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PROJECT DELIVERABLE REPORT

Introducing advanced ICT
and Mass Evacuation Vessel design
to ship evacuation and rescue systems

D2.4 First version of PALAEMON Use Cases Definition & Operational Requirements

A holistic passenger ship evacuation and rescue ecosystem
MG-2-2-2018
Marine Accident Response

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Contents

Figures

Tables

Abbreviations

ABS	American Bureau of Shipping
AE	Acoustic Emission
AIS	Automatic Identification System
Amazon S3	Amazon Simple Storage Service
AR	Augmented Reality
ASM	Application Specific Messages
AtoN	Aids to Navigation
BLE	Bluetooth Low Energy
BN	Bayesian Network
BP	Blood Pressure
BSL	Bootstrap Loader
CAD	Computer-Aided Design
CCTV	Closed-Circuit Television
CDC	Centres for Disease Control
CLIA	Cruise Line International Organisation
CM	Condition Monitoring
CPRI	Common Public Radio Interface
CRC	Cyclic Redundancy Check
CSR	Common Structural Rules
CSV	Comma-separated values
DEM	Discrete Element Method
DFB	Data Fusion Bus
DoA	Description of Action
DOC	Document of Compliance
DoS	Denial of Service
DSS	Decision Support System
EC	Evacuation Coordinator
ECDIS	Electronic Chart Display and Information System
eCPRI	Evolved Common Public Radio Interface
EEA	European Economic Area
EEBD	Emergency Escape Breathing Device
EGC	Enhanced Group Calling
EMSA	European Maritime Safety Agency
ENISA	European Union Agency for Cybersecurity
EPC	Evolved Packet Core
EPIRB	Emergency Position Indicating Radio Beacon
eSIM	Embedded Subscriber Identity Module
EU	European Union
EUC	Equipment Under Control
FFE	Fire Fighting Equipment
FMEA	Failure Mode and Effects Analysis
Fps	Frames per second
FSEG	Fire Safety Engineering Group
FSS	Fire Safety Systems
GA	General Alarm
GCS	Ground Control Station
GDPR	General Data Protection Regulation

GL	Germanischer Lloyd
GMDSS	Global Maritime Distress Safety System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GUI	Graphical User Interface
HDFS	Hadoop Distributed File System
HMI	Human Machine Interface
HR	Heart Rate
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
HW	Hardware
IACS	International Association of Classification Societies
IALA	International Association of Maritime Aids to Navigation and Lighthouse Authorities
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMCA	International Marine Contractors Association
IMO	International Maritime Organization
IoT	Internet of Things
IPS	Indoor Positioning Systems
ISM	International Safety Management
ISO	International Organisation of Standardisation
ISO/OSI	International Standard Organization / Open System Interconnection
ISPS	International Ship and Port Facility Security code
IT	Information technology
ITU	International Telecommunication Union
JIT	Just-In-Time
JSON	JavaScript Object Notation
KPI	Key Performance Indicators
LAN	Local Area Network
LED	Light-Emitting Diode
LRRS	Lifeboat Release and Retrieval System
LRS/LMS	Learning Record Store/ Learning Management System
LSA	Life Saving Appliance(s)
MAC	Media Access Control
MAD	Mutual Authentication with Distance-bounding
MANET	Mobile Ad-hoc Network
MARPOL	International Convention for the Prevention of Pollution from Ships
MEE	Maritime Emergency Evacuation
MES	Marine Evacuation System
MEV	Massive Evacuation Vessel
MLC	Maritime Labour Convention
MOB	Man Over Board
MQTT	MQ Telemetry Transport
MRCC	Maritime Rescue Coordination Centre
MSC	Maritime Safety Committee
NA	Not Applicable
NASF	Non-Accidental Structural Failures
NM	Nautical Mile

OSI	Open System Interconnection
P&I Club	Protection & Indemnity Club
PA	Public Address
PaMEAS	Passengers Mustering and Evacuation Process Automation System
PC	Product Certificate
PDA	Personal Digital Assistant
PEC	PALAEMON Evacuation Coordinator
PECS	Physical Conditions, Emotional State, Cognitive Capabilities and Social Status
PHP	Hypertext processor
PIMM	PALAEMON Incident Management module
PKI	Public Key Infrastructure
PLC	Programming Logic Circuits
RAN	Radio Access Network
RAO	Response Amplitude Operators
REFIT	Regulatory Fitness and Performance
RF	Radio Frequency
RFID	Radio Frequency Identification
RO	Recognised Organisation
ROPAX	Roll-on/Roll-off Passenger
Ro-Ro	Roll-on/Roll-off
RSSI	Received Signal Strength Indication
RTLS	Real-Time Location System
SAR	Search and Rescue
SART	Search and Rescue Transmitter
SB	Smart Bracelet
SC	Smart Cameras
SEM	Smart Evacuation Management
SHEBA	Ship Evacuation Behaviour Assessment
SHM	Ship Hull Monitoring
SHM	Structural Health Monitoring
SIRC	Seafarers International Research Centre
SMC	Safety Management Certificate
SMS	Safety Management System
SoC	System on Chip
SOLAS	International Convention for the Safety of Life at Sea
SRAP	Smart Risk Assessment Platform
SSRC	Ship Stability Research Centre
SSS	Smart Safety System
SST	Ship Stability Toolkit
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
TBC	To be confirmed
TBD	To be Determined
TCP/IP	Transmission Control Protocol/Internet Protocol
TDMA	Time Division Multiplex Access
TRL	Technology Readiness Level
TX.Y	Task Y from WPX
TX/RX	Transmit and Receive
UAV	Unmanned Aerial Vehicle

UID	User Input Device
UML	Unified Modelling Language
UR	IACS Unified Requirement
UWB	Ultra-wideband
VDES	VHF Data Exchange System
VDL	VHF Data Link
VDR	Voyage Data Recorder
VDU	Visual Display Unit
VHF	Very High Frequency
VR	Virtual Reality
VTS	Vessel Traffic Service
WFT	Weather Forecast tool
WHO	World Health Organization
WIFI	Wireless Fidelity
WLAN	Wireless Local Access Network
WP	Work Package
WSN	Wireless Sensor Network
xAPI	Experience API
YLD	Years Lost due to Disability
YLL	Years of Life Lost

1 Summary

The main objective of this Report is to provide a detailed definition of the use cases and application (reference) scenarios that will be used in PALAEMON IT system/platform design and as essential input to the pilots (Field Trials) that will demonstrate the capacity of the project to address ship evacuation needs under an innovative and holistic approach. The Report draws on the relevant Marine Emergency Evacuation (MEE) literature, and more broadly on the research undertaken these last years in the domain of evacuation management but also incorporates the technical knowledge accumulated within the organizations participating in Project Work Package 1 (WP1) – Task 2.3 (Reference Scenarios, Pilot Operations Specifications and KPIs) and by collecting information from use case (pilot) partners and other external sources. The Report adopts high-tech technological means (e.g. IT systems technologies, automated Incidence Management and Decision Support System functionality, passenger and crew indoor positioning methods, 5G networks and IoT, etc.), integrates the function of ship evacuation, and establishes a Smart Evacuation Management System. This system improves over the current simulation-based and intelligent evacuation system, and realizes the adaptive to the ship prevailing conditions guidance of the passengers and the crew during the evacuation process, and the people flow monitoring in real-time.

The Report is structured in the following sections, besides the Summary section:

Section 2 introduces the Report and gives the context of this Report and how it related to Tasks and other Reports of the Project Work Package 2 (Use Case Driven Requirements – Engineering and Architecture).

Section 3 explores the relevant literature and the previous work inside and outside of the project to define the concepts of Smart Evacuation Management (SEM) and Smart Evacuation Management Systems as a layer of additional to existing evacuation functionality to allow for technology-aided Evacuation Management in cruise and RoPax vessels. The proposed SEM provides technology-enhanced and software0-enabled evacuation possibilities, which can be used by evacuation coordinators to: a) support the effective application of an Evacuation Plan (EP) by providing proper guidance to crew and passengers, b) Manage incidents that could possibly hinder the timely execution of the EP from the initial time the incidence is reported to the conclusion of the incidence, c) track the status & location of resources and passengers, and reassess response plans if needed and, d) design and post-evacuation analysis of the response, on the basis of Key Performance Indicators (KPIs).

Section 4 looks at key evacuation requirements in realistic operational scenarios and outlines a set of clearly defined evacuation scenarios. They are based on a detailed look at available historical data with reference to accident reports and at available in the literature evacuation management cases; they also sought feedback from the PALAEMON Consortium members and other professional mariners out of the Consortium, with the aim of bringing realism and credibility to the scenarios. The reference scenarios included in this Report should serve as

reference scenarios for the PALAEMON IT platform development and for the deployment of PALAEMON SEM in the context of Project Pilots (Field Trials)

Section 5 discusses in further detail the key functionality of a technology-aided Marine Evacuation Emergency and more specifically the functions: a) providing information and advice intended to support various aspects of the evacuation task (Standard Evacuation Functions) and, b) supporting the management of incidents hindering the evacuation process (Incident Management Functions). The Report provides an outline of the specifications of these functions, with the greatest emphasis being placed on the incident management functions that are executed essentially by the PIMM (PALAMEON Incident Management Module) component of PALAEMON SEM – while the PaMEAS component of PALAEMON SEM (Passengers Mustering and Evacuation process Automation System), supported by a stand-alone 5G network deployed on the ship, is responsible for retrieving and processing the location information of passengers and crew and construct, on the basis of this information, the appropriate evacuation response.

Section 6 defines evacuation ;uantitative requirements on system level and KPIs. Although the unpredictable nature of MEE situations makes it difficult to know for certain if everything will go as planned until after a specific situation has occurred, relying only on “seeing what happens when the situation occurs” to assess design efforts in PALAEMON cannot provide all the ingredients needed to craft a good SEM system. It is therefore important to be able to measure how well the proposed SEM system is designed to perform, not just watch how well it performs after the fact.

Section 7 concludes on the Report.

2 Introduction

This deliverable is the first version of the main PALAEMON Task 2.3 document, entitled "PALAEMON Use Cases Definition & Operational Requirements". A second and definitive version of this Deliverable will be available later on, in Month M24 (May 2021) of the project life. T2.3 is led by the University of the Aegean (UAegean - UAEG) which coordinates a group of 19 project partners.

According to the Grant Agreement (GA), Task 2.3 "Reference Scenarios and Pilot Operations Specifications and KPIs" should provide a detailed definition of the use cases and application scenarios that will drive the development of the PALAEMON overall architecture and feed the pilot deployment of this architecture within WP8 Application Field Trials. More specifically, the work in this Task has been planned to unfold in two distinct periods (from M3 to M12 and from M18 to M24) to cover the following issues:

- Detailed definition of the use cases and application scenarios based on the feedback received by the project partners and on information that should be collected from external sources.
- A detailed list of issues and threats for ship evacuation that need to be prevented or mitigated in a passenger ship business environment.
- A definition of innovative user scenarios with reference to advanced crew and passenger management, MEV (Mass Evacuation Vessel) deployment, ship monitoring, passengers' security, etc., in conditions of ship evacuation.

Essentially, Task 2.3 is an important two-stages intermediary step between two critical processes for the evolution of PALAEMON. It is the transition from the analysis of trends in passengers' ships evacuation management, and the definition of operational requirements for improving the effectiveness of the evacuation process, to the definition of an architecture for the PALAEMON technology-aided ship evacuation ecosystem. As a result, this Deliverable builds on the principal conclusions of the first two project deliverables, D2.1 and D2.2 (Report on the analysis of SoA, existing and past projects/initiatives and PALAEMON Requirement Capture Framework, respectively), which have provided an extended Requirement Analysis. Based on these Requirements, D2,4 gives input, in the form of design principles and required functionality, on the main Deliverable of WP2, i.e., the Deliverable describing PALAEMON architecture design (D2.6). A second version of this Deliverable, with an update of the current Reference Scenarios, Pilot Specification and KPIs, will be provided at the end of the 2nd Year of the project (D2.5). It will report on the progress achieved within Task 2.3 as the project matures at evolves towards the finalization of the technical architecture and the pilot application.

3 The generic framework for PALAEMON Reference Scenarios and Pilot Operations: Smart Evacuation Management (SEM)

3.1 Ship Evacuation Management: Main concepts and trends

Maritime safety is one of the most important issues promoted with international maritime regulations and guidelines (MSC/Circ.909 in IMO 1999; MSC/Circ. 1033 in IMO 2002; MSC.1/Circ.1238 in IMO 2007; MSC.1/Circ. 1533 in IMO 2016; SOLAS II-2/28.3 in SOLAS 1995; and STW 38/5/1 in IMO 2006)[1]. The shipping companies and other organizations performing marine transportation pay particular attention on issues related to the safety of passengers and crew. Providing safe and effective evacuation of ships in an emergency situation becomes a critical necessity that need the definition of strategy and organization.

