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

Main author of the chapter: Martin Carlsson, STL

This chapter presents an overview of the life cycle cost assessment for the solutions proposed by Action 11-C i.e. Safe design with ro-ro space openings. Two RCMs finally proposed by WP11 and assessed within this report are:

- 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"Preliminary impact of solutions and related testing and demonstrations plan" [1].
The following solutions were discarded during the development process and not considered for further assessments within WP05, Ref. D05.7"Ship integration evaluation" [3]:

- RCM Cont7 - Closure of side openings
- RCM Cont8 - Shutters for side openings

22.1 Life cycle cost assessment

An installation cost assessment for one system solutions was made:

- **System#01** - Ship maneuvering/operation to limit the effect of fire at least in critical areas (Cont9)

The proposed RCM Cont10 was not assessed as the development was found to be not mature for ship integration and further assessments, Ref. D05.7 [3].

The cost assessment was made for reference ships selected by the project with respect to the applicability of the solutions proposed; Magnolia Seaways the generic ro-ro cargo ship operated by DFDS Seaways, Stena Flavia, the generic ro-pax ship and Torrens, operated by Wallenius Marine. The cost assessment was made for new buildings and existing ships.

22.1.1 Description of the developed solution

22.1.1.1 System#01: Ship manoeuvring/operation to limit the effect of fire at least in critical areas (RCM Cont9)

Changing course to favorable direction can help to avoid smoke spread to critical areas. It should be noted, however, that maneuvering can be impossible due to a blackout and that while side wind is favorable in terms of avoiding smoke, it might be in contradiction with safe evacuation procedures. General guidelines are given within D05.7 [3]. More detailed guidelines should be prepared for each ship individually, to assist the ship's master in a possible emergency.

22.1.2 Life cycle cost model

22.1.2.1 Cost items description and assumptions

Independent of the system and ship type the following costs were considered:

- Investment cost,
- operation cost,

- inspections, testing, and maintenance, and
- end of life cost.

The expected lifetime for a newly built ship was assumed to be 43 years for the ro-pax, 40.3 years for the ro-ro cargo and 28.8 years for the vehicle carrier. The expected lifetime for existing ships was assumed to be 22.8 years for the ro-pax, 22.9 years for the ro-ro cargo and 17 years for the vehicle carrier.

22.1.2.1.1 System#01: Ship manoeuvring/operation to limit the effect of fire at least in critical areas (RCM Cont9)

22.1.2.1.1.1 Investment cost

The following items are considered:

- Establish procedures in company,
- establish procedures on board, and
- crew training.

Cost for establishing procedures and crew training on board was estimated based on Stena best practice experience.

22.1.2.1.1.2 Operation cost

No operational cost considered.

22.1.2.1.1.3 Maintenance cost

No maintenance cost considered.

22.1.2.1.1.4 End of life cost

No end of life cost considered.

22.1.2.2 Life cycle cost component

22.1.2.2.1 Investment cost

The estimated cost for the installation of the system solution was assumed similar for all ship types as well as new buildings and existing ships, summarized in

Table 200.

Table 200 Action 11C- The estimated cost for the installation of the system solution

System Number		System#01
System Name		Cont 9 - Ship manoeu
Investment cost		
Purchasing cost	EUR	-
Insurance cost	EUR	-
Integration design & validation cost	EUR	-
Disassemble and modify the old system or structure	EUR	-
Road transporter cost	EUR	-
Ship transporter cost	EUR	-
Assembly/Installation cost	EUR	-
Comissioning cost	EUR	-
Document, certification and other administration costs	EUR	760.00
Loss of hire costs	EUR	-
Operator traning cost	EUR	2 080.00
Other cost	EUR	-
		-
		-
		-
		-
		-
		-
		-
Total cost	EUR	2 840.00

22.1.3 LCC Result

Main author of the chapter: Vito Radolovic, FLOW

The LCC results for all ship types as well as new buildings and existing ships is shown in Table 201.

Table 201. Action 11C- The LCC results for a ro-ro cargo new building

System Number		**System#01**
System Name		Cont 9 - Ship manoeu
Unit		**Per Ship**
Total Investment cost	**EUR**	2 840.00 €
Total Operation cost	**EUR**	- €
Total Maintenance cost	**EUR**	- €
Total End of Life cost	**EUR**	- €
Total Life Cycle Cost	**EUR**	2 840.00 €

Results summary is shown in Table 202.

Table 202. Action 11C- Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Cont9	Ship manoeuvring/operation to limit the effect of fire at least in critical areas	Investment	2 840.00 €	2 840.00 €	2 840.00 €	2 840.00 €	2 840.00 €	2 840.00 €
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		Maintance	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		TOTAL	**2 840.00 €**	**2 840.00 €**	**2 840.00 €**	**2 840.00 €**	**2 840.00 €**	**2 840.00 €**
Cont10	Safety distances between side and end openings and critical areas	Investment	N/A	N/A	N/A	N/A	N/A	N/A
		Operation	N/A	N/A	N/A	N/A	N/A	N/A
		Maintance	N/A	N/A	N/A	N/A	N/A	N/A
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed

22.2 Conclusion

An assessment of the lifecycle cost for the solution proposed by Action 11-C was performed. Further, the assessment was performed for three ship types, the selected generic ro-ro cargo, ro-pax and vehicle carriers that were used for integration and LCC assessment. The considered solution cost is independent of the arrangement of the vessel.

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

Main author of the chapter: Vito Radolovic, FLOW

This chapter presents an overview of the life cycle cost assessment for the solutions proposed by Action 11-D i.e. Ro-ro space ventilation and smoke extraction. Four RCMs were proposed by WP11 and one RCO was selected (Ref. D04.6 "Cost-effectiveness assessment report" [2]) and assessed within this report:

- 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
- RCO16 - Guideline for fire ventilation in closed ro-ro space

For the description of the RCM's please refer to Deliverable D04.9 "Preliminary impact of solutions and related testing and demonstrations plan"[1], for the description of the RCO please refer to Deliverable D04.6, [2].

23.1 Life cycle cost assessment

An installation cost assessment for selected system solutions was made:

- **System#01** - Tactical guidelines for manual intervention (RCM Cont13)
- **System#02** - SOLAS requirement of reversible fans (RCM Cont14)

The objective of RCM Cont11 is not to literally develop a solution, instead it is to establish a harmonized procedure how to calculate side openings. Therefore, no cost assessment was performed. However, no additional cost compared to the current state is forseen.

RCM Cont12 was discarded during the development process and not considered for further assessments within WP05. However, it was considered no additional cost for integration.

Cost assessment for the RCO16 was found to be same as for System#1, RCM Cont13.

23.1.1 Description of the developed solution

23.1.1.1 System#01: Tactical guidelines for manual intervention (RCM Cont13)

The guideline is a tactical guideline intended for the crew on board the ship and will provide predefined "how-to" scenarios on how to use the ventilation system and how to manoeuvre the ship to allow access for the fire team into the ro-ro space, if possible.

The proposed guideline shall be applicable for ro-pax and ro-ro cargo new buildings and existing ships. The integration onboard ships would include preparation of onboard procedures for each ship and continuous training through fire drills.

23.1.1.2 System#02: SOLAS requirement of reversible fans (RCM Cont14)

The proposed solution is to install reversible fans in closed ro-ro spaces on ro-ro cargo and ro-pax new buildings. The proposed solution requires that all ducts should be equipped with reversible fans in closed ro-ro spaces. Further, the fans that are installed in a ro-ro space shall fulfil the ventilation requirement in SOLAS II-2/20 and should be able to operate in both supply and exhaust mode, i.e., be reversible. The reversible fans should be the fans that are used in the every-day ventilation system onboard and be able to operate in the required capacity range.