Typically, evacuation management is a risk-management strategy that is applied to mitigate the effects of an emergency. It always involves the organized movement of people threatened to a safer location. A Handbook on Evacuation Planning from the Australian Institute for Disaster Resilience, made and regularly updated for the needs of the Australian Government, defines evacuation management as a “complex and demanding activity that may be carried out under hazardous and time critical conditions, sometimes over several days or, occasionally, over several weeks”[2]. Of course, the evacuation of ships has many different aspects as compared to the evacuation of building or other infrastructures. Especially, the evacuation of cruise ships and RoPax vessels with a large carrying passenger capacity, is a multipart and multifaceted problem (procedural, behavioural, technical) that should be resolved: a) in conditions of an ambient and fundamental uncertainty due to simultaneously developing incidents, such as progressive flooding, foundering, fire/smoke etc., exacerbated by the unpredictability of human behaviour[3], b) within a very limited time span, given the IMO

1 IMO, 1999, Interim Guidelines for a Simplified Evacuation Analysis on Ro-Ro Passenger Ships. MSC/Circ. 909. London, UK: International Maritime Organization.

IMO, 2002, Interim Guidelines for Evacuation Analyses for New and Existing Passenger Ships. MSC/Circ. 1033. London, UK: International Maritime Organization.

IMO, 2006, Passenger Ship Safety. STW 38/5/1. London, UK: International Maritime Organization.

IMO, 2007, Guidelines for Evacuation Analysis for New and Existing Passenger Ships. MSC.1/Circ. 1238. London, UK: International Maritime Organization.

IMO, 2010. Strategy and Planning (A) Monitoring of Performance. London, UK: International Maritime Organization.

IMO, 2016, Revised Guidelines for Evacuation Analysis for New and Existing Passenger Ships. MSC.1/Circ. 1533. London, UK: International Maritime Organization.

2 Australian Institute for Disaster Resilience, 2017, Australian Disaster Resilience Handbook Collection - Evacuation Planning, available at https://knowledge.aidr.org.au/media/5617/aidr-evacuation-planning-handbook.pdf

3 Vassalos D. et al, 2002, Evacuability of Passenger Ships at Sea, available at http://polycad.co.uk/downloads/SASMEX_2002.pdf

under SOLAS Regulation requirement for a maximum allowable total passenger ship evacuation time in the range of 60 to 80 minutes[4].

Evidently, modern ships form “floating cities”, hosting thousands of “habitants” (passengers and crew) which attract a multilingual/multi-cultural clientele. Nothing is easy when one should assemble thousands of people speaking different languages at the muster stations and then get them to the lifeboats, life-rafts etc. Congestion, coordination slacks and back-and-forth movements are the norm, while the natural stress of passengers weakens their ability to deal appropriately with the complexity and the urgency of the situation. Further, the structural complexity of passenger ships (i.e., stairways and narrow escape routes), the operation conditions (i.e., manoeuvring), and the dynamic environmental factors (i.e., weather conditions, ship stability etc.) are essentially influencing the evacuation process. Figure 1 summarizes the different influences on the movement of passengers onboard a ship in case of an evacuation[5] which should be certainly taken in consideration in the design of a Marine Evacuation System – MES.

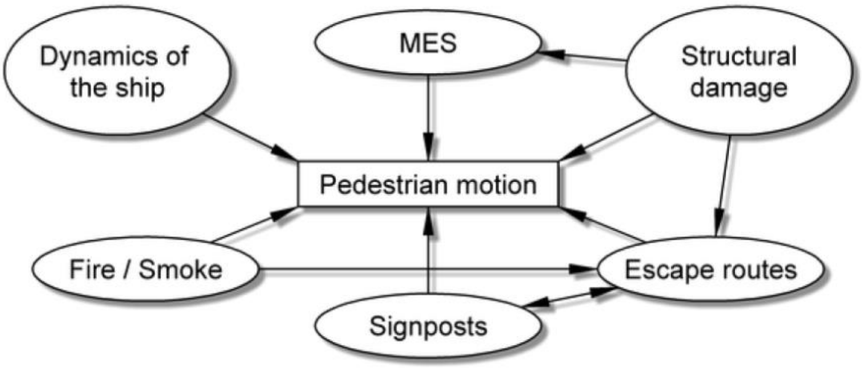

Figure 1: The influences on the movement of passengers onboard a ship in case of an evacuation

Generally speaking, the factors influencing the evacuation process can be categorized in four main areas[6]: a) environmental, b) geometrical, c) procedural and, d) population – where the ship population includes both the passengers and the crew. In fact, the evacuation procedure in ship environments rely much on information and guidance coming from the crew. As the working environment of seafarers typically involves time-zone crossing, noise, heat, cold and

4 IMO, 2017, Revised Guidelines on Evacuation Analysis for New and Existing Passenger Ships, available at https://www.traffgo-ht.com/downloads/pedestrians/downloads/documents/MSC.1,Circ.1533,2016.pdf

5 Klupfel H., 2010, Ship Evacuation – Guidelines, Simulation, Validation, and Acceptance Criteria, 10.1007/978-3-642-04504-2_21 available at https://www.researchgate.net/publication/226367566_Ship_Evacuation-Guidelines_Simulation_Validation_and_Acceptance_Criteria

6 ibid; see also: Lee D. et al, 2003, The current status and future issues in human evacuation from ships, Safety Science. 41. 861-876. 10.1016/S0925-7535(02)00046-2 available at https://www.researchgate.net/publication/222665232_The_current_status_and_future_issues_in_human_evacuation_from_ships

continuous work, the stress and the fatigue related to such working conditions may impact on health and safety outcomes[7].

All these interacting and coexisting influences are factors of complexity and time-delays which explain why very large differences may occur between the estimated and realized evacuation times in ship accidents, as pointed out by a recent global review of the emergence evacuation management methods and practices in maritime transportations[8]. The organization and the effective deployment of the evacuation plan is of primordial importance.

In a previous PALAEMON Deliverable[9], we have explained in detail how the process of Maritime Emergency Evacuation (MEE) is regulated and organized in context. We provide here a short summary while focusing on what is needed for designing the core principles of the PALAEMON proposition.

First, maritime safety is the subject of an extended and updated framework of requirements and rules to be implemented. The IMO ISM Code explicitly requires from Shipping Companies to identify potential emergency shipboard situations and establish procedures to appropriately respond to them.

Second, traditionally, the shipping companies have contingency plans in place for shipboard emergencies. The objective of these evacuation plans is to ensure that the Master, the officers and the crew of the ship can respond to emergency situations efficiently and effectively. In practice, evacuation plans should provide clear and unambiguous instructions and guidance, effectively manage the emergency, gain control over the situation through systematic action, and avoid, or minimize, the risk to human life, to environment and company's property. Plans and procedures for ship abandonment are included in these contingency plans[10], where also are described in detail the duties and responsibilities of the crew members. In short, all predictable emergency situations should be explicitly detailed in the vessel evacuation plan. Usually, they are ship specific, developed during the design phase of a ship and approved by a flag/classification society, to ensure the most effective egress of passengers and crew in

7 Chung Y. S, et al,. 2017. Burnout in Seafarers: Its Antecedents and Effects on Incidents at Sea. Maritime Policy & Management, 44(7):916-931 doi:10.1080/03088839.2017.1366672. available at https://www.tandfonline.com/doi/abs/10.1080/03088839.2017.1366672?journalCode=tmpm20

8 Sarvari P. A., 2018, Studies on emergency evacuation management for maritime transportation, Maritime Policy & Management, 45:622-648, available at https://www.tandfonline.com/doi/full/10.1080/03088839.2017.1407044?needAccess=true

9 PALAEMON D2.1, 2020, Report on the analysis of SoA, existing and past projects/initiatives

10 ibid. As this document (PALAEMON D2.1) points out, the Master of the ship has the overriding authority and the responsibility to make and exercise decisions with respect to safety at sea, prevention of human injury or loss of life, and avoidance of damage to the environment, and to property. Thus, in an emergency, she has the responsibility to act promptly according to his professional judgment of the overall circumstances. It is also under her responsibility the activation of the shore emergency response whenever required.

the event of an emergence evacuation[11]. Normally, evacuation plan(s) must be accompanied by a study describing the evacuation analysis performed to produce and optimize the plan, and by onboarding emergency training actions and drills.

An evacuation plan is based on ship's general layout. The plan should include a diagram showing the distribution of passengers from spaces where they may stay the moment when evacuation to assembly stations starts[12]. But the essential part of evacuation plan are its optimization as a function of real evacuation time, and the planning of the evacuation routes so to establish many alternative routes and escape possibilities.

Finally, the preparation for the execution of the evacuation plan define the evacuation management approach. The term "evacuation management" encompasses several actions, among them:

i. The planning "in context" and the forecasting of needs for logistics (evacuation execution plan).
ii. The analysis based on evacuation scenarios, simulations and accumulated knowledge from actual accident experiences (evacuation models).
iii. The maintenance and updating of the ship evacuation system and the conduct of emergency evacuation drills and frequent exercises, performed in order to train staff and passengers and to evaluate the ship efficiency and effectiveness in carrying out emergency evacuation procedures (evacuation operations).

All these matters have been extensively investigated in the last years and the related research through marine emergency evacuation has greatly been enhanced. The shipping companies and the practitioners have, in fact, accumulated important tacit and codified knowledge on how to plan, maintain and operate specific evacuation models. The researchers contributed with an abundant literature on the topics of theoretical models and simulations for passengers ship evacuation[13]. What is even more interesting is a recent trend towards proactive risk management thinking, an innovative approach for evacuation applying to the whole

11 Lozowicka D., 2012, Organization of evacuation from passenger ships – a concept of safety enhancement, Scientific Journals 32(104):110-114, available at https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwiAkt2k5L_qAhXnx4UKHbeNAMAQFjAAegQIAxAB&url=http%3A%2F%2Fyadda.icm.edu.pl%2Fbaztech%2Felement%2Fbwmeta1.element.baztech-article-BWM7-0007-0042%2Fc%2Flozowicka.pdf&usg=AOvVaw0bj3n9T_sSKqhXKMrjGBGx

12 ibid.

13 A Google Scholar search of the topic "ship evacuation management", in early July 2020, reveals the existence of 11.600 references only since 2016, see: (https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&as_ylo=2016&q=ship+evacuation+management&btnG=).

evacuation process, from the design stage to the operation stage[14]. In this context, two key enablers specifically emerge: a) the increasing use of real-time sensorized Decision Support Systems (DSSs), able to provide feedback and guidance to all actors participating in an evacuation process and, b) the integration into the ship evacuation system of the mobile and wireless communications technologies and networks, and the new possibilities offered by the smart devices (owned by the passengers) and the deployment of IoT infrastructures. These two key enablers create the conditions for designing a technology-aided and increasingly automated evacuation process.

3.2 Towards a technology-aided evacuation management

In state-of-the-art research, marine emergency evacuation is defined as mustering, directing, and taking many people away from a ship under an existing or potential hazard to a relatively safe place (Lifeboats and other Maritime Evacuation Systems - MES, nearby ships, air rescue helicopters, etc.), in a planned manner[15]. An evacuation follows a sequence of events shown in the Figure below[16].

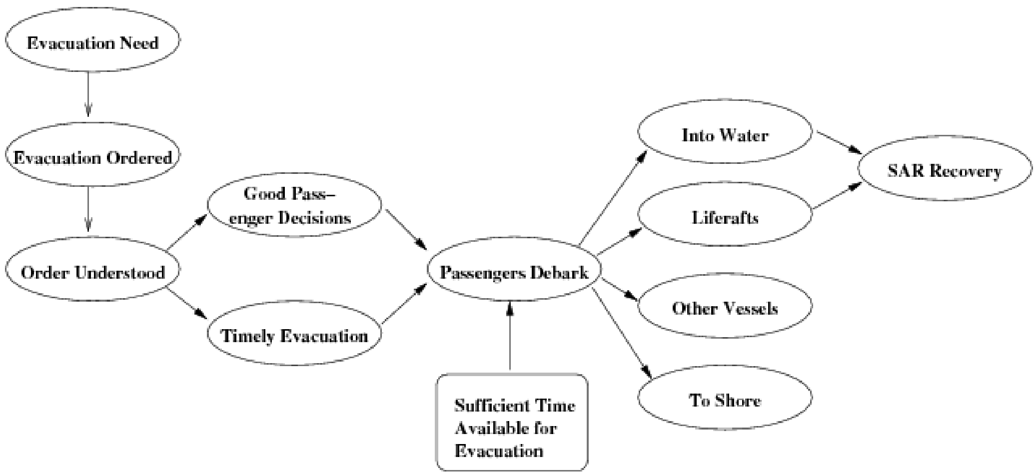

Figure 2: The sequence of events during an evacuation process

More specifically, the process can be divided into the following processes and tasks[17]:

14 Stefanidis F., et al, 2019, Ship Evacuation and Emergency Response Trends, Design & Operation of Passenger Ships 2019, available at https://www.researchgate.net/publication/337619932_Ship_Evacuation_and_Emergency_Response_Trends

15 Sarvari P. A., et al, 2019, A maritime safety on-board decision support system to enhance emergency evacuation on ferryboats, Maritime Policy and Management 46(4):410-435, available at https://www.tandfonline.com/doi/abs/10.1080/03088839.2019.1571644

16 H. Klupfel, op. cit.

17 PALAEMON D2.1, op. cit.

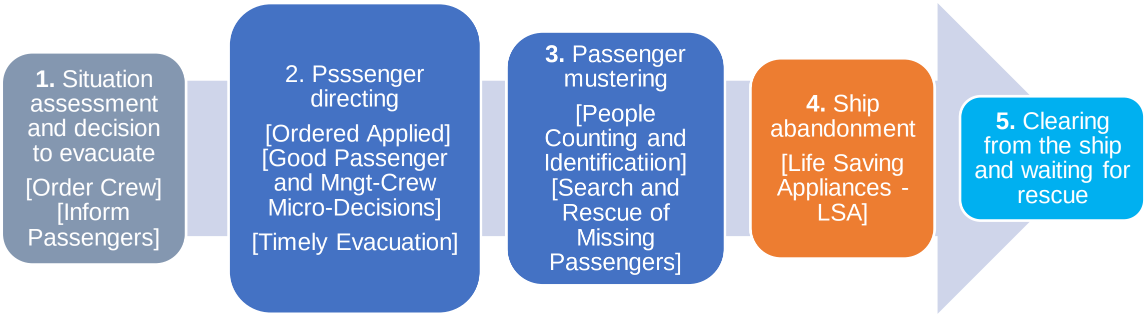

Figure 3: The five stages of an evacuation process

In case of an emergency (e.g., fire, flooding, grounding, collision, pollution, heavy weather damage, security threat, failure of critical machinery, etc.), the response strategy depends first on the appreciation of the nature and extent of the incident by the Master of the ship. Traditionally, this is a very important human task that is accomplished with the support of the crew members who continuously transmit real-time information on the emergency conditions prevailing within the ship, the level of risk and its spread, and on how it affects the safety of passengers. More recently, however, the assessment of an emergency and the decision of the ship management to evacuate the ship are also aided by digital Decision Support Systems (DSS), eventually operating with ship evacuation modelling software[18]. Specifically, these systems work in two distinct operating modes: a) vulnerability monitoring for increasing the safety awareness onboard the intact ship and, b) survivability assessment and Decision Support in case of an incident[19].

Decision Support Systems are not the only technological enabler for an enhanced evacuation process. As already mentioned, during the very last years, key enabling technologies are wireless and mobile communications, smart networked devices and IoT (ship sensor technologies and smart cameras, intelligent evacuation indication systems[20]). These technologies allow for the development of a new generation of accurate ship evacuation technologies, much beyond evacuation modelling and simulations, to provide passengers tracking in real time conditions, technology-assisted passenger directing, mustering and ship

18 Stefanidiis F. et al, op. cit.

19 Pennanen P., et al, 2015, Integrated decision support system for increased passenger ship safety, The Royal Institution of Naval Architects available at https://www.researchgate.net/publication/283878182_Integrated_decision_support_system_for_increased_passenger_ship_safety

20 Mei Y. et al, 2019, IoT-based real time intelligent routing for emergent crowd evacuation, Library Hi-Tech 37(3):604-624, available at https://www.emerald.com/insight/content/doi/10.1108/LHT-11-2017-0251/full/pdf?title=iot-based-real-time-intelligent-routing-for-emergent-crowd-evacuation

abandonment. A review of the related literature[21] proposes the generic concept of "Intelligent Evacuation Management Systems" (IEMS) which are defined broadly and independently of the application context, as a possible combination of different methods in the area of evacuation navigation, from crowd monitoring and prediction techniques that could foresee the occurrence of crowd disasters, to computing technologies relevant to evacuation modelling and to rule-based models that provide guidelines and information on efficient evacuation pathways.

In this rather complicated, unclear and technologically fluid context, the present Deliverable develops the functional specifications of the PALAEMON Smart Evacuation Management System (SEM), considering different possible conditions and situations during Marine Emergency Evacuation (MEE). The term "Smart Evacuation System" is defined at the operational level, as a layer of additional to existing evacuation functionality to allow for technology-aided Evacuation Management in cruise and RoPax vessels. More specifically, we envision a software suite providing technology-enhanced evacuation possibilities, which can be used by evacuation coordinators to:

- Support the effective application of an Evacuation Plan (EP) by providing proper guidance to crew and passengers;
- Manage incidents that could possibly hinder the timely execution of the EP from the initial time the incidence is reported to the conclusion of the incidence;
- Track the status & location of resources and passengers, and reassess response plans if needed; and
- Design and post-evacuation analysis of the response, on the basis of Key Performance Indicators (KPIs).

To deliver to this objective, different template evacuation scenarios are developed which consider passenger, environmental, crew, routing and other ship factors that can play a decisive role during MEE. These scenarios will provide the operational framework for the detailed definition of the PALAEMON pilot functionality and drive the deployment of the PALAEMON Smart Evacuation Management System in the pilot context of Field Trials and beyond[22].

3.3 The SEM System Overview

In a complex environment with a high level of unpredictability and out-of-equilibrium dynamics, due to the degradation of the ship stability and to the behaviour of passengers

[21] Ibrahim A.M., et al, 2016, Intelligent Evacuation Management Systems: A Review, ACM Transactions on Intelligent Systems and Technology 7(3):1-27. 10.1145/2842630, available at https://www.semanticscholar.org/paper/Intelligent-Evacuation-Management-Systems%3A-A-Review-Ibrahim-Venkat/dd4ff7dc1d61229ea9df751f7f4767dee37e998b

[22] PALAEMON WP 8: PALAEMON Application Field Trials, Evaluation and Outcomes. WP8 points to three specific pilots (Field Trials): a) Mass Evacuation Vessels (MEV) Prototype Validation Demo, b) Passengers Evacuation Demo and, c) Passengers Mustering Demo.

"guided by the instinctual urge to get away from the danger" (with limited rational thinking on finding a way-out[23]), the assembly and evacuation of a passenger ship requires an integrated approach to evacuation management. This approach should account for all aspects of maritime operations: from crew training (and passenger training through safety drills on board cruise ships), to the design of standards of emergency equipment, emergency procedures, safety rules, regulations, guidelines, etc. As pointed out by Stefanidis et al.[24] the biggest challenge today is the integration of all the systems participating in ship evacuation and emergency response under the guidance of an IT multi-layer platform.

PALAEMON designs and develops such a platform under a holistic approach called "passenger ship evacuation ecosystem". The following Figure, taken by the Deliverable 2.6[25], displays the different types of components that take part of the system from the information generation (left part of the Figure) until the moment a service is consumed. It also presents the wide spectrum of end users that will play an important role throughout the different phases of the evacuation process, as illustrated at the right frame of the Figure 4.

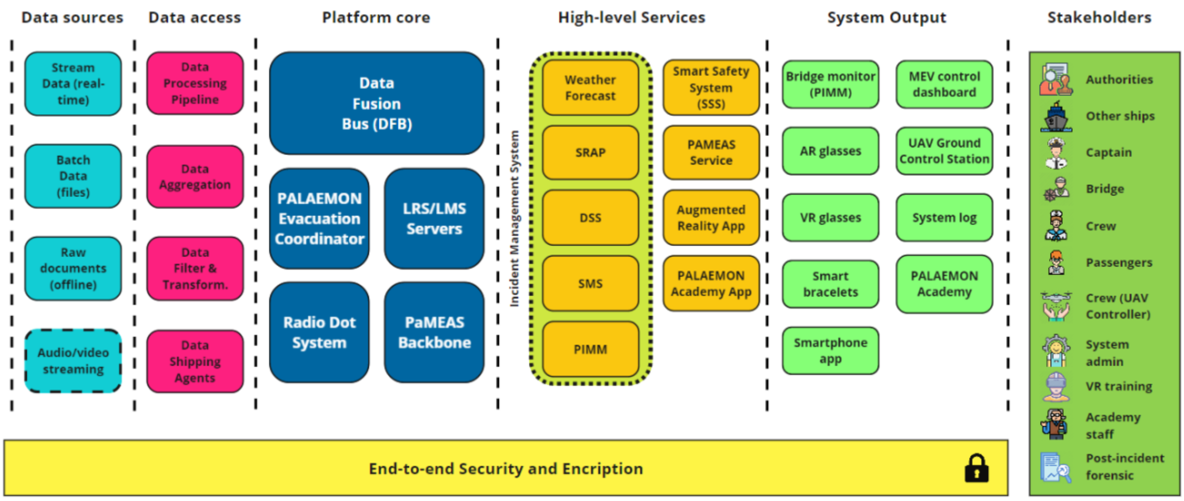

Figure 4: PALAEMON overall architecture vision

In fact, the architecture of PALAEMON implements a holistic approach which envisions a sophisticated centralized evacuation system, based on a radical re-thinking of Mass Evacuation Vessels (MEVs) combined with an intelligent ecosystem of interoperable IT components which can:

23 Nevalainen J., et al, 2015, Modeling Passenger Ship Evacuation from Passenger Perspective, available at https://www.researchgate.net/publication/281458321_Modeling_Passenger_Ship_Evacuation_from_Passenger_Perspective

24 Op. cit.

25 PALAEMON D2.6, 2020, PALAEMON architecture

- Provide homogeneous representation of evacuation data and real-time access to these data.
- Use these data to support the deployment of technology-aided evacuation strategies for optimizing the operational planning of the evacuation process on damaged or flooded vessels.

The intelligent ecosystem of PALAEMON Platform components incorporates state-of-the-art technologies for sensing, people monitoring and counting (including passenger indoor location identification services), and evacuating them with help from ICT-equipped Mass-Evacuation Vessels (MEVs), as well as technologies for real-time data and event management during accident time. These components will be integrated into an independent, smart situation-awareness and guidance system/platform for sustaining active evacuation routes, to improve the efficiency of emergency response in passenger ships.

Within this large system, one can distinguish between several layers of functionality and services, the Monitoring Layer (Ship Evacuation Manager), the Infrastructure Layer (Mobile and Wireless Networks, IoT and Smart Devices, etc.), the Data Exchange Layer, the DSS layer (providing recommendations to bridge) and so on, and finally the SEM system (Smart Evacuation Management System) which is the operational branch of the whole PALAEMON IT platform[26]. PALAEMON SEM is designed to act in real conditions to deal with hazard upon its occurrence by using a reactive approach: in normal times, SEM will be allowed to run on a minimal function mode; it will be activated when an irregular situation is detected and become functional under the administration of the bridge. Its goal is to optimize the evacuation process, as well as the efforts of rescue teams, via an “augmented”, technology-aided evacuation process, thus improving on evacuability.

Evacuability is a term used to signify performance-in-context, i.e. to measure the capability of passenger evacuation process. As it is explained in the relevant literature, the concept entails the appreciation of a wide range of parameters, such as: assessment of evacuation layout plan, evaluation of evacuation time, identification of potential bottlenecks, ease of saving appliances use, familiarization of passengers with the environment of the ship, crew training, evacuation procedures/strategies and design/modification for ease of evacuation, decision support systems and other IT facilities for evacuation management etc. Technically speaking, the term evacuability represents a risk measure for passenger evacuation at sea, expressed as an index[27]. As explained by Vassalos et al.[28]., and shown in the next Figure, “it is essentially defined as the probability of an environment being completely evacuated no later than a given

26 PALAEMON project Deliverable D6 (op. cit) designates five (5) categories of components: Data Sources, Data Access, Platform Core, Smart Evacuation Management and System Outputs.

27 Vassalos D., et al, 2002, Evacuability of Passenger Ships at Sea, available at https://www.researchgate.net/profile/Marcus_Bole2/publication/237657474_Evacuability_of_Passenger_Ships_at_Sea_By/links/568bac3508ae051f9afc573e/Evacuability-of-Passenger-Ships-at-Sea-By.pdf

28 ibid.

time elapsed after the alarm went off, in a given state of the environment and a given state of initial distribution of people onboard".