23.1.1.3 Integration on a ro-pax

There are two closed ro-ro spaces arranged on the Stena Flavia reference ship. All ventilation ducts are equipped with fans. Total 19 fans are installed, of which 10 units are reversable. According to the available cost data from the suppliers, there would be a negligible cost difference between the reversible and non reversible fan of the same capacity. Therefore, for a ro-pax new bulding it was considered no additional cost for implementation and thus not assessed.

23.1.1.4 Integration on a ro-ro cargo

There are two closed ro-ro spaces arranged on the Magnolia Seaways reference ship, lower and upper hold. At upper hold, all ventilation ducts are equipped with fans where 14 units are reversable of total 24 fans installed. At lower hold, there are three ventilation ducts arranged, where two exhaust ducts in the fore cargo hold area equipped with total 4 fans, and one (large) supply ducts in the aft area, equipped with one buster fan installed. Integration of the proposed solution considers installation of reversible fans in all ducts. According to the available cost data from the suppliers, there would be a negligible cost difference between the reversible and non reversible fan of the same capacity. Therefore, fans are to be added only in the lower hold supply duct. A conservative approach was considered, adding 4 reversible fans in the supply duct of the same capacity as the exhaust fans. Cost data from the suppliers was considered.

23.1.2 Life cycle cost model

23.1.2.1 Cost items description and assumptions

Independent of the system and ship type the following costs were considered:

- Investment cost,
- operation cost,
- inspections, testing, and maintenance, and
- end of life cost.

It was assumed that all system solutions will be serviceable during the entire time if properly maintained.

23.1.2.1.1 System#01: Tactical guidelines for manual intervention (RCM Cont13)

23.1.2.1.1.1 Investment cost

The following items are considered:

- Establishment of onboard procedures, and
- adjustment of the ventilation system: predefined operation “fire” modes.

23.1.2.1.1.2 Operation cost

The following item was considered:

- Training of fire scenarios through fire drills.

23.1.2.1.1.3 Maintenance cost

No maintanace cost considered.

23.1.2.1.1.4 End of life cost

No end of life cost considered.

23.1.2.1.2 System#02: SOLAS requirement of reversible fans (RCM Cont14)

23.1.2.1.2.1 Investment cost

The following items are considered:

- The purchasing cost of fans, fire dampers, motor starter cabinets, cabling,
- the labour cost for the installation work:
  - installation of equipment units.

23.1.2.1.2.2 Investment cost assessment assumptions

For each of the systems, the cost for purchasing, production and installation was considered.

The purchasing costs for each component were estimated based on figures from system component suppliers. The estimated cost provided for the production, installation, and commissioning was based on a Croatian shipyards standard.

23.1.2.1.2.3 Operation cost

No operational cost considered.

23.1.2.1.2.4 Maintenance cost

Additional equipment maintenance cost considered.

23.1.2.1.2.5 End of life cost

No end of life cost considered.

23.1.2.2 Life cycle cost component for ro-pax

23.1.2.2.1 Investment cost

The estimated cost for the installation of the system solutions on a ro-pax new building is summarized in Table 203. For existing ships, same cost was considered for System#1 where System#2 is not applicable for ro-pax existing ships.

Table 203 Action 11D- The estimated cost for the installation of the four system solutions, respectively, on a ro-pax

System Number		System#01	System#02
System Name		Cont 13: Tactical guid	Cont 14: SOLAS requ
Investment cost			
Purchasing cost	EUR	-	-
Insurance cost	EUR	-	-
Integration design & validation cost	EUR	-	-
Disassemble and modify the old system or structure	EUR	-	-
Road transporter cost	EUR	-	-
Ship transporter cost	EUR	-	-
Assembly/Installation cost	EUR	-	-
Comissioning cost	EUR	-	-
Document, certification and other administration costs	EUR	4 500.00	-
Loss of hire costs	EUR	-	-
Operator traning cost	EUR	-	-
Other cost	EUR	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total cost	EUR	4 500.00	-

23.1.2.2.2 Operation cost

The operational cost on a ro-pax new building was considered and summarized in Table 204. For ro-pax existing ships, same cost was considered for System#1 where System#2 is not applicable.

Table 204. Action 11D- The estimated operation cost for the installation of the four system solutions, respectively, on a ro-pax new building

System Number		System#01	System#02
System Name		Cont 13: Tactical guid	Cont 14: SOLAS requ
Operation cost			
Additional Energy consumption	kWh/year	-	-
Additional Fuel Consumption	t/year	-	-
Reduce Fuel Consumption	t/year	-	-
Operator cost	EUR/year	1 000.00	-
Insurance, taxes, and other fees cost	EUR/year	-	-
Loss of cargo/loss revenue	EUR/year	-	-
Additional of cargo/profit revenue	EUR/year	-	-
Other operation cost	EUR/year	-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
		-	-
Total operation cost exc. Energy cost	EUR/year	1 000.00	-

23.1.2.2.3 Maintenance cost

No maintenance cost considered.

23.1.2.2.4 End of life cost

No end of life cost considered.

23.1.2.3 Life cycle cost component for ro-ro cargo

23.1.2.3.1 Investment cost

The estimated cost for the installation of the two system solutions, respectively, on a ro-ro cargo new building is summarized in

Table 205. For ro-ro cargo existing ships, same cost was considered for System#1, where System#2 is not applicable.

Table 205 Action 11D- The estimated cost for the installation of the two system solutions, respectively, on a ro-ro cargo new building

	System Number		System#01	System#02
	System Name		Cont 13: Tactical guid	Cont 14: SOLAS requ
Investment cost				
	Purchasing cost	EUR	-	33 250.00
	Insurance cost	EUR	-	-
	Integration design & validation cost	EUR	-	-
	Disassemble and modify the old system or structure	EUR	-	-
	Road transporter cost	EUR	-	-
	Ship transporter cost	EUR	-	-
	Assembly/Installation cost	EUR	-	1 200.00
	Comissioning cost	EUR	-	-
	Document, certification and other administration costs	EUR	4 500.00	-
	Loss of hire costs	EUR	-	-
	Operator traning cost	EUR	-	-
	Other cost	EUR	-	-
			-	-
			-	-
			-	-
			-	-
			-	-
			-	-
	Total cost	EUR	4 500.00	34 450.00

23.1.2.3.2 Operation cost

The operational cost for the installation of the two systems, respectively, on a ro-ro cargo new building was considered and summarized in Table 206. For ro-ro cargo existing ships, same cost was considered for System#1 where System#2 is not applicable.

Table 206. Action 11D- The estimated operation cost for the installation of the two system solutions, respectively, on a ro-ro cargo new building

	System Number		System#01	System#02
	System Name		Cont 13: Tactical guid	Cont 14: SOLAS requ
Operation cost				
	Additional Energy consumption	kWh/year	-	-
	Additional Fuel Consumption	t/year	-	-
	Reduce Fuel Consumption	t/year	-	-
	Operator cost	EUR/year	1 000.00	-
	Insurance, taxes, and other fees cost	EUR/year	-	-
	Loss of cargo/loss revenue	EUR/year	-	-
	Additional of cargo/profit revenue	EUR/year	-	-
	Other operation cost	EUR/year	-	-
			-	-
			-	-
			-	-
			-	-
			-	-
			-	-
			-	-
	Total operation cost exc. Energy cost	EUR/year	1 000.00	-

23.1.2.3.3 Maintenance cost

The estimated cost for the System#2 on a ro-ro cargo new building is summarized in Table 207. No maintenance cost considered for System#1 for both existing ships and new buildings. Further, System#2 is not applicable for existing ships.

Table 207. Action 11D- The estimated cost for the inspection, testing and maintenance of the two system solutions for a ro-ro cargo newbuilding

System Number		System#01	System#02
System Name		Cont 13: Tactical guid	Cont 14: SOLAS requ
Maintenance cost			
Annual maintenance			
Annual system maintenance cost	EUR/year	-	400.00
Loss due to vessel downtime during maintenance	EUR/year	-	-
Other annual maintenance cost	EUR/year	-	-
		-	-
Total annual maintenance cost	EUR/year	-	400.00

23.1.2.3.4 End of life cost

No end of life cost considered

23.1.3 LCC Result

The LCC results for a ro-pax new building is shown in Table 208.

Table 208. Action 11D- The LCC results for a ro-pax new building

System Number		System#01	System#02
System Name		al guidelines for manua	OLAS requirement of reve
Life cycle cost result			
Unit		**Per Ship**	
Total Investment cost	EUR	4 500.00 €	- €
Total Operation cost	EUR	23 548.67 €	- €
Total Maintenance cost	EUR	- €	- €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	28 048.67 €	- €
Unit		**Per Lane meter**	
Total Investment cost	EUR	2.05 €	- €
Total Operation cost	EUR	10.70 €	- €
Total Maintenance cost	EUR	- €	- €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	12.75 €	- €

The LCC results for a ro-pax existing ship is shown in Table 209.

Table 209. Action 11D- The LCC results for a ro-pax existing ship

System Number		System#01
System Name		al guidelines for manua
Life cycle cost result		
Unit		**Per Ship**
Total Investment cost	EUR	4 500.00 €
Total Operation cost	EUR	16 167.12 €
Total Maintenance cost	EUR	- €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	20 667.12 €
Unit		**Per Lane meter**
Total Investment cost	EUR	2.05 €
Total Operation cost	EUR	7.35 €
Total Maintenance cost	EUR	- €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	9.39 €

The LCC results for a ro-ro cargo newbuilding is shown in Table 210.

Table 210. Action 11D- The LCC results for a ro-ro cargo newbuilding

System Number		System#01	System#02
System Name		al guidelines for manua	LAS requirement of reve
Life cycle cost result			
Unit		**Per Ship**	
Total Investment cost	EUR	4 500.00 €	34 450.00 €
Total Operation cost	EUR	22 655.53 €	- €
Total Maintenance cost	EUR	- €	9 062.21 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	27 155.53 €	43 512.21 €
Unit		**Per Lane meter**	
Total Investment cost	EUR	1.17 €	8.99 €
Total Operation cost	EUR	5.91 €	- €
Total Maintenance cost	EUR	- €	2.37 €
Total End of Life cost	EUR	- €	- €
Total Life Cycle Cost	EUR	7.09 €	11.36 €

The LCC results for a ro-ro cargo existing ship is shown in Table 211.

Table 211. Action 11D- The LCC results for a ro-ro cargo existing ship

System Number		**System#01**
System Name		al guidelines for manua
Life cycle cost result		
Unit		**Per Ship**
Total Investment cost	EUR	4 500.00 €
Total Operation cost	EUR	16 167.12 €
Total Maintenance cost	EUR	- €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	20 667.12 €
Unit		**Per Lane meter**
Total Investment cost	EUR	1.17 €
Total Operation cost	EUR	4.22 €
Total Maintenance cost	EUR	- €
Total End of Life cost	EUR	- €
Total Life Cycle Cost	EUR	5.39 €

Results summary is shown in Table 212.

Table 212. Action 11D- Breakdown of the marginal costs (in euros)

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Cont11	Guidance on calculation of side openings in ro-ro spaces	Investment	N/A	N/A	N/A	N/A	N/A	N/A
		Operation	N/A	N/A	N/A	N/A	N/A	N/A
		Maintance	N/A	N/A	N/A	N/A	N/A	N/A
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Cont13	Tactical guidelines for manual interventions	Investment	4 500.00 €	4 500.00 €	4 500.00 €	4 500.00 €	N/A	N/A
		Operation	23 548.67 €	16 167.12 €	22 655.53 €	16 167.12 €	N/A	N/A
		Maintance	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		TOTAL	**28 048.67 €**	**20 667.12 €**	**27 155.53 €**	**20 667.12 €**	**N/A**	**N/A**
Cont14	SOLAS requirement of reversible fans	Investment	0.00 €	N/A	34 450.00 €	N/A	N/A	N/A
		Operation	0.00 €	N/A	0.00 €	N/A	N/A	N/A
		Maintance	0.00 €	N/A	9 062.21 €	N/A	N/A	N/A
		TOTAL	**0.00 €**	**N/A**	**43 512.21 €**	**N/A**	**N/A**	**N/A**
RCO16	Guideline for fire ventilation in closed ro-ro space	Investment	4 500.00 €	4 500.00 €	4 500.00 €	4 500.00 €	N/A	N/A
		Operation	23 548.67 €	16 167.12 €	22 655.53 €	16 167.12 €	N/A	N/A
		Maintance	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		TOTAL	**28 048.67 €**	**20 667.12 €**	**27 155.53 €**	**20 667.12 €**	**N/A**	**N/A**

Ro-Pax = ro-ro passenger ships, Ro-Ro = ro-ro cargo ships, VC = vehicle carriers.
NB = new buildings, Ex = existing ships.
N/A = not assessed

23.2 Conclusion

An assessment of the lifecycle cost for the system solutions proposed by Action 11-D was performed. Further, the assessment was performed for two ship types, the selected generic ro-ro cargo, and ro-pax, ships that were used for integration and LCC assessment.

For the proposed solutions RCM Cont11 and RCM Cont12 it was considered no additional cost for implementation and thus not assessed. The investment and operational cost at RCM Cont13 was considered not dependent of the ship type but it needs to be emphasized that the integration is dependent on ventilation arrangement onboard.

Generally, according to available information on the ventilation arrangements at ro-ro and ro-pax ships it may be concluded that no additional cost shall be considered by integration of RCM Cont14, due to typical installation of fans in all ventilation ducts (as required by RCM Cont14). However, at the ro-ro cargo generic ship, the ventilation arrangement slightly differs from the typical arrangement and therefore a conservative approach was considered.

24 Input for Formal Safety Assessment (FSA)

Main author of the chapter: Vito Radolovic, FLOW

For the Formal Safety assessment (FSA), the cost assessment was calculated on the level for Risk Control Options (RCOs). A summary of the RCO's marginal cost is shown in Table 213.

Table 213. Summary of the marginal costs (in euros) for the RCOs.