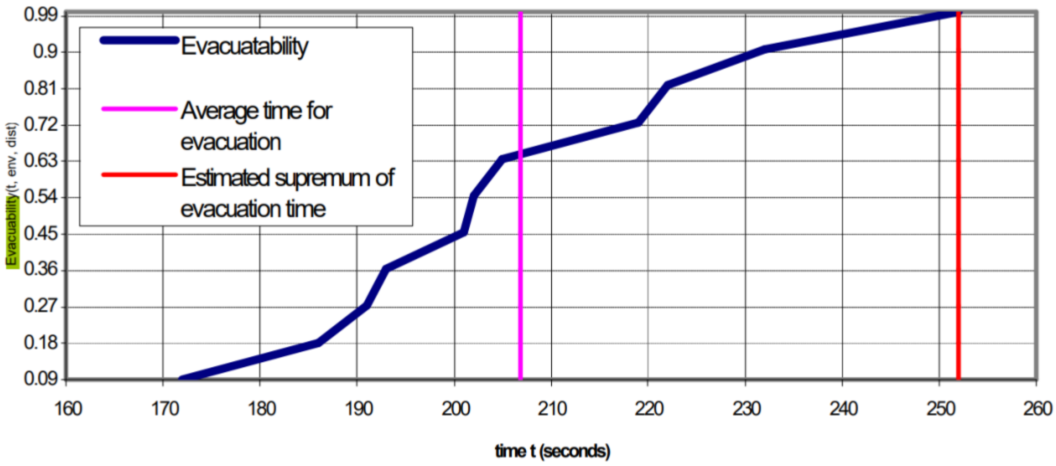

Figure 5: Evacuability as a probability function

Apparently, to improve ships' evacuability a significant degree of automation is needed to achieve greater efficiency goals, to adapt to unforeseen emergencies or incidents, reduce human error, and assign roles and responsibilities in a continuously changing situation. But how much automation is needed? There are many ways of classifying automation. Parasuraman et al.[29] proposed a model for types and levels of human interaction with automation. According to that model, functions that can be automated are divided into information acquisition, information analysis, decisions and action selection, and action implementation. In each of these classes of functions, automation can vary from fully manual to fully automatic. Specific automated systems can involve automation of one or many of these classes to a varying degree, on the continuum from fully manual to fully automatic.

A more domain-specific categorization of automation for Marine Emergency Evacuation (MEE) can be borrowed from the Advanced Driver Assistance Systems (ADAS). Taking the work of Parasuraman et al further, Carsten and Nilsson[30] have proposed four different groups of ADAS based on their ability to intervene in vehicles' control: systems that provide information, issue warnings and feedback, partly intervene in driving, and fully automate driving.

29 Parasuraman R. et al, 2000, A model for types and levels of human interaction with automation, IEEE Transactions on Systems, Man, and Cybernetics – Part A: Systems and Humans, 30(3):286–297, available at https://ieeexplore.ieee.org/document/844354

30 Carsten O. and Nilsson L., 2001, Safety assessment of driver assistance systems, European Journal of Transport and Infrastructure Research, 1(3):225–243, available at

https://journals.open.tudelft.nl/ejtir/article/view/3666

By analogy to the ADAS, we can distinguish among systems that provide automation and support for "technology-aided MEE", systems with automation functionality and the capacity to:

i. Provide information intended to assist the evacuation task (e.g. way-finding instructions to passengers, post reassignment to crew).
ii. Issue advice and warnings (proximity to danger or deviation from a designated escape path).
iii. Assist and/or intervene in ship's control, but without completely supplanting the operator who holds the power to overrule system actions (e.g. automatic door lock or blocking of areas where hazard exist).
iv. Support, if necessary, fully automatic MEE, in which the operator is completely out of the loop and cannot overrule system actions.

In the context of this categorization, we can argue that the PALAEMON SEM should be a system designed to provide functionality similar to, or on a par with the first two categories of systems, i.e. systems that provide information and/or issue advice and warnings. As long as the levels of automation of ships permit it (i.e., automated door locking, automated public addressing systems, smart lighting and evacuation paths with LED indications, etc.) the PALAEMON SEM could be easily extended so that the resulting system would be placed higher on the automation level scale, to the third category, i.e., systems that intervene in ship's control. In a similar vein, when modern ships reach the level of getting closer to what in the literature is known as "automated vessels" – which can support more intervening forms of evacuation management – the evolution of PALAEMON SEM could be placed even higher on the automation scale, to the fourth category, i.e. systems that support fully automatic MEE. But, until we reach this point and time, the design of the PALAEMON SEM is realistically grounded on current marine needs and best-practices that encourage innovation through added-value services, which fundamentally affect the relationship between the passengers, the crew and the ship environment during a MEE.

So far, much attention has been paid to the development of SEM systems based on sophisticated modelling and simulations for advanced analyses of ship evacuation – with models ranging from ship construction to human behavior and to passenger mustering/evacuation process etc. However, less effort has been directed towards including such models in an operational framework for smart evacuation management, which brings together IT and process management technology, human factor, ship's safety processes and (regulated) operating procedures to improve evacuability. The PALAEMON project has been designed to bridge this gap and build a next generation of evacuation management systems.

The PALAEMON SEM is a system designed to:

- Combine advanced passenger traceability with operations management capabilities that allow crew to efficiently be part of the decision loop.

- Make real-time adjustments to the MEE response based on passengers' location monitoring.
- Impact the response's reliability and evacuability by providing directions to and through the evacuation paths.
- Provide sufficient flexibility to cope with the broad range of incidents[31] that may occur during the ship evacuation process.

PALAEMON SEM should work as the operational branch of the PALAEMON IT platform and will consist of a suite of integrated software packages used to generally manage the evacuation process; to initiate an incidence record, if an evacuation hindering incident is reported; to dispatch responding personnel; to monitor the evacuation process through high accuracy people tracking, observation of passengers towards the mustering stations, counting and analytics; and, finally, to assist SAR (Search and Rescue) dispatched forces to search and find survivors and approach them. It is designed and configured to meet the operational and administrative needs of the ship's crew, and to comply with the maritime regulations (SOLAS, MSC, IMO various res. etc.), as well as with the information privacy, data privacy and data protection laws, common practices and standards for privacy safeguarding (GDPR etc.).

PALAEMON SEM is essentially composed from two main components:

i. The PALAEMON Incident Management Module (PIMM) allowing for the identification of evacuation-critical incidents, the execution or response plans and, as its main contribution, the semi-automated real-time adaptation of these plans.
ii. A Passengers Mustering and Evacuation Process Automation System (PaMEAS) to track and monitor the position of customers within the ship (in the various areas of a ship, from the lower decks, where the state rooms locate, to the uppermost levels, which include the promenade and activity decks) and automatically launch, in the case of an emergency, a pre-defined evacuation plan. It will be communicated directly to passengers' mobile phone (with simple notifications) and projected to the physical ship space, by using the appropriate LED indications for the suggested evacuation paths (managed through IoT networked devices).

From a specific technological perspective, the PIMM is a corner hub for managing (and displaying information) from different modules during an incident. It will used by the bridge and the competent crew to initiate an incident record, to dispatch, to maintain the status of

31 For the purposes of this document, an "incident" is a real-world event that occurs during a MEE which might hinder the evacuation process or cause serious delays. An incident could range from something as routine as a crew helping an elderly up the stairs, or as major as a fire or an explosion. Once the Evacuation Coordinator (EC) has been notified, a record is created in the system and the incident type is set for the purpose of tracking and responding to the incident. Typically, each incident type is associated with a specific response plan that establishes the number and types of resources required for mitigating the incident, the crew members responsible for the incident, and its default priority.

responding units and resources in the ship, and to generally manage the incident. It includes interfaces that permit the software to provide services to Evacuation Coordinators (ECs) and other MEE-designated crew (users) in evacuation situations. The functionality of PIMM is extended, via PAMEAS, out to ship personnel and passengers (responders) through their mobile and other devices (smartphones, bracelets etc.) – to facilitate and monitor evacuation of passengers and crew, using 5G networking, software and algorithmic capabilities.

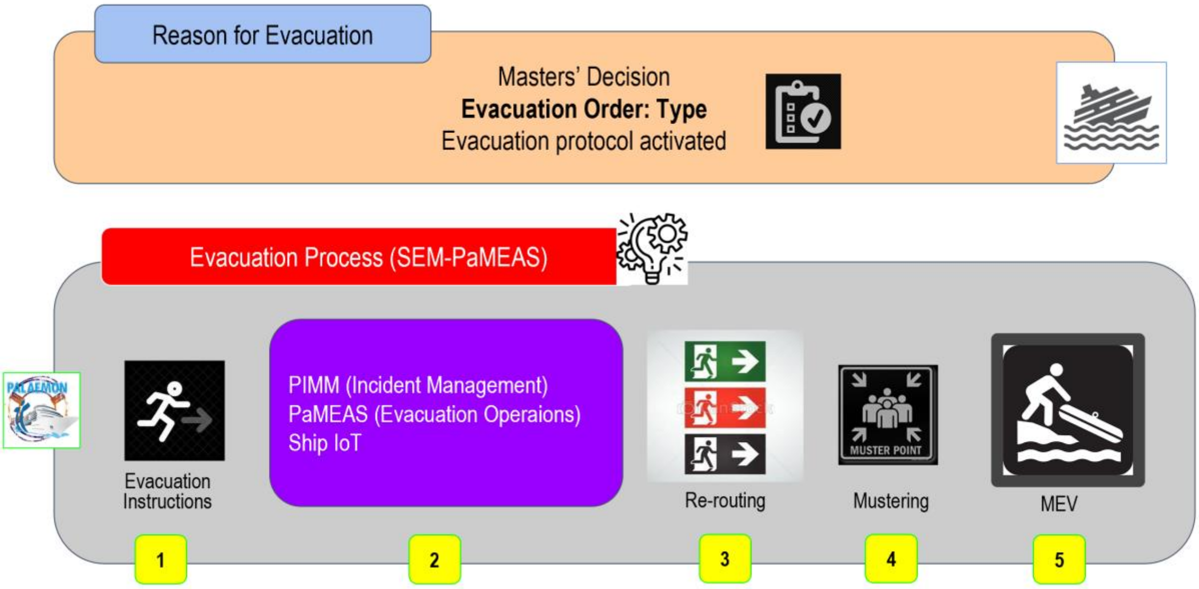

Figure 6: Structure and functionality of PALAEMON Smart Evacuation Management System (SEM)

In sum: Of the overall functionality of the PALAEMON SEM, the PIMM and the PAMEAS sub-systems, along with their associated modules, execute what in the following is termed "Standard Evacuation Functions" and "Incident Management Functions". More specifically:

- The PAMEAS sub-system provides the means for the execution of the Standard Evacuation Functions, which include:
  - ✓ Marking the Evacuation Path
  - ✓ Engaging the Notification System(s)
  - ✓ Tracking the status & location of passengers and resources & reassessing response plans
  - ✓ Providing directions to and through the Evacuation Paths.

  For a more detailed discussion on the various Standard Evacuation Functions see section 5.1 below.

- The PIMM sub-system allows for the execution of the Incident Management Functions, which include:
  - ✓ Call-in Handling
  - ✓ Dispatch Support
  - ✓ Resource / Crew Management
  - ✓ Incident Management.

  For a more detailed discussion on the various Incident Management Functions see section 5.2 below.

All functions require that passengers, crew and ship interact during the evacuation or the incident handling process[32].

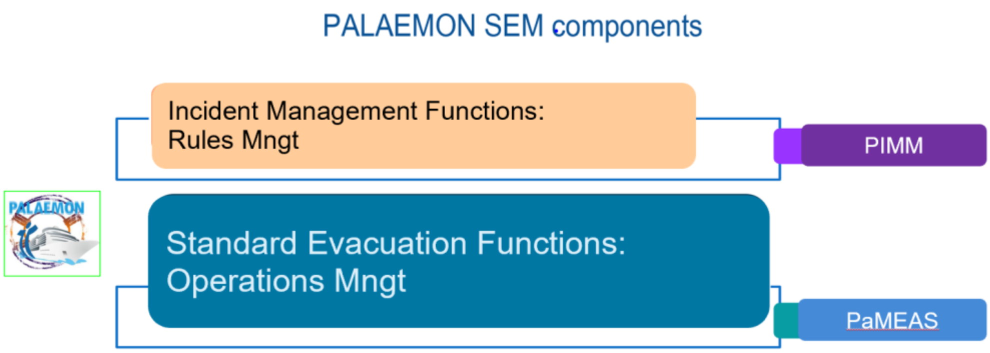

Figure 7: PALAEMON Smart Evacuation Management System – Principal Components

4 PALAEMON Use Case Context (Reference Scenarios)

The design of PALAEMON SEM, and mostly the specific application of the functionality of this system within the pilot framework of WP8[33], will look at key evacuation requirements in realistic operational scenarios. This is exactly the main objective of the present Report, propose a set of clearly defined evacuation scenarios. The work presented here involved a detailed look at available historical data with reference to accident reports and at available in the literature evacuation management cases. It has also sought feedback from the PALAEMON Consortium members and other professional mariners out of the Consortium, with the aim of bringing realism and credibility to the scenarios.