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
RCO1	Fire patrol. Fire confirmation & localization	Investment	24 200.00 €	24 200.00 €	21 320.00 €	21 320.00 €	18 820.00 €	18 820.00 €
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		Maintance	41 240.64 €	26 684.95 €	26 684.95 €	26 684.95 €	17 372.69 €	10 165.90 €
		TOTAL	**65 440.64 €**	**50 884.95 €**	**48 004.95 €**	**48 004.95 €**	**36 192.69 €**	**28 985.90 €**
RCO2	Signage and markings for effective wayfinding and localization	Investment	8 840.00 €	30 840.00 €	8 840.00 €	30 840.00 €	12 040.00 €	36 040.00 €
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		Maintance	12 189.08 €	8 348.60 €	11 711.85 €	8 348.60 €	9 640.86 €	6 761.84 €
		TOTAL	**21 029.08 €**	**39 188.60 €**	**20 551.85 €**	**39 188.60 €**	**21 680.86 €**	**42 801.84 €**
RCO3	Efficient first response	Investment	8 590.00 €	8 590.00 €	6 550.00 €	6 550.00 €	6 550.00 €	6 550.00 €
		Operation	32 732.65 €	22 472.30 €	19 936.86 €	14 227.07 €	16 426.98 €	11 522.82 €
		Maintance	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		TOTAL	**41 322.65 €**	**31 062.30 €**	**26 486.86 €**	**20 777.07 €**	**22 976.98 €**	**18 072.82 €**
RCO4	Manual firefighting for Alternatively Powered Vehicles	Investment	23 700.00 €	23 700.00 €	22 260.00 €	22 260.00 €	27 260.00 €	27 260.00 €
		Operation	22 606.72 €	15 520.44 €	15 224.51 €	10 864.31 €	12 544.24 €	8 799.25 €
		Maintance	31 845.47 €	19 989.50 €	26 787.28 €	19 989.50 €	26 046.92 €	15 241.75 €
		TOTAL	**78 152.19 €**	**59 209.94 €**	**64 271.79 €**	**53 113.81 €**	**65 851.16 €**	**51 301.00 €**
RCO5	Alarm system interface prototype	Investment	73 700.00 €	N/A	73 700.00 €	N/A	73 700.00 €	N/A
		Operation	0.00 €	N/A	0.00 €	N/A	0.00 €	N/A
		Maintance	12 106.53 €	N/A	12 106.53 €	N/A	7 162.69 €	N/A
		TOTAL	**85 806.53 €**	**N/A**	**85 806.53 €**	**N/A**	**80 862.69 €**	**N/A**
RCO6	Process for development of procedures and design for efficient activation of extinguishing system	Investment	3 640.00 €	84 540.00 €	3 640.00 €	68 100.00 €	3 640.00 €	5 140.00 €
		Operation	20 534.44 €	14 097.73 €	19 755.62 €	14 097.73 €	16 277.64 €	11 418.07 €
		Maintance	0.00 €	1 616.71 €	0.00 €	1 616.71 €	0.00 €	0.00 €
		TOTAL	**24 174.44 €**	**100 254.44 €**	**23 395.62 €**	**83 814.44 €**	**19 917.64 €**	**16 558.07 €**
RCO7	Training module for efficient activation of extinguishing system	Investment	24 330.00 €	24 330.00 €	24 330.00 €	24 330.00 €	23 730.00 €	23 730.00 €
		Operation	64 546.91 €	44 314.09 €	62 098.80 €	44 314.09 €	88 593.67 €	62 144.68 €
		Maintance	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		TOTAL	**88 876.91 €**	**68 644.09 €**	**86 428.80 €**	**68 644.09 €**	**112 323.67 €**	**85 874.68 €**
RCO8	Safe electrical connection for reefers	Investment	138 926.00 €	167 796.10 €	106 726.00 €	124 156.10 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	23 548.67 €	16 167.12 €	22 655.53 €	16 167.12 €	N/A	N/A
		TOTAL	**162 474.67 €**	**183 963.22 €**	**129 381.53 €**	**140 323.22 €**	**N/A**	**N/A**
RCO9	Safe electrical connection of reefers and electric vehicles (EVs)	Investment	168 290.68 €	197 150.78 €	N/A	N/A	N/A	N/A
		Operation	0.00 €	0.00 €	N/A	N/A	N/A	N/A
		Maintance	47 097.34 €	32 334.25 €	N/A	N/A	N/A	N/A
		TOTAL	**215 388.02 €**	**229 485.03 €**	**N/A**	**N/A**	**N/A**	**N/A**
RCO10	Fire detection on weather decks	Investment	66 733.00 €	84 207.00 €	87 169.00 €	106 014.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	117 743.36 €	80 835.62 €	113 277.64 €	80 835.62 €	N/A	N/A
		TOTAL	**184 476.36 €**	**165 042.62 €**	**200 446.64 €**	**186 849.62 €**	**N/A**	**N/A**
RCO11	Fire detection in closed ro-ro spaces & open ro-ro spaces	Investment	209 469.00 €	269 719.00 €	288 444.00 €	372 194.00 €	589 400.00 €	751 400.00 €
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		Maintance	202 518.58 €	139 037.27 €	194 837.54 €	139 037.27 €	240 804.54 €	168 914.11 €
		TOTAL	**411 987.58 €**	**408 756.27 €**	**483 281.54 €**	**511 231.27 €**	**830 204.54 €**	**920 314.11 €**
RCO12	Visual system for fire confirmation and localization	Investment	184 877.00 €	220 227.00 €	265 764.00 €	304 539.00 €	935 039.00 €	981 539.00 €
		Operation	23 548.67 €	16 167.12 €	22 655.53 €	16 167.12 €	18 667.02 €	13 094.12 €
		Maintance	117 743.36 €	194 005.50 €	271 866.33 €	194 005.50 €	102 668.60 €	72 017.64 €
		TOTAL	**326 169.03 €**	**430 399.62 €**	**560 285.86 €**	**514 711.62 €**	**1 056 374.62 €**	**1 066 650.76 €**
RCO13	Dry-pipe sprinkler system for vehicle carriers	Investment	N/A	N/A	N/A	N/A	1 293 118.07 €	1 641 763.07 €
		Operation	N/A	N/A	N/A	N/A	480 587.73 €	296 992.54 €
		Maintance	N/A	N/A	N/A	N/A	249 627.67 €	173 334.79 €
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**2 023 333.47 €**	**2 112 090.39 €**
RCO14	Fixed remotely-controlled fire monitor system using water for weather decks	Investment	185 635.00 €	207 275.00 €	266 690.00 €	292 870.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	131 872.56 €	90 535.90 €	158 588.69 €	113 169.87 €	N/A	N/A
		TOTAL	**317 507.56 €**	**297 810.90 €**	**425 278.69 €**	**406 039.87 €**	**N/A**	**N/A**
RCO15	Fixed autonomous fire monitor system using water for weather decks	Investment	292 735.00 €	332 375.00 €	369 290.00 €	413 970.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	131 872.56 €	90 535.90 €	158 588.69 €	113 169.87 €	N/A	N/A
		TOTAL	**424 607.56 €**	**422 910.90 €**	**527 878.69 €**	**527 139.87 €**	**N/A**	**N/A**
RCO16	Guideline for fire ventilation in closed ro-ro space	Investment	4 500.00 €	4 500.00 €	4 500.00 €	4 500.00 €	N/A	N/A
		Operation	23 548.67 €	16 167.12 €	22 655.53 €	16 167.12 €	N/A	N/A
		Maintance	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		TOTAL	**28 048.67 €**	**20 667.12 €**	**27 155.53 €**	**20 667.12 €**	**N/A**	**N/A**

25 Conclusion

Main author of the chapter: Vito Radolovic, FLOW

This report presents the life cycle cost (LCC) and environmental assessment (LCA) results addressed to the developments within the LASH FIRE project.

The economic feasibility study of Risk Control Measures (RCMs) and Risk Control Options (RCOs) was conducted by LCC methodology where all related costs are included, from investment/production to operation/maintenance and until the end of the life span. A selection of solutions provided by specific developments was assessed, where the LCC assessment was performed for integration on selected three generic ro-ro ship types (Ref D05.1 "Definition of generic ships" [4]), including new buildings and existing ships, according to the proposed applicability. Finally, more than 40 RCMs and 16 RCOs were assessed, resulting in more than 200 LCC assessment.

It is to be highlighted that ship designers and operators were involved in the assessments in order to provide a reliable input, considering the design, production and operational processes.

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.*

A summary of the results through a breakdown of the marginal costs (in euros) for all the RCMs and RCOs is given in

Table 214.

25.1 LCA conclusions

Environmental assessment through the Life cycle assessment (LCA) was performed for the manual firefighting solutions (Action 6-D) and weather deck extinguishment solutions (Action 10-B).

For Action 6-D the LCA analysis is utilized to compare the environmental impacts of a collection of manual firefighting devices and their respective operational procedures in response to a fire originating in an alternative powered vehicle (APV) on a ro-pax ship car deck. The devices include three types of handheld extinguisher (CO_2, dry powder (ABC), and compressed air foam (CAF)), a fire blanket, and three water application devices (standard nozzle, fognail nozzle, and water-cooling nozzle).

The LCA models used in this analysis include smoke emitted to the atmosphere, fire water run-off into surface water, replacing damaged vehicles and/or traction batteries, and the manufacturing, use, and end-of-life phases of three types of handheld fire extinguisher (ABC, CO_2, CAF), a fire blanket, and three types of nozzles. These results are compared with a reference case in which a fire occurs but there are no manual firefighting operations on the car deck.

The results reinforce the concept that the ability to arrive at a fire quickly and use handheld fire extinguishers and/or a fire blanket reduces the overall impact of the fire considerably when compared with manual firefighting operations after the fire has developed. All three handheld fire extinguishers and the fire blanket had similar results, assuming the CAF extinguisher uses fluorine free foam.

It is normal protocol for a drencher system to be activated if a fire on a car deck cannot be controlled quickly. Thus, it is unlikely that a fire will spread from the original burning vehicle, however, it is possible that collateral damage will occur to adjacent vehicles, e.g., damaged plastic parts, paint, windows, soot deposition, etc. Replacing damaged vehicles and/or a traction battery account for most of the environmental impact of a vehicle fire in most cases, but no information is available about the extent of damage leading to the need to replace a vehicle or traction battery. This is a sensitive and uncertain condition and a weakness of the analysis.

For Action 10-B the LCA analysis includes assessments of the environmental impact of commercially producing, using, and disposing of a fixed weather deck fire protection system consisting of five fire monitors that use water only and 1) is operated remotely by humans from a safe position on board the ship, and 2) operates autonomously using fire detectors to direct the water flow toward the fire and thereafter (if considered necessary) operated by humans. Both systems are compared with a REF case in which no weather deck fire protection system exists.

The results indicate that the predicted number of serious fires likely to occur on the weather deck of a ship configured like the Magnolia Seaways is so low that the environmental impacts of producing, using, and disposing of a fixed water-based fire protection system outweigh the benefits.

The impacts of manufacturing and using the autonomous system are higher than the remotely operated system primarily due to the additional fire detection components.

It is, of course, a good thing that the probability of a serious fire is very low; hopefully this trend will continue to decrease over time as more fire safety measures are implemented. However, a low probability of serious fire does not mean that new fire safety measures should not be implemented. It is important to be prepared in case a fire does happen.

Table 214. Summary of the marginal costs (in euros) for the RCMs and RCOs.

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Op1	Improved fire patrol procedures and minimum assisting equipment for a more effective screening of fire hazards	Investment	7 596.4(	5 380.0	5 563.2	3 940.0	N	N
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	13 564.03 €	9 312.26 €	13 049.58 €	9 312.26 €	N/A	N/A
		TOTAL	**21 160.52 €**	**14 692.26 €**	**18 612.81 €**	**13 252.26 €**	**N/A**	**N/A**
Op2	Manual screening of cargo at port before the loading operations	Investment	11 126.46 €	7 880.00 €	11 126.46 €	7 880.00 €	N/A	N/A
		Operation	965 495.54 €	662 852.12 €	928 876.63 €	662 852.12 €	N/A	N/A
		Maintance	14 694.37 €	10 088.29 €	14 137.05 €	10 088.29 €	N/A	N/A
		TOTAL	**991 316.37 €**	**680 820.41 €**	**954 140.14 €**	**680 820.40 €**	**N/A**	**N/A**
Op3	Improvement of current signage and markings standards/conditions to support effective wayfinding and localization	Investment	8 840.00 €	30 840.00 €	8 840.00 €	30 840.00 €	12 040.00 €	36 040.00 €
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		Maintance	12 189.08 €	8 348.60 €	11 711.85 €	8 348.60 €	9 640.86 €	6 761.84 €
		TOTAL	**21 029.08 €**	**39 188.60 €**	**20 551.85 €**	**39 188.60 €**	**21 680.86 €**	**42 801.84 €**
Op4	Guidelines for the standardization and formalization of manual fire confirmation and localization	Investment	18 820.00 €	18 820.00 €	18 820.00 €	18 820.00 €	18 820.00 €	18 820.00 €
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		Maintance	27 676.61 €	17 372.69 €	23 280.58 €	17 372.69 €	17 372.69 €	10 165.90 €
		TOTAL	**46 496.61 €**	**36 192.69 €**	**42 100.58 €**	**36 192.69 €**	**36 192.69 €**	**28 985.90 €**
RCO1	Fire patrol. Fire confirmation & localization	Investment	24 200.00 €	24 200.00 €	21 320.00 €	21 320.00 €	18 820.00 €	18 820.00 €
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		Maintance	41 240.64 €	26 684.95 €	26 684.95 €	26 684.95 €	17 372.69 €	10 165.90 €
		TOTAL	**65 440.64 €**	**50 884.95 €**	**48 004.95 €**	**48 004.95 €**	**36 192.69 €**	**28 985.90 €**
RCO2	Signage and markings for effective wayfinding and localization	Investment	8 840.00 €	30 840.00 €	8 840.00 €	30 840.00 €	12 040.00 €	36 040.00 €
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		Maintance	12 189.08 €	8 348.60 €	11 711.85 €	8 348.60 €	9 640.86 €	6 761.84 €
		TOTAL	**21 029.08 €**	**39 188.60 €**	**20 551.85 €**	**39 188.60 €**	**21 680.86 €**	**42 801.84 €**