32 In D2.6 (Deliverable 2.6, op. cit.), SEM is described, in technical terms, as follows: Atop the core of the platform, PALAEMON will come up with a number of heterogeneous services that will help stakeholders (e.g., Master, Bridge, crew in general, passengers, etc.) improve their response when it comes to proceed to evacuate the ship. It works with other systems (Smart Risk Assessment Platform-SRAP, DSS, Safety Management System-SMS, Weather Forecast etc.) to provide a “smart evacuation service”.

33 PALAEMON WP8: PALAEMON Application Field Trials, Evaluation and Outcomes.

With the purpose of providing meaningful information to PALAEMON evacuation pilots (Field Trials), we have designed these scenarios to be as simple, realistic and relevant as possible. They are anchored in a basic understanding of the overall MEE framework, including human factor, ship's safety processes and operating procedures. Taking all these factors into account, we can enable truly user-based evacuation use-case analyses.

As already mentioned, there are different factors that make up an evacuation scenario and these should all be clearly defined in such a way that they unambiguously describe the scenario. Ideally the different factors may relate to the total number of people on board, the demographics of the population on board the ship, the type of accident the ship is exposed to, the time of day when the mustering alarm sounds, the weather condition at the time of accident (influencing the movement of the vessel), the lack of accessibility of different parts of the ship (e.g. due to an accident) etc. The main causes for an evacuation from passenger ships should also be considered, namely fire, explosion and collision[34].

Although the current IMO requirements[35] regarding evacuation times from passenger ships correspond to the requirements related to confinement of fires within each main fire zone, explosions and collisions can also become critical regarding evacuation from passenger ships. This is because these types of accidents generally leave less time for evacuation than fire accidents. If a ship should sink subsequent to an explosion or a collision accident, it will obviously impose an absolute maximum time for evacuation—the time it will take the ship to sink or capsize, rendering evacuation no longer possible.

In a typical fire accident, it will be more crucial to rapidly evacuate certain affected fire zones than to rapidly abandon the whole ship. Only rarely will a fire result in damages that are extensive enough to cause the ship to sink, and fires that do escalate will normally be delayed by firewalls separating the fire zones. Furthermore, those ships that sink due to a fire will normally start sinking after a certain period of time. People on board that are not directly exposed to the fire will thus generally have enough time to abandon the ship before the fire spreads throughout the ship. For those people occupying the areas of the fire (within the same fire zone), however, there may be very little time available to escape before heat and toxic gas becomes a major threat to life and health.

In this context of variable abandonment times, there are two fundamentally different types of evacuation from a passenger ship that can be distinguished, i.e. precautionary evacuations and emergency evacuations. A precautionary evacuation can be initiated in potentially dangerous situations even though there are no immediate threats to the people on board. Considering the risk associated with the evacuation process itself, the necessity of a

34 Grounding is also a primary MEE cause but is not addressed here for reasons of simplicity and because the proposed scenarios are of indicative and not inventory purpose.

35 IMO, 2001, SOLAS Amendments 2000. International Maritime Organization, London, UK, ISBN 92-801-5110-X.

precautionary evacuation will be thoroughly considered before it is initiated. In such situations, the time used in the evacuation process will not be critical and a typically precautionary evacuation scenario will be to direct the ship ashore and to abandon ship there, or to proceed to an anchorage where the respective damages (if any) can be assessed.

The characteristics of an emergency evacuation are much more different from that of a precautionary evacuation. In such circumstances the overall objective will be to muster as quickly as possible and to abandon the ship before it is too late. Failure to evacuate people in time will be fatal and the time spent escaping from the ship will be crucial. Such evacuations will typically only be carried out in case of a serious incident, such as an explosion with subsequent water ingress, or a fire that has escalated and run out of control. The focus of the current document will be to construct evacuation scenarios describing emergency evacuations in these different situations.

Finally, it should be argued that in a MEE situation analysis it is not possible to take every thinkable accident scenario into account. After all, this is not necessary to derive explicit use-cases for the PALAEMON pilot activity. Our effort started from the long-term vision of the PALAEMON response in the generic case of the collision of a passenger ship with another vessel that results in the abandonment of the passenger ship (provided in a previous project Deliverable[36] and summarized in an online document[37]) that is attached to this Deliverable). However, the objective here is rather to identify operational scenarios that will allow for testing the system's components and for providing proof of its overall functionality in the context of pilot applications that will conclude the project. So a set of evacuation scenarios that are thought to be most relevant for the PALAEMON piloting needs have been developed and are presented in the following. The scenarios correspond to three types of accident cases, i.e. an explosion scenario, a fire scenario and a collision scenario.

All Reference Scenarios follow a methodological template which is shown in the Table below.

36 PALAEMON D2.2, 2020, First version of PALAEMON Requirements Capture Framework

37 PALAEMON WP2 Evacuation Scenarios v2.2 See: https://drive.google.com/file/d/1oLx100pTv_46_VW53EA2i6-T1Gt9f2B9/view?usp=sharing | Sheet D2.2

Table 1 Reference Scenarios

1. (State 0) Reason for Evacuation – Assessment of criticality
   - ✓ A Master's decision should take place
   - ✓ Eventually, this will launch an Evacuation Order
     - ▪ Types Of Evacuation Order (Abandon Ship, Evacuate Passengers etc.)
     - ▪ An evacuation protocol is activated
2. (State 1) Evacuation Process Loop
   - ✓ Supported by PALAEMON SEM
3. Worsening issue: An incident happens
   - ✓ Incident Management: Supported by PIMM
4. The Smart Evacuation Management System and PaMEAS address the issue
   - ✓ The incident is closed
5. Mustering and Evacuation processes terminate (from PaMEAS to MEV)
   - ✓ Lifeboats and liferafts (MEVs) are clear from the ship and waiting for rescue (or passengers and crew clear from the ship on the dock, if the ship is docked).

The following Figure summarizes the methdology approach and the context of application of the Reference Scenarios.

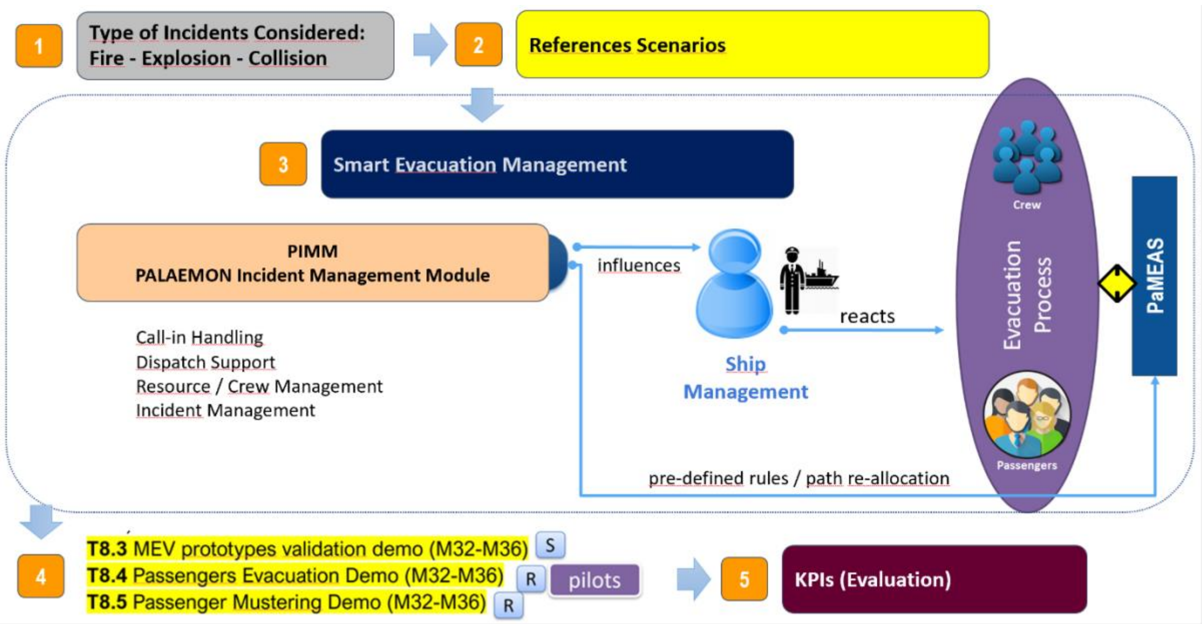

Figure 8 Methodology approach and the context of application of the Reference Scenarios

4.1 Fire and explosion scenarios (emergency evacuation scenarios)

A fire, or an explosion, on a ship at sea is always serious and dangerous.

The possibility of a fire breaking in a Ro-Ro passenger ship is much different than that in a cruise liner[38]. The main difference between the two is that Ro-Ro ships contain enclosed car decks whereas cruise liners have laundry rooms, where fires are most likely to start. Between one out of three and one out of four onboard fires will escalate and spread to other parts of the ship, while the remaining will be confined and extinguished within the fire origin. Other places where fires are likely to occur are accommodation areas, public spaces and car decks or laundry rooms for Ro-Ro passenger ships and cruise liners respectively.

A fire might trigger the initiation of a MEE, and it may influence the evacuation performance, primarily, in two different ways. First, a fire might totally cut off some of the escape routes, e.g. corridors or stairways, so that alternative routes must be used. Secondly, smoke and poisonous gas produced in the fire might spread through the corridors and slow down people that use them for escape due to reduced visibility or difficulty to breathe. In addition, a fire may have a psychological effect on the people onboard affecting their behaviour, causing e.g. panic, shock or paralysis of the passengers.

Escape from the affected fire zone will normally be more critical than abandonment of the whole ship in case of fire. One important scenario should therefore include that people occupying the zone where a fire starts need to evacuate the fire zone to muster somewhere else on the ship, away from the fire. The time allowed for such evacuations should be rather short, as heat and smoke might be fatal in a few minutes. However, a more fitting fire scenario to the needs of the PALAEMON project would be that of a fire that escalates and forces everyone onboard to abandon the ship. The time allowed for evacuation in this scenario will typically be quite long, but the fire might cut off some of the escape routes and/or the embarkation stations.

Besides the case of an escalating fire disaster, an evacuation scenario due to an explosion, also leading to ship abandonment, would be considered. We assume an explosion that occurs causing water ingress and serious injuries to crew. In this scenario, the most critical issue will be whether or not people are able to escape the affected zone by themselves, and/or how response units can be guided to move the injured personnel to an area of refuge in time.

38 Vanem, E. and Skjong, R. (2004). Fire and evacuation risk assessment for passenger ships. In: Proceedings of the 10th International Fire Science and Engineering Conference (Interflam) 2004, vol. 1. Edinburgh, Scotland, July 5–7, 2004, pp. 365–374, ISBN 0 9541216-4-3. available at https://scholar.google.com/scholar_lookup?title=Fire+and+evacuation+risk+assessment+for+passenger+ships&conference=Proceedings+of+the+10th+International+Fire+Science+&+Engineering+Conference+(Interflam)&author=Vanem,+E.&author=Skjong,+R.&publication_year=2004

The following Tables present the considered fire and explosion scenarios in a structured way to ensure that they can be readily applied for the development of the PALAEMON basic use-case, to support the design of the PALAEMON. More specifically, the first two columns draw a line between the underlying conditions leading to the evacuation decision, the beginning and the end of (a) the Standard Evacuation Process (Evacuation Process Loop), and (b) the Incident Management Process in each scenario. The third column lists in chronological order the sequence of critical events. The fouth column describes whether the associated function is standard operating procedure, standard evacuation function, or incident management function – the last two are PALAEMON SEM functions. Finally, the fifth column names the PALAEMON subsystem executing the respective function.