Op5	First response guidelines and new equipment to put out the fire in the initial stage	Investment	8 590.00 €	8 590.00 €	6 550.00 €	6 550.00 €	6 550.00 €	6 550.00 €
		Operation	32 732.65 €	22 472.30 €	19 936.86 €	14 227.07 €	16 426.98 €	11 522.82 €
		Maintance	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		TOTAL	**41 322.65 €**	**31 062.30 €**	**26 486.86 €**	**20 777.07 €**	**22 976.98 €**	**18 072.82 €**
Op6	Technology for localization of first responders through digital information processed via network	Investment	72 200.00 €	92 200.00 €	57 460.00 €	80 460.00 €	131 460.00 €	191 460.00 €
		Operation	11 774.34 €	8 083.56 €	11 327.76 €	8 083.56 €	9 333.51 €	6 547.06 €
		Maintance	127 187.62 €	90 111.85 €	51 723.66 €	47 176.20 €	117 202.63 €	117 698.49 €
		TOTAL	**211 161.96 €**	**190 395.41 €**	**120 511.42 €**	**135 719.76 €**	**257 996.14 €**	**315 705.55 €**
RCO3	Efficient first response	Investment	8 590.00 €	8 590.00 €	6 550.00 €	6 550.00 €	6 550.00 €	6 550.00 €
		Operation	32 732.65 €	22 472.30 €	19 936.86 €	14 227.07 €	16 426.98 €	11 522.82 €
		Maintance	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		TOTAL	**41 322.65 €**	**31 062.30 €**	**26 486.86 €**	**20 777.07 €**	**22 976.98 €**	**18 072.82 €**
Op7	Training, new equipment and procedures to suppress fires in Alternatively Powered Vehicles with special focus on Li-ion batteries fires	Investment	23 700.00 €	23 700.00 €	22 260.00 €	22 260.00 €	27 260.00 €	27 260.00 €
		Operation	22 606.72 €	15 520.44 €	15 224.51 €	10 864.31 €	12 544.24 €	8 799.25 €
		Maintance	31 845.47 €	19 989.50 €	26 787.28 €	19 989.50 €	26 046.92 €	15 241.75 €
		TOTAL	**78 152.19 €**	**59 209.94 €**	**64 271.79 €**	**53 113.81 €**	**65 851.16 €**	**51 301.00 €**
RCO4	Manual firefighting for Alternatively Powered Vehicles	Investment	23 700.00 €	23 700.00 €	22 260.00 €	22 260.00 €	27 260.00 €	27 260.00 €
		Operation	22 606.72 €	15 520.44 €	15 224.51 €	10 864.31 €	12 544.24 €	8 799.25 €
		Maintance	31 845.47 €	19 989.50 €	26 787.28 €	19 989.50 €	26 046.92 €	15 241.75 €
		TOTAL	**78 152.19 €**	**59 209.94 €**	**64 271.79 €**	**53 113.81 €**	**65 851.16 €**	**51 301.00 €**
Des1	User friendly alarm system interface design guidelines	Investment	49 700.00 €	N/A	49 700.00 €	N/A	49 700.00 €	N/A
		Operation	0.00 €	N/A	0.00 €	N/A	0.00 €	N/A
		Maintance	0.00 €	N/A	0.00 €	N/A	0.00 €	N/A
		TOTAL	**49 700.00 €**	**N/A**	**49 700.00 €**	**N/A**	**49 700.00 €**	**N/A**
Des2	Alarm system interface prototype	Investment	73 700.00 €	N/A	73 700.00 €	N/A	73 700.00 €	N/A
		Operation	0.00 €	N/A	0.00 €	N/A	0.00 €	N/A
		Maintance	12 106.53 €	N/A	12 106.53 €	N/A	7 162.69 €	N/A
		TOTAL	**85 806.53 €**	**N/A**	**85 806.53 €**	**N/A**	**80 862.69 €**	**N/A**
RCO5	Alarm system interface prototype	Investment	73 700.00 €	N/A	73 700.00 €	N/A	73 700.00 €	N/A
		Operation	0.00 €	N/A	0.00 €	N/A	0.00 €	N/A
		Maintance	12 106.53 €	N/A	12 106.53 €	N/A	7 162.69 €	N/A
		TOTAL	**85 806.53 €**	**N/A**	**85 806.53 €**	**N/A**	**80 862.69 €**	**N/A**
Des3	Procedures and design for efficient extinguishment system activation	Investment	3 640.00 €	84 540.00 €	3 640.00 €	68 100.00 €	3 640.00 €	5 140.00 €
		Operation	20 534.44 €	14 097.73 €	19 755.62 €	14 097.73 €	16 277.64 €	11 418.07 €
		Maintance	0.00 €	1 616.71 €	0.00 €	1 616.71 €	0.00 €	0.00 €
		TOTAL	**24 174.44 €**	**100 254.44 €**	**23 395.62 €**	**83 814.44 €**	**19 917.64 €**	**16 558.07 €**
Des4	Training module for activation of extinguishment systems	Investment	24 330.00 €	24 330.00 €	24 330.00 €	24 330.00 €	23 730.00 €	23 730.00 €
		Operation	64 546.91 €	44 314.09 €	62 098.80 €	44 314.09 €	88 593.67 €	62 144.68 €
		Maintance	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		TOTAL	**88 876.91 €**	**68 644.09 €**	**86 428.80 €**	**68 644.09 €**	**112 323.67 €**	**85 874.68 €**
RCO6	Process for development of procedures and design for efficient activation of extinguishing system	Investment	3 640.00 €	84 540.00 €	3 640.00 €	68 100.00 €	3 640.00 €	5 140.00 €
		Operation	20 534.44 €	14 097.73 €	19 755.62 €	14 097.73 €	16 277.64 €	11 418.07 €
		Maintance	0.00 €	1 616.71 €	0.00 €	1 616.71 €	0.00 €	0.00 €
		TOTAL	**24 174.44 €**	**100 254.44 €**	**23 395.62 €**	**83 814.44 €**	**19 917.64 €**	**16 558.07 €**
RCO7	Training module for efficient activation of extinguishing system	Investment	24 330.00 €	24 330.00 €	24 330.00 €	24 330.00 €	23 730.00 €	23 730.00 €
		Operation	64 546.91 €	44 314.09 €	62 098.80 €	44 314.09 €	88 593.67 €	62 144.68 €
		Maintance	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		TOTAL	**88 876.91 €**	**68 644.09 €**	**86 428.80 €**	**68 644.09 €**	**112 323.67 €**	**85 874.68 €**
Des5	Integrated solutions for fire resource management, combining relevant sources of information, including drone and camera monitoring system	Investment	26 500.00 €	N/A	26 500.00 €	N/A	26 500.00 €	N/A
		Operation	0.00 €	N/A	0.00 €	N/A	0.00 €	N/A
		Maintance	23 548.67 €	N/A	22 655.53 €	N/A	18 667.02 €	N/A
		TOTAL	**50 048.67 €**	**N/A**	**49 155.53 €**	**N/A**	**45 167.02 €**	**N/A**
Des6	Guidelines for organizing the response in case of a fire emergency	Investment	6 700.00 €	6 700.00 €	6 700.00 €	6 700.00 €	6 700.00 €	6 700.00 €
		Operation	23 548.67 €	16 167.12 €	22 655.53 €	16 167.12 €	18 667.02 €	13 094.12 €
		Maintance	5 651.68 €	3 880.11 €	5 437.33 €	3 880.11 €	4 480.08 €	3 142.59 €
		TOTAL	**35 900.35 €**	**26 747.23 €**	**34 792.86 €**	**26 747.23 €**	**29 847.10 €**	**22 936.71 €**

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Pre1a	Cargo scanning and identification and tracking system by the means of a called Vehicle Hot Spot Detector system	Investment	381 450.00 €	381 450.00 €	381 450.00 €	381 450.00 €	381 450.00 €	381 450.00 €
		Operation	640 523.87 €	439 745.80 €	616 230.35 €	439 745.80 €	261 338.26 €	183 317.64 €
		Maintance	70 646.01 €	48 501.37 €	67 966.58 €	48 501.37 €	56 001.06 €	39 282.35 €
		TOTAL	**1 092 619.88 €**	**869 697.17 €**	**1 065 646.93 €**	**869 697.17 €**	**698 789.32 €**	**604 049.99 €**
Pre1b	Automatic screening and management of cargo fire hazards by means of Automated Guided Vehicles	Investment	N/A	N/A	N/A	N/A	N/A	N/A
		Operation	N/A	N/A	N/A	N/A	N/A	N/A
		Maintance	N/A	N/A	N/A	N/A	N/A	N/A
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Pre2	Stowage planning tool with optimization algorithm for cargo distribution	Investment	91 800.00 €	91 800.00 €	91 800.00 €	91 800.00 €	89 560.00 €	89 560.00 €
		Operation	9 961 088.09 €	6 838 693.81 €	9 583 288.15 €	6 838 693.81 €	7 896 148.97 €	5 538 811.41 €
		Maintance	14 930.72 €	9 541.25 €	13 827.12 €	9 541.25 €	11 064.58 €	7 732.02 €
		TOTAL	**10 067 818.81 €**	**6 940 035.06 €**	**9 688 915.27 €**	**6 940 035.06 €**	**7 996 773.55 €**	**5 636 103.43 €**
Pre3	Develop guidelines for safe electrical power connections in ro-ro spaces for reefer units	Investment	138 926.00 €	167 796.10 €	106 726.00 €	124 156.10 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	23 548.67 €	16 167.12 €	22 655.53 €	16 167.12 €	N/A	N/A
		TOTAL	**162 474.67 €**	**183 963.22 €**	**129 381.53 €**	**140 323.22 €**	**N/A**	**N/A**
Pre4	Develop guidelines for safe electrical power connections in ro-ro spaces for charging of Evs	Investment	29 364.68 €	29 364.68 €	N/A	N/A	N/A	N/A
		Operation	0.00 €	0.00 €	N/A	N/A	N/A	N/A
		Maintance	23 548.67 €	16 167.12 €	N/A	N/A	N/A	N/A
		TOTAL	**52 913.35 €**	**45 531.80 €**	**N/A**	**N/A**	**N/A**	**N/A**
RCO8	Safe electrical connection for reefers	Investment	138 926.00 €	167 796.10 €	106 726.00 €	124 156.10 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	23 548.67 €	16 167.12 €	22 655.53 €	16 167.12 €	N/A	N/A
		TOTAL	**162 474.67 €**	**183 963.22 €**	**129 381.53 €**	**140 323.22 €**	**N/A**	**N/A**
RCO9	Safe electrical connection of reefers and electric vehicles (EVs)	Investment	168 290.68 €	197 150.78 €	N/A	N/A	N/A	N/A
		Operation	0.00 €	0.00 €	N/A	N/A	N/A	N/A
		Maintance	47 097.34 €	32 334.25 €	N/A	N/A	N/A	N/A
		TOTAL	**215 388.02 €**	**229 485.03 €**	**N/A**	**N/A**	**N/A**	**N/A**
Pre5	Proposal for requirements of surface materials in ro-ro spaces, with reference to suitable test method and material property performance criteria	Investment	N/A	N/A	N/A	N/A	N/A	N/A
		Operation	N/A	N/A	N/A	N/A	N/A	N/A
		Maintance	N/A	N/A	N/A	N/A	N/A	N/A
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Det1	Flame wavelength detectors	Investment	68 918.00 €	87 266.00 €	100 490.00 €	120 530.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	117 743.36 €	80 835.62 €	113 277.64 €	80 835.62 €	N/A	N/A
		TOTAL	**186 661.36 €**	**168 101.62 €**	**213 767.64 €**	**201 365.62 €**	**N/A**	**N/A**
Det8	Thermal imaging (infrared) cameras	Investment	64 548.00 €	81 148.00 €	73 848.00 €	91 498.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	117 743.36 €	80 835.62 €	113 277.64 €	80 835.62 €	N/A	N/A
		TOTAL	**182 291.36 €**	**161 983.62 €**	**187 125.64 €**	**172 333.62 €**	**N/A**	**N/A**
RCO10	Fire detection on weather decks	Investment	66 733.00 €	84 207.00 €	87 169.00 €	106 014.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	117 743.36 €	80 835.62 €	113 277.64 €	80 835.62 €	N/A	N/A
		TOTAL	**184 476.36 €**	**165 042.62 €**	**200 446.64 €**	**186 849.62 €**	**N/A**	**N/A**
Det3	Video fire detection	Investment	139 547.00 €	155 047.00 €	150 090.00 €	166 240.00 €	1 227 262.00 €	1 285 262.00 €
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		Maintance	70 646.01 €	48 501.37 €	67 966.58 €	48 501.37 €	112 002.11 €	78 564.70 €
		TOTAL	**210 193.01 €**	**203 548.37 €**	**218 056.58 €**	**214 741.37 €**	**1 339 264.11 €**	**1 363 826.70 €**
Det4	Adaptive threshold settings for detection	Investment	N/A	N/A	N/A	N/A	N/A	N/A
		Operation	N/A	N/A	N/A	N/A	N/A	N/A
		Maintance	N/A	N/A	N/A	N/A	N/A	N/A
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Det7	Fibre optic linear heat detection	Investment	209 469.00 €	269 719.00 €	288 444.00 €	372 194.00 €	589 400.00 €	751 400.00 €
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		Maintance	202 518.58 €	139 037.27 €	194 837.54 €	139 037.27 €	240 804.54 €	168 914.11 €
		TOTAL	**411 987.58 €**	**408 756.27 €**	**483 281.54 €**	**511 231.27 €**	**830 204.54 €**	**920 314.11 €**
RCO11	Fire detection in closed ro-ro spaces & open ro-ro spaces	Investment	209 469.00 €	269 719.00 €	288 444.00 €	372 194.00 €	589 400.00 €	751 400.00 €
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		Maintance	202 518.58 €	139 037.27 €	194 837.54 €	139 037.27 €	240 804.54 €	168 914.11 €
		TOTAL	**411 987.58 €**	**408 756.27 €**	**483 281.54 €**	**511 231.27 €**	**830 204.54 €**	**920 314.11 €**
Det5	Video fire detection	Investment	139 547.00 €	155 047.00 €	150 090.00 €	166 240.00 €	1 227 262.00 €	1 285 262.00 €
		Operation	23 548.67 €	16 167.12 €	22 655.53 €	16 167.12 €	18 667.02 €	13 094.12 €
		Maintance	70 646.01 €	48 501.37 €	67 966.58 €	48 501.37 €	112 002.11 €	78 564.70 €
		TOTAL	**233 741.68 €**	**219 715.49 €**	**240 712.11 €**	**230 908.49 €**	**1 357 931.13 €**	**1 376 920.82 €**
Det6	Thermal imaging (infrared) cameras	Investment	64 548.00 €	81 148.00 €	73 848.00 €	91 498.00 €	N/A	N/A
		Operation	23 548.67 €	16 167.12 €	22 655.53 €	16 167.12 €	N/A	N/A
		Maintance	117 743.36 €	80 835.62 €	113 277.64 €	80 835.62 €	N/A	N/A
		TOTAL	**205 840.03 €**	**178 150.74 €**	**209 781.17 €**	**188 500.74 €**	**N/A**	**N/A**
RCO12	Visual system for fire confirmation and localization	Investment	184 877.00 €	220 227.00 €	265 764.00 €	304 539.00 €	935 039.00 €	981 539.00 €
		Operation	23 548.67 €	16 167.12 €	22 655.53 €	16 167.12 €	18 667.02 €	13 094.12 €
		Maintance	117 743.36 €	194 005.50 €	271 866.33 €	194 005.50 €	102 668.60 €	72 017.64 €
		TOTAL	**326 169.03 €**	**430 399.62 €**	**560 285.86 €**	**514 711.62 €**	**1 056 374.62 €**	**1 066 650.76 €**
Ext1a	Dry pipe sprinkler system for ro-ro spaces on vehicle carriers	Investment	N/A	N/A	N/A	N/A	1 293 118.07 €	1 641 763.07 €
		Operation	N/A	N/A	N/A	N/A	480 587.73 €	296 992.54 €
		Maintance	N/A	N/A	N/A	N/A	249 627.67 €	173 334.79 €
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**2 023 333.47 €**	**2 112 090.39 €**
Ext1b	Automatic deluge water spray system utilizing open nozzles	Investment	N/A	N/A	N/A	N/A	1 747 108.00 €	2 124 953.60 €
		Operation	N/A	N/A	N/A	N/A	480 587.73 €	296 992.54 €
		Maintance	N/A	N/A	N/A	N/A	627 003.85 €	437 040.49 €
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**2 854 699.58 €**	**2 858 986.62 €**