Table 2: The fire scenario

WP2 - D2.3 Evacuation Scenarios - Basic Use Cases | Fire Scenario				
	Type of accident: A very serious fire suddenly brakes out in a RoPax. The fire is detected by the ship's alarm system at a vessel's deck, calling for immediate evacuation. The fire is escaping on the starboard side of the ship making the use of the survival equipment on that side of the board practically impossible. The ship management relies on SEM and PaMEAS to re-route passengers originally assigned to embarkation stations above the fire deck to other embarkation stations from which they can freely evacuate.			
Pilot-specific Use Case Components			**Process type**	**PALAEMON response**
Conditions	**Reason for Evacuation – Assessment of criticality**			
		Fire is detected by the ship's alarm system at a vessel's deck	Ship's alarm	
		The Bridge/Duty officer requests for visual reconnaissance	Standard operating procedure	
		Crew is dispatched to make visual identification	Standard operating procedure	
		Dispatched crew reports inability to reach the area due to extremely high temperatures	Crew reporting	
		The Bridge/Duty officer orders for the closing of fire resistant doors to prevent further propagation of fire	Standard operating procedure	
		The Master of the ship is summoned on the bridge and the situation is evaluated	Standard operating procedure	

WP2 - D2.3 Evacuation Scenarios - Basic Use Cases | Fire Scenario				
		The Master orders for immediate assessment of the: – Vessel's ability to maintain stability, movement and navigation – Functionality of major machinery systems and equipment – Crew, passengers and environment safety	Standard operating procedure	
		The "Abandon Ship" order is given	Master's decision	
		All related stakeholders are notified	Standard operating procedure	
		The evacuation protocol is activated	Action	
Process	**Evacuation Process Loop**			
		The Evacuation Coordinator (EC) is assuming position	Standard operating procedure	
		Crew teams (firefighters, damage-control units, boat preparation units, passenger mustering personnel, first-aid units, etc.) are informed—via radio and cellular devices—to move to their predesignated emergency posts	Standard evacuation procedure/enhanced by PALAEMON SEM	Incidence Mngt System (Evacuation Actions Mngt Funct.) PaMEAS
		Signaging of the routes of escape for passengers using emergency lighting is activated	PALAEMON SEM evacuation function	Incidence Mngt System (Standard Evacuation Functions) PaMEAS
		Automated instructions are broadcasted over the ship's public address system	Standard evacuation procedure/enhanced by PALAEMON SEM	Incidence Mngt System (Standard Evacuation Functions)

WP2 - D2.3 Evacuation Scenarios - Basic Use Cases | Fire Scenario				
		Instructions are sent to passengers' personal notification devices (smartphones, bracelets) in the form of easy to read messages, including escape paths and muster/embarkation station location	Standard evacuation procedure/enhanced by PALAEMON SEM	PaMEAS
		The PALAEMON SEM is monitoring the exact position of passengers and crew and informing the EC/dispatcher about the expected evacuation time	PALAEMON SEM evacuation function	PaMEAS
		The PALAEMON SEM is tracking the status & location of passengers & crew and continuously evaluating the need for possible response plans reassessment	PALAEMON SEM evacuation function	PaMEAS
Incident	**Evacuation Process – Incident Management**			
		A crew member calls-in (via radio) that the fire is escaping on the starboard side of the ship making the approach to the survival equipment on that side of the board practically impossible.	New incident (reported by crew)	
		The EC/dispatcher uses the PALAEMON SEM to verify location, classify the incident and assign priority	PALAEMON SEM Incidence Mngt Func.	PaMEAS Incidence Mngt System (Incidence Classif. and Priority Funct.)
		A few minutes later a passenger reports lifeboats burning on the side of the ship immediately above the deck where the fire has started	Passenger reporting	
		The EC/dispatcher requests for visual reconnaissance	Standard operating procedure	
		Crew is dispatched to make visual identification	Standard operating procedure	
		Dispatched crew reports the extent of the damage to the lifeboats	Crew reporting	

WP2 - D2.3 Evacuation Scenarios - Basic Use Cases | Fire Scenario				
		The EC/dispatcher uses the PALAEMON SEM system to raise the levels of incidence priority and recommend a response complement that meet the new requirements of the incident (firefighters on the upper deck to contain the fire so as not to extend to adjacent liferafts)	PALAEMON SEM Incidence Mngt Func.	Incidence Mngt System (Adjustable Dispatch Levels Funct. Update Assigned Resources Funct.)
		The PALAEMON SEM assigns readjusted resources to the incident, based on the incidence's location and ship's response plans, and notifies the assigned units that they have been dispatched to the incidence	PALAEMON SEM Incidence Mngt Func.	Incidence Mngt System (Dispatch Units Funct. Resource Alerting Funct.)
		The PALAEMON SEM checks if the response teams specifically recommended or selected for the incident are positioned at their designated post locations	PALAEMON SEM Incidence Mngt Func.	PaMEAS
		If yes: The PALAEMON SEM electronically routes the collected (by the EC/dispatcher) information to the assigned crew and their acknowledgment is recorded	PALAEMON SEM Incidence Mngt Func.	PaMEAS Incidence Mngt System (Determining Response Crew and Service Area Funct. Event Routing Funct.)
		If not: The PALAEMON SEM pull offs units assigned to other incidents with a lower priority status to handle the current incident of higher priority	PALAEMON SEM Incidence Mngt Func.	PaMEAS Incidence Mngt System (Assign Units Funct.)

WP2 - D2.3 Evacuation Scenarios - Basic Use Cases | Fire Scenario				
		The PALAEMON SEM advises the assigned crew units of the best route to respond to the incident	PALAEMON SEM Incidence Mngt Func.	PaMEAS Incidence Mngt System (Unit Routing Funct.)
		The PALAEMON SEM re-assigns passengers, who were to board the damaged lifeboats, to a new embarkation station and advises them of the best route to move there	PALAEMON SEM evacuation function	PaMEAS
		Crew teams (passenger mustering personnel, boat preparation units, etc.) are informed—via radio and cellular devices—to move to their re-assigned emergency posts	PALAEMON SEM Incidence Mngt Func.	Incidence Mngt System (Dispatch Units Funct. Resource Alerting Funct.)
		The PALAEMON SEM continuously re-evaluates the need for possible reassessment of response plans to the incident and informs the EC/dispatcher about the new expected time of evacuation completion	Standard evacuation procedure/enhanced by PALAEMON SEM	PaMEAS Incidence Mngt System
		Passengers are safe at their re-assigned embarkation stations	Crew reporting	
		Crew is safe at their re-assigned emergency posts	Crew reporting	
		The PALAEMON SEM incident record is closed	The PALAEMON SEM incident record is closed	Incidence Mngt System (Incident Record Mngt)
	Incident Loop ends			

WP2 - D2.3 Evacuation Scenarios - Basic Use Cases | Fire Scenario				
Process		Boarding to lifeboats and liferafts continues without new incidents	Standard evacuation procedure/enhanced by PALAEMON SEM	PaMEAS Incidence Mngt System (Standard Evacuation Functions)
		The PALAEMON SEM continuously informs the EC/dispatcher about the expected evacuation time	PALAEMON SEM evacuation function	PaMEAS
	End of Evacuation Loop	Lifeboats and liferafts are clear from the ship and waiting for rescue	PALAEMON SEM evacuation function	PaMEAS

Table 3: The Explosion scenario

WP2 - D2.3 Evacuation Scenarios - Basic Use Cases | Explosion Scenario				
	Type of accident: A passenger ship is affected by an explosion. The explosion caused a severe leakage of the vessel's hull which led to the gradual flooding of the engine room, calling for immediate evacuation. Shortly after the evacuation alarm has gone off, a crew member is reported to have life-threatening critical injuries making it impossible to move. The ship management receiving the information needs to assign resources—including helpers/porters, and first-aid rescuers—as well as to place the ship's infirmary on standby. The ship management relies on SEM and PaMEAS to monitor the location and status of crew member and evolution of the process on the basis of the identification of position of helpers/rescuers.			
Pilot-specific Use Case Components			**Process type**	**PALAEMON response**
Conditions	**Reason for Evacuation – Assessment of criticality**			
		Explosion is called-in by a crew member (via radio) to the duty officer	Crew reporting	
		The Bridge/Duty officer requests for visual reconnaissance	Standard operating procedure	
		Crew is dispatched to make visual identification	Standard operating procedure	
		While crew has not yet reached the area of the explosion, the ship's alarm goes off indicating inflow of water to the vessel's shaft tunnel	Ship accident reporting procedure	
		Dispatched crew now reports inability to reach the area due to rising water levels	Crew reporting	
		The Bridge/Duty officer orders for the closing of watertight doors to prevent further ingress of water	Standard operating procedure	
		The Master of the ship is summoned on the bridge and the situation is evaluated	Standard operating procedure	

WP2 - D2.3 Evacuation Scenarios - Basic Use Cases | Explosion Scenario				
		• The Master orders for immediate assessment of the: – Vessel's ability to maintain stability, movement and navigation – Functionality of major machinery systems and equipment – Crew, passengers and environment safety	Standard operating procedure	
		The "Abandon Ship" order is given	Master's decision	
		All related stakeholders are notified	Standard operating procedure	
		The evacuation protocol is activated	Action	
Process	**Evacuation Process Loop**			
		The Evacuation Coordinator (EC) is assuming position	Standard operating procedure	
		Crew teams (firefighters, damage-control units, boat preparation units, passenger mustering personnel, first-aid units, etc.) are informed—via radio and cellular devices—to move to their predesignated emergency posts	Standard evacuation procedure/enhanced by PALAEMON SEM	Incidence Mngt System (Evacuation Actions Mngt Funct.) PaMEAS
		Signaging of the routes of escape for passengers using emergency lighting is activated	PALAEMON SEM evacuation function	Incidence Mngt System (Standard Evacuation Functions) PaMEAS
		Automated instructions are broadcasted over the ship's public address system	Standard evacuation procedure/enhanced by PALAEMON SEM	Incidence Mngt System (Standard Evacuation Functions)

WP2 - D2.3 Evacuation Scenarios - Basic Use Cases | Explosion Scenario				
		Instructions are sent to passengers' personal notification devices (smartphones, bracelets) in the form of easy to read messages, including escape paths and muster/embarkation station location	Standard evacuation procedure/enhanced by PALAEMON SEM	PaMEAS
		The PALAEMON SEM is monitoring the exact position of passengers and crew and informing the EC/dispatcher about the expected evacuation time	PALAEMON SEM evacuation function	PaMEAS
		The PALAEMON SEM is tracking the status & location of passengers & crew and continuously evaluating the need for possible response plans reassessment	PALAEMON SEM evacuation function	PaMEAS
Incident	**Evacuation Process – Incident Management**			
		An alarm goes off indicating that a waterproof door has subsided causing severe water inflow in the engine room; the alarm is triggered	New incident (detected by ship's alarm system)	Incidence Mngt System (Alarm Processing Funct.)
		The EC/dispatcher uses the PALAEMON SEM to verify location, classify the incident and assign priority	PALAEMON SEM Incidence Mngt Func.	PaMEAS Incidence Mngt System (Incidence Classif. and Priority Funct.)
		A few minutes later a crew member calls-in the same event via radio	Crew reporting	
		The EC/dispatcher uses the PALAEMON SEM to avoid unnecessary assignment of resources to the same event	PALAEMON SEM Incidence Mngt Func.	Incidence Mngt System (Check for Duplicate Incidents Funct.)
		Another caller reports that 2 crew members are stranded in the engine room, with one suffering life-threatening injuries which makes it impossible to move without assistance	Crew reporting	

WP2 - D2.3 Evacuation Scenarios - Basic Use Cases | Explosion Scenario				
		The EC/dispatcher uses the PALAEMON SEM to raise the levels of incidence priority and recommend a response complement (first-aid unit and infirmary personnel) that meet the new requirements of the incident	PALAEMON SEM Incidence Mngt Func.	Incidence Mngt System (Adjustable Dispatch Levels Funct. Update Assigned Resources Funct.)
		The PALAEMON SEM assigns readjusted resources to the incident, based on the incidence's location and ship's response plans, and notifies the assigned units that they have been dispatched to the incidence	PALAEMON SEM Incidence Mngt Func.	Incidence Mngt System (Dispatch Units Funct. Resource Alerting Funct.)
		The PALAEMON SEM checks if the response teams specifically recommended or selected for the incident are positioned at their designated post locations	PALAEMON SEM Incidence Mngt Func.	PaMEAS
		If yes: The PALAEMON SEM electronically routes the collected (by the EC/dispatcher) information to the assigned crew and their acknowledgment is recorded	PALAEMON SEM Incidence Mngt Func.	PaMEAS Incidence Mngt System (Determining Response Crew and Service Area Funct. Event Routing Funct.)
		If not: The PALAEMON SEM pull offs units assigned to other incidents with a lower priority status to handle the current incident of higher priority	PALAEMON SEM Incidence Mngt Func.	PaMEAS Incidence Mngt System (Assign Units Funct.)