Ref.	Title	Cost item	Δ Cost					
			Ro-Pax		Ro-Ro cargo		Vehicle carrier	
			NB	Ex	NB	Ex	NB	Ex
Ext2	Deluge system using rotating CAFS nozzles on vehicle carriers	Investment	N/A	N/A	N/A	N/A	193 180.00 €	2 310 025.60 €
		Operation	N/A	N/A	N/A	N/A	480 587.73 €	296 992.54 €
		Maintance	N/A	N/A	N/A	N/A	706 155.74 €	491 554.58 €
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**1 379 923.47 €**	**3 098 572.71 €**
RCO13	Dry-pipe sprinkler system for vehicle carriers	Investment	N/A	N/A	N/A	N/A	1 293 118.07 €	1 641 763.07 €
		Operation	N/A	N/A	N/A	N/A	480 587.73 €	296 992.54 €
		Maintance	N/A	N/A	N/A	N/A	249 627.67 €	173 334.79 €
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**2 023 333.47 €**	**2 112 090.39 €**
Ext3	Autonomous fire monitor (water only) system for the protection of weather decks	Investment	185 635.00 €	207 275.00 €	266 690.00 €	292 870.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	131 872.56 €	90 535.90 €	158 588.69 €	113 169.87 €	N/A	N/A
		TOTAL	**317 507.56 €**	**297 810.90 €**	**425 278.69 €**	**406 039.87 €**	**N/A**	**N/A**
Ext3a	Remotely-controlled fire monitor (water only) system for the protection of weather decks	Investment	292 735.00 €	332 375.00 €	369 290.00 €	413 970.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	131 872.56 €	90 535.90 €	158 588.69 €	113 169.87 €	N/A	N/A
		TOTAL	**424 607.56 €**	**422 910.90 €**	**527 878.69 €**	**527 139.87 €**	**N/A**	**N/A**
Ext4	Remotely-controlled Compressed Air Foam fire monitor system for the protection of weather deck	Investment	148 735.00 €	168 375.00 €	225 290.00 €	249 970.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	113 033.62 €	77 602.20 €	135 933.17 €	97 002.75 €	N/A	N/A
		TOTAL	**261 768.62 €**	**245 977.20 €**	**361 223.17 €**	**346 972.75 €**	**N/A**	**N/A**
Ext4a	Autonomous Compressed Air Foam fire monitor system for the protection of weather deck	Investment	329 635.00 €	371 275.00 €	410 690.00 €	456 870.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	150 711.50 €	103 469.60 €	181 244.22 €	129 337.00 €	N/A	N/A
		TOTAL	**480 346.50 €**	**474 744.60 €**	**591 934.22 €**	**586 207.00 €**	**N/A**	**N/A**
RCO14	Fixed remotely-controlled fire monitor system using water for weather decks	Investment	185 635.00 €	207 275.00 €	266 690.00 €	292 870.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	131 872.56 €	90 535.90 €	158 588.69 €	113 169.87 €	N/A	N/A
		TOTAL	**317 507.56 €**	**297 810.90 €**	**425 278.69 €**	**406 039.87 €**	**N/A**	**N/A**
RCO15	Fixed autonomous fire monitor system using water for weather decks	Investment	292 735.00 €	332 375.00 €	369 290.00 €	413 970.00 €	N/A	N/A
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		Maintance	131 872.56 €	90 535.90 €	158 588.69 €	113 169.87 €	N/A	N/A
		TOTAL	**424 607.56 €**	**422 910.90 €**	**527 878.69 €**	**527 139.87 €**	**N/A**	**N/A**
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	Investment	N/A	N/A	N/A	N/A	N/A	N/A
		Operation	N/A	N/A	N/A	N/A	N/A	N/A
		Maintance	N/A	N/A	N/A	N/A	N/A	N/A
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Cont1b1	A-30 fire insulation	Investment	42 600.00 €	N/A	N/A	N/A	N/A	N/A
		Operation	0.00 €	N/A	N/A	N/A	N/A	N/A
		Maintance	23 548.60 €	N/A	N/A	N/A	N/A	N/A
		TOTAL	**66 148.60 €**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Cont1b2	Extinguishing system simultaneously activated above and below sub-dividing deck	Investment	67 075.00 €	N/A	N/A	N/A	N/A	N/A
		Operation	0.00 €	N/A	N/A	N/A	N/A	N/A
		Maintance	0.00 €	N/A	N/A	N/A	N/A	N/A
		TOTAL	**67 075.00 €**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Cont3b	Solid curtain, transversal mounting, fully rolled down	Investment	284 760.00 €	N/A	328 450.00 €	N/A	N/A	N/A
		Operation	27 222 264.38 €	N/A	44 699 355.84 €	N/A	N/A	N/A
		Maintance	47 097.34 €	N/A	45 311.06 €	N/A	N/A	N/A
		TOTAL	**27 554 121.72 €**	**N/A**	**45 073 116.90 €**	**N/A**	**N/A**	**N/A**
Cont3d	Solid striped curtain, transversal mounting, fully/partly rolled down	Investment	432 750.00 €	N/A	537 490.00 €	N/A	N/A	N/A
		Operation	0.00 €	N/A	1 857 753.26 €	N/A	N/A	N/A
		Maintance	141 292.03 €	N/A	135 933.17 €	N/A	N/A	N/A
		TOTAL	**574 042.03 €**	**N/A**	**2 531 176.43 €**	**N/A**	**N/A**	**N/A**
Cont5	Alternative disembarkation path based on slides	Investment	N/A	N/A	N/A	N/A	N/A	N/A
		Operation	N/A	N/A	N/A	N/A	N/A	N/A
		Maintance	N/A	N/A	N/A	N/A	N/A	N/A
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Cont9	Ship manoeuvring/operation to limit the effect of fire at least in critical areas	Investment	2 840.00 €	2 840.00 €	2 840.00 €	2 840.00 €	2 840.00 €	2 840.00 €
		Operation	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		Maintance	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €	0.00 €
		TOTAL	**2 840.00 €**	**2 840.00 €**	**2 840.00 €**	**2 840.00 €**	**2 840.00 €**	**2 840.00 €**
Cont10	Safety distances between side and end openings and critical areas	Investment	N/A	N/A	N/A	N/A	N/A	N/A
		Operation	N/A	N/A	N/A	N/A	N/A	N/A
		Maintance	N/A	N/A	N/A	N/A	N/A	N/A
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Cont11	Guidance on calculation of side openings in ro-ro spaces	Investment	N/A	N/A	N/A	N/A	N/A	N/A
		Operation	N/A	N/A	N/A	N/A	N/A	N/A
		Maintance	N/A	N/A	N/A	N/A	N/A	N/A
		TOTAL	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Cont13	Tactical guidelines for manual interventions	Investment	4 500.00 €	4 500.00 €	4 500.00 €	4 500.00 €	N/A	N/A
		Operation	23 548.67 €	16 167.12 €	22 655.53 €	16 167.12 €	N/A	N/A
		Maintance	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		TOTAL	**28 048.67 €**	**20 667.12 €**	**27 155.53 €**	**20 667.12 €**	**N/A**	**N/A**
Cont14	SOLAS requirement of reversible fans	Investment	0.00 €	N/A	34 450.00 €	N/A	N/A	N/A
		Operation	0.00 €	N/A	0.00 €	N/A	N/A	N/A
		Maintance	0.00 €	N/A	9 062.21 €	N/A	N/A	N/A
		TOTAL	**0.00 €**	**N/A**	**43 512.21 €**	**N/A**	**N/A**	**N/A**
RCO16	Guideline for fire ventilation in closed ro-ro space	Investment	4 500.00 €	4 500.00 €	4 500.00 €	4 500.00 €	N/A	N/A
		Operation	23 548.67 €	16 167.12 €	22 655.53 €	16 167.12 €	N/A	N/A
		Maintance	0.00 €	0.00 €	0.00 €	0.00 €	N/A	N/A
		TOTAL	**28 048.67 €**	**20 667.12 €**	**27 155.53 €**	**20 667.12 €**	**N/A**	**N/A**

26 References

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

[2] LASH FIRE, *Cost-effectiveness assessment report (D04.6), 2023.*

[3] LASH FIRE, *Ship integration evaluation (D05.7), 2023.*

[4] LASH FIRE, *Definition of generic ships (D05.1), 2021.*

[5] LASH FIRE, *Cost assessment tool (D05.2), 2022.*

[6] LASH FIRE, *Development of cost assessment tool (D05.3), 2022.*

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[8] LASH FIRE, *Development of environmental assessment tool (D05.5), 2022.*

[9] LASH FIRE, *Description of the development of local application fire-extinguishing systems and selected solutions (D10.1), 2022.*

[10] LASH FIRE, *Development and testing of APV firefighting routines, equipment and tactics (D06.8), 2023.*

27 Indexes

27.1 Index of tables

27.2 Index of figures