WP2 - D2.3 Evacuation Scenarios - Basic Use Cases | Explosion Scenario				
		The PALAEMON SEM advises the assigned crew units of the best route to respond to the incident	PALAEMON SEM Incidence Mngt Func.	PaMEAS Incidence Mngt System (Unit Routing Funct.)
		The incident is managed by continually updating the PALAEMON SEM record with any additional information reported by passengers or crew on scene.	Standard evacuation procedure/enhanced by PALAEMON SEM	PaMEAS Incidence Mngt System
		The PALAEMON SEM continuously re-evaluates the need for possible reassessment of response plans to the incident and informs the EC/dispatcher about the new expected time of evacuation completion	Standard evacuation procedure/enhanced by PALAEMON SEM	PaMEAS Incidence Mngt System
		Stranded and injured crew are safe at a muster/embarkation station	Crew reporting	
		The PALAEMON SEM incident record is closed	PALAEMON SEM Incidence Mngt Func.	Incidence Mngt System (Incinent Record Mngt)
	Incident Loop ends			
Process		Boarding to lifeboats and liferafts continues without new incidents	Standard evacuation procedure/enhanced by PALAEMON SEM	PaMEAS Incidence Mngt System (Standard Evacuation Functions)
		The PALAEMON SEM continuously informs the EC/dispatcher about the expected evacuation time	PALAEMON SEM evacuation function	PaMEAS

WP2 - D2.3 Evacuation Scenarios - Basic Use Cases | Explosion Scenario				
	End of Evacuation Loop	Lifeboats and liferafts are clear from the ship and waiting for rescue (Passengers and crew clear from the ship on the dock)	PALAEMON SEM evacuation function	PaMEAS

4.2 Collision scenario (precautionary evacuation scenario)

In this scenario evacuation is initiated subsequent to a collision that does not cause the ship to sink. The scenario describes the collision between two ships, where a cruise liner is the struck ship that receives the collision energy to the side. Both vessels are able to proceed to an anchorage where the respective damages will be assessed, but for precautionary reasons the Master of the cruise ship orders the evacuation of passengers; the crew remains onboard.

Table 4: The collision scenario

WP2 - D2.3 Evacuation Scenarios - Basic Use Cases | Collision Scenario				
	Type of accident: Two vessels, one bulk carrier (vessel A) and one cruise ship (vessel B), are transiting in a sea strait. Vessel A suffered a power loss, which resulted in a temporary loss of propulsion and steering. The vessel did not warn VTIS or the surrounding vessels. Due to the loss of power, the AIS transmission ceased, causing the loss of the AIS plot. Vessel B's bridge team was only monitoring AIS targets on its radars and could not detect the change in Vessel A's heading and speed. This change was discovered at a very late stage, resulting in the collision of the two vessels. Vessel A sustained damages to her bow. Vessel B, sustained major damages, one to the port side forward ballast tanks both above and below the waterline, and another to the port side hull and deck fittings. Both vessels were able to proceed to an anchorage where the respective damages were assessed.			
Pilot-specific Use Case Components			**Process type**	**PALAEMON response**
Conditions	**Reason for Evacuation – Assessment of criticality**			
		A collision with another vessel occurs while the ship is transiting in a sea strait		
		The Bridge/Duty officer requests for visual reconnaissance	Standard operating procedure	
		Crew is dispatched to make visual identification	Standard operating procedure	
		Dispatched crew reports major damages, one to the port side forward ballast tanks (both above and below the waterline) and, another one to the port side hull and deck fittings	Crew reporting	
		The Master of the ship is summoned on the bridge and the situation is evaluated	Standard operating procedure	

WP2 - D2.3 Evacuation Scenarios - Basic Use Cases | Collision Scenario				
		• The Master orders for immediate assessment of the: – Vessel's ability to maintain stability, movement and navigation – Functionality of major machinery systems and equipment – Crew, passengers and environment safety	Standard operating procedure	
		The "Evacuate Passengers" order is given	Master's decision	
		All related stakeholders are notified	Standard operating procedure	
		The passenger evacuation protocol is activated	Action	
Process	**Evacuation Process Loop**			
		The Evacuation Coordinator (EC) is assuming position	Standard operating procedure	
		Crew teams (firefighters, damage-control units, boat preparation units, passenger mustering personnel, first-aid units, etc.) are informed—via radio and cellular devices—to move to their predesignated emergency posts	Standard evacuation procedure/enhanced by PALAEMON SEM	Incidence Mngt System (Evacuation Actions Mngt Funct.) PaMEAS
		Signaging of the routes of escape for passengers using emergency lighting is activated	PALAEMON SEM evacuation function	Incidence Mngt System (Standard Evacuation Functions) PaMEAS
		Automated instructions are broadcasted over the ship's public address system	Standard evacuation procedure/enhanced by PALAEMON SEM	Incidence Mngt System (Standard Evacuation Functions)

WP2 - D2.3 Evacuation Scenarios - Basic Use Cases | Collision Scenario				
		Instructions are sent to passengers' personal notification devices (smartphones, bracelets) in the form of easy to read messages, including escape paths and muster/embarkation station location	Standard evacuation procedure/enhanced by PALAEMON SEM	PaMEAS
		The PALAEMON SEM is monitoring the exact position of passengers and informing the EC/dispatcher about the expected evacuation time	PALAEMON SEM evacuation function	PaMEAS
		The PALAEMON SEM is tracking the status & location of passengers and continuously evaluating the need for possible response plans reassessment	PALAEMON SEM evacuation function	PaMEAS
Incident	**Evacuation Process – Incident Management**			
		A crew member reports that at the moment of collision a 3-year-old girl has been injured after falling from her family's cabin veranda to an open deck area (1 level below)	New incident (reported by crew)	
		The EC/dispatcher uses the PALAEMON SEM to verify location, classify the incident and assign priority	PALAEMON SEM Incidence Mngt Func.	PaMEAS Incidence Mngt System (Incidence Classif. and Priority Funct.)
		The PALAEMON SEM assigns response units (first-aid unit, infirmary personnel and helpers) to the incident, based on the incidence's location and ship's response plans, and notifies the assigned units that they have been dispatched to the incidence	PALAEMON SEM Incidence Mngt Func.	Incidence Mngt System (Dispatch Units Funct. Resource Alerting Funct.)
		The PALAEMON SEM checks if the response units specifically recommended or selected for the incident are positioned at their designated post locations	PALAEMON SEM Incidence Mngt Func.	PaMEAS

WP2 - D2.3 Evacuation Scenarios - Basic Use Cases | Collision Scenario				
		If yes: The PALAEMON SEM electronically routes the collected (by the EC/dispatcher) information to the assigned crew and their acknowledgment is recorded	PALAEMON SEM Incidence Mngt Func.	PaMEAS Incidence Mngt System (Determining Response Crew and Service Area Funct. Event Routing Funct.)
		If not: The PALAEMON SEM pull offs units assigned to other incidents with a lower priority status to handle the current incident of higher priority	PALAEMON SEM Incidence Mngt Func.	PaMEAS Incidence Mngt System (Assign Units Funct.)
		The PALAEMON SEM advises the assigned crew units of the best route to respond to the incident	PALAEMON SEM Incidence Mngt Func.	PaMEAS Incidence Mngt System (Unit Routing Funct.)
		While on scene, the assigned units report that the girl is sustaining fractures of the forearm and needs to be medevaced from the ship.	Crew reporting	
		The EC/dispatcher uses ship's telecoms to call in air rescue to dispatch a helicopter crew to the area	Standard operating procedure	
		Assigned units are informed—via radio and cellular devices—to move to the designated hoisting point	PALAEMON SEM Incidence Mngt Func.	Incidence Mngt System (Dispatch Units Funct. Resource Alerting Funct.)

WP2 - D2.3 Evacuation Scenarios - Basic Use Cases | Collision Scenario				
		The EC/dispatcher is continually updating the PALAEMON SEM incident record with any additional information reported by the assigned units	Standard evacuation procedure/enhanced by PALAEMON SEM	PaMEAS Incidence Mngt System
		Ater the kid is airlifted to be transported to the hospital the PALAEMON SEM incident record is closed	PALAEMON SEM Incidence Mngt Func.	Incidence Mngt System (Incinent Record Mngt)
	Incident Loop ends			
Process		The PALAEMON SEM is re-monitoring the exact position of passengers and informing the EC/dispatcher about the expected evacuation time	Standard evacuation procedure/enhanced by PALAEMON SEM	PaMEAS Incidence Mngt System
		Boarding to lifeboats and liferafts continues without new incidents	Standard evacuation procedure/enhanced by PALAEMON SEM	PaMEAS Incidence Mngt System (Standard Evacuation Functions)
	End of Evacuation Loop	Lifeboats and liferafts are clear from the ship and waiting for rescue	PALAEMON SEM evacuation function	PaMEAS

5 Requirements Specifications of a technology-aided MEE system (improving on evacuability)

As already mentioned, in PALAEMON, the term technology-aided MEE (Marine Evacuation Emergency) covers a full range of functionality varying from functions providing information and advice intended to support various aspects of the evacuation task (Standard Evacuation Functions), to functions supporting the management of incidents hindering the evacuation process (Incident Management Functions).

This section provides an outline of the specifications of these functions, with the greatest emphasis being placed on the incident management functions that are executed essentially by the PIMM component of PALAEMON SEM (Smart Evacuation Management System). As far as Standard Evacuation Functions are regarded, as explained before, the PaMEAS component of PALAEMON SEM is responsible for retrieving and processing the location information of passengers and crew and construct, on the basis of this information, the appropriate evacuation response.

5.1 Standard Evacuation Functions

Operational Example

On board a cruise ship, the general emergency alarm is sounded (seven short blasts and one long blast of the ship's horn) to call passengers to assemble, which is the first cue an individual receives that an accident has occurred which may require evacuation. All passengers will immediately cease all activities and begin moving towards the assembly point. Illuminated markings in the ship's stairways/corridors, notifications on the ship's public address system, verbal instructions from crew, and personalized advice broadcasted across passengers' mobile devices, will help passengers identify escape paths and assembly stations. Provided that no serious incident occurs, the ship's evacuation protocols are applied to ensure the matching of passengers with appropriate evacuating paths and assembly/embarkation stations, thus leading to the timely evacuation of the ship.

5.1.1 Marking the Evacuation Path

The PALAEMON SEM will consider an evacuation path as a continuous and unobstructed way of travel from any point in a ship to the mustering and embarkation stations or to a temporary area of refuge. An evacuation path will include cabins, corridors, doors, stairs, smoke proof enclosures, horizontal exits, ramps, exit passageways, escalators, moving walkways, fire escape stairs, fire escape ladders, slide escapes, alternating tread devices, areas of refuge, and elevators. PaMEAS will indicate evacuation paths with LED stripes.

Sample requirements

The SEM system [Shall/Should][39] flag an evacuation path as a usable circulation path if it meets one of the following criteria:

- A person is able to travel unassisted through that path to the muster and embarkation stations; measured in terms of persons density and average walking speed
- A person is able to travel unassisted through that path to the muster and embarkation stations when no major incidents are reported for that path causing fire, smoke, flooding, any kind of blocking hindering free access
- A person is able to travel unassisted through a portion of the path necessary to reach a temporary area of refuge.

5.1.2 Engaging the Notification System(s)

Sample requirements

The SEM notification system [shall/should] provide:

- Audible outputs
- Visible outputs, or
- Any combination thereof.

It [shall/should] include, but not limited to:

- Mobile data devices (Smartphones and Bracelets)
- Alarms
- Emergency lighting, and
- Public address systems.

5.1.3 Providing directions to and through the Evacuation Paths

Sample requirements

The PALAEMON SEM [shall/should] readily identify the routes of escape when the normal emergency lighting is less effective due to smoke—in case one exit may not be used, passengers will still be able to easily find their way towards another exit.

Directions to and through a usable evacuation path [shall/should] be given in one of the following manners:

[39] The use of the word “shall” as used here refers to a requirement (must-have), whereas the word “should” means that a specification is merely requested (nice-to-have). It is the responsibility of each working team using this document to decide which specifications are mandatory and which are requested but not mandatory.

- Signage using a combination of fixed emergency lighting (LED stripes) and notifications to smartphones and bracelets (instructions to passengers' personal notification devices may be displayed in a number of forms and outputs including navigation directions, expected time of arrival at a muster or embarkation station, etc.).
- Instructions passed from the SEM system to the crew through their personal notification devices, AR glasses or radio.
- Instructions, which may be live or automated, broadcasted over the ship's public address system.

Tracking the status & location of resources and reassessing response plans:

- The system [shall/should] be able to pinpoint the location of passengers and inform about their possible need of assisted activities.
- It [shall/should] monitor, in real-time, the move of passengers towards muster & embarkation stations and continuously assess the expected evacuation time.
- It [shall/should] communicate to the crew and passengers' instructions based on knowledge of evolving contingencies.
- It [shall/should] inform rescue teams about stranded or belated passengers that need assistance.
- It [shall/should] re-plan routes to muster & embarkation stations when the originally planned routes are no longer available.

5.2 Incident Management Functions

5.2.1 Call-in Handling sub-functions

This sub-function category comprises all functions allowing the EC (Evacuation Coordinator) to be notified of the need for assistance through a variety of sources (electronic notification, radio request, etc.):

- Receiving a telephone call, electronic notification, radio request.
- Obtaining sufficient and accurate information from a reporting party or electronic device to determine the location and incident classification.
- Determining if the incident being reported is a duplicate of an incident in progress and
- Creating or updating the incident record in the PIMM.

The PIMM [shall/should] provide ECs with an automated process to verify, analyze, classify, and prioritize incidents before electronically routing them to the appropriate destinations, such as a reporting crew unit. Incidents [shall/should] also be generated by other designated units in the ship via their mobile digital device or generated by a monitoring device such as a fire detection unit, a water ingress alarm, etc. and transmitted to the PIMM via a data interface.

Operational Examples

Av accident occurs due to overcrowding on a stairway and it is obvious to witnesses that there are injured people. Smoke is emanating from the lower end of the stairway. Information is gathered from the first crew caller and entered into the PIMM using the incident data entry screen. The call taker (possibly designated crew assisting the EC) enters the incident's location into the PIMM and selects the appropriate incident type based on information provided by the reporting party. The call taker enters the incident so the request to respond can be simultaneously sent to the appropriate crew units. The EC is now able to immediately assign and dispatch response units to the incident by using pre-determined response plans, which are based on the incident's location and type.

Meanwhile, the call taker continues to gather additional information from the reporting party and updates the incident record. Each involved crew unit receives notification that the incident record has been updated and is able to view the updates. Other passengers and/or crew may report the same incident, or a smoke detection device in the stairway may also report the presence of smoke. As call takers begin the data entry process, the PIMM alerts them that an incident is currently active for the same location and has a similar type. The call taker can then determine whether the new reporting parties have additional information that was not reported by the initial reporting party. A new incident entered but later determined to be a duplicate of an incident already in progress can be flagged in the incident's record as a duplicate of the original incident. Pertinent details gained from these new reporting parties can be provided as updates to all involved crew units.

<u>i. Assign Incident Classification and Priority</u>

One of the key pieces of information utilized in an incident creation is incident classification. This process will determine the appropriate response needs.

A list of pre-defined incident type codes is presented to the EC and/or other PIMM users to allow the most appropriate incident type to be selected. Each of these codes has a default priority assigned based on unit type (firefighters, damage repair units, etc.), ship-area, response plans, and deployment plans. Upon completion of this task, a type code is assigned to the incident.

Based upon information gathered, the incident classification process should be able to be upgraded or downgraded as the incident details depict.

Sample Requirements

In order to support the Assign Incident Classification and Priority sub-function, the PALAEMON PIMM:

- [Shall/Should] enable PIMM users to select the appropriate incident type from a pre-defined list of codes based upon information received from reporting party.
- [Shall/Should] provide the ability to generate an incident record with only the location and incident type code entered.
- [Shall/Should] allow the user to upgrade or downgrade the incident record to fit the reported incident by changing the priority for the incident.
- [Shall/Should] allow the user to utilize incident screening menus, such as a drop-down menu, to assist in determining the appropriate incident type code.
- [Shall/Should] provide the ability to override the incident priority for each responding unit.
- [Shall/Should] provide the ability to redirect assigned resources to a higher priority incident based on ship's defined criteria.
- [Shall/Should] allow the user to interrupt the incident creation process and save entered information, sometimes known as call stacking, to process a higher priority incoming incident.
- [Shall/Should] provide a warning (visual and/or audible) that a partially completed incident has been held for an administrator-defined period of time.
- [Shall/Should] provide the ability to view a summary of all system-wide, partially completed incidents being held and awaiting completion.
- [Shall/Should] allow users to be able to select a partially completed incident from an incident queue and complete the incident entry process.

ii. Incidence Location Verification

In many cases, particularly when an incident is called-in by a passenger (who may be or not be at the location of the incident, e.g. smoke in the stairway below), the incident location might not be able to accurately determine and must be elicited from the passenger. PIMM's incident locations should always be validated (i.e. checked) against a ship's layout file (relative coordinates file) that includes all of the different areas of the ship. The PIMM should contain an easily invoked tool to assist users in validating entered locations. The tools may vary in how they operate, but should include prompts and ordered lists that present the user with suggested locations when the exact location cannot be validated from the caller's device or narrative.

Locations that cannot be verified should provide an indication that the location information may be inaccurate. In these situations, the call taker may need to collect additional information that may be stored in a narrative format (i.e. as comments) in the incident record to assist the EC in assigning the proper resources, as well as guiding emergency responders to the correct location of the incident.

Finally, the PIMM's relative coordinates file should assist users to:

- Resolve location ambiguities, while accounting for spelling variations and duplications.
- Relate common place names to actual ship areas.
- Translate incident locations to crew units reporting areas.
- Assign and display crew response areas containing an incident.
- Display prior incidents that occurred at an incident's location within a configurable period of time.
- Display nearby incidents (user-defined criteria).

Sample Requirements

In order to support the Location Verification sub-function, the PIMM:

- [Shall/Should] provide the ability to enter a unique ship block, deck and unit (cabin) number to clearly identify the location.
- [Shall/Should] validate entered incident locations against the relative coordinates file.
- [Shall/Should] provide various suggestions to assist users in selecting accurate incident locations.
- [Shall/Should] organize the display of possible location matches in an ergonomic, easily understood manner that aids users in identifying valid incident locations.
- [Shall/Should] allow authorized users to configure their map display to show responding units' responsibility/service area and to display potential valid incident locations by responsibility area.
- [Shall/Should] allow the user, in case the location entered by the user is unverifiable (e.g. the location does not exist in the relative coordinates file), the capability to exit or bypass the verification process and manually route the incident to the appropriate response unit.
- [Shall/Should] provide the ability to enter a location name, with a minimum number of characters, and be presented with a list of possible matches to pick from for an exact match.
- [Shall/Should] provide the ability to enter an incorrect location name for a correct location name and be presented with a list of valid ranges.
- [Shall/Should] provide the ability to display the incident location in relation to other active incidents on the PIMM's map display during the incident entry process.

<u>iii. Alarm Processing</u>

The PIMM will be notified whenever an alarm monitored by the ship's alarm system is triggered. A standardized alarm interface [shall/should] be available to digitally transfer the details of the alarms using a standardized data exchange format. Whereas some alarm monitoring systems in modern ships are able to transmit the alarm details to the PIMM by using a standardized data exchange format, other monitoring systems (usually of older ships) might require a crew member to manually call and verbally inform call takers of the nature of the alarm and its location.

If an alarm interface is employed, then the entire alarm incident can be automatically created by the PIMM and routed to appropriate response units without requiring any call taker interaction. Otherwise, the call takers should manually create the alarm incident and forward it to the appropriate crew units for responder assignments.

Sample Requirements

In order to support the Alarm Processing sub-function, the PIMM:

- [Shall/Should] receive alarm notifications and updates related to the alarm notification from the ship's alarm monitoring systems.
- [Shall/Should] process updates from the alarm monitoring system as an update to the incident and shown to the EC with an audible and visual indication that a new update has been received.

iv. Check for Duplicate Incidents

Multiple incident notifications for the same incident may be received via many sources; for example:

- Smoke is detected by a crew member calling it in via radio or,
- A fire alarm is reported from the ship's electronic monitoring system and, at the same time, a passenger calls in to report smoke coming from the lower end of a stairway.

The PIMM [shall/should] be able to automatically evaluate an entered incident's location and call type to determine whether it is a duplicate or new incident (using primarily the PAMEAS location capabilities). The duplicate incident detection process must be based on pre-determined location search parameters that include exact ship blocks, ship areas within the same block, system administrator-configurable radius searches around the reported location of the incident location, and/or other system administrator-defined search parameters. The PIMM should analyze all open incidents, as well as closed incidents, within an administrator-configurable time period. Upon indication by the PIMM of a possible duplicate incident, the users must be able to evaluate the duplicate incident detection information presented by the PIMM to make the final decision of whether new incident notifications are duplicates of a previously entered incident.

If the new incident is determined to be a duplicate, then PIMM users should be able to add any new information contained in the current incident entry screen and link the new information to the primary active incident record without having to re-enter it.

If the primary incident record associated with a duplicate incident is closed, then PIMM users should be able to add new information to the closed incident record, possibly with a reminder to the user that the record was closed. If the new information requires a dispatch of response units, then PIMM users must be able to re-open the incident, add the new information, and route the incident back for a new allocation of resources.

Sample Requirements

In order to support the Check for Duplicate Incidents sub-function, the PIMM:

- [Shall/Should] store all transactions resulting from the duplicate incident detection process in the system's audit log.
- [Shall/Should] identify during the creation of an incident whether the incident is a potential duplicate of an active PIMM incident, or an incident recently closed, and [Shall/Should] notify the call taker of the results.
- [Shall/Should] check, as configured by the system administrator, by exact ship block, ship area, or ship unit (cabin or public space), the location of each new incident to determine whether another incident exists.
- Based on system parameters set by the administrator, either all matching incidents [Shall/Should] be presented to the user, or only those incidents with the same or similar type code.
- [Shall/Should] check, as configured by the system administrator, within a pre-defined search radius of the location of each new incident, to determine whether another incident exists within the search radius.
- [Shall/Should] allow an authorized user to change the duplicate incident search parameters (e.g. distance, exact ship block match only).
- [Shall/Should] present the user with the following information for each potential duplicate incident if potential duplicates are located:
    - ✓ Incident ID
    - ✓ Type of incident
    - ✓ Location of the incident
    - ✓ Status of the incident
- [Shall/Should] allow the user the ability to create a new incident and link the incident to the primary incident record, or to merge any new information contained in a duplicate incident into the main incident record associated with the identified duplicate incident.
- [Shall/Should] allow the call taker to re-open closed incidents that are duplicates of a new incident, add additional information to the re-opened incident records, and, if necessary, re-route them back through the resource allocation process.

v. Determine Dispatch Need

For every called-in incident, a decision must be made as to whether to dispatch resources or to close the record.

If the information gathered indicates that a response is not required (based on ship's protocols), then the incident should be closed. If a decision is made that resources are required, then the collected information must be routed to the EC to begin the resource assignment process. As noted throughout this document, these two functions (call taking and dispatch) can also be performed by the same person (the EC).

Sample Requirements

In order to support the Determine Dispatch Need sub-function, the PIMM:

- [Shall/Should] provide the capability to close out the incident record without assigning a resource, if it is determined that an incident does not require the assignment of a response unit.
- [Shall/Should] allow the user to append comments to incidents that are not assigned any resources.

vi. Determining Response Crew and Service Area

After the actual incident location has been validated the ECs can identify the available resources in the vicinity of the incident—the incident type will help determine which crew team must respond (firefighters, medical personnel, etc.).

Response crew and service areas can be assigned in a variety of ways. Manual assignment can be made by the EC based on personal knowledge of an incident's location, manual look-up in the ship's map, ship-structure table look-ups, or some other technique if an automated system is not available. With the PIMM, the user can rely on the digital map (showing the relative coordinates file) to computationally determine the appropriate response crews and service areas. However, even if the PIMM comes with an excellent relative coordinates file, manual methods must occasionally be used in those situations where an incident's location cannot be validated or the location is ambiguous.

Sample Requirements

In order to support the Determining Response Crew and Service Area sub-function, the PIMM:

- [Shall/Should] store all service areas and response crew assignments in incidents and the system's audit log file.
- [Shall/Should] validate the location of a new incident against the system's relative coordinates file to verify the location is within the service area handled by the assigned responding unit.
- [Shall/Should] identify the new incident's location and type code, and use the system's relative coordinates file to identify the appropriate responding units that need to handle the incident.
- [Shall/Should] identify the appropriate responding units to handle an incident, and use the system's relative coordinates file to determine the appropriate service area(s) within each unit's service area.
- [Shall/Should] provide a method for PIMM users to manually enter/assign the appropriate responding units and service areas to incidents if the incident's location cannot be validated against the system's relative coordinates file or if the validation process results in the assignment of an improper crew unit or response area.

5.2.2 Dispatch Support sub-functions

The dispatch support sub-functions are aimed at assisting the EC to utilize available resources to respond to an evacuation-critical incident. This section of the document will cover some of the most common and important features for the PALAEMON PIMM to assist the EC in the incident management process.

Operational Example

An 80-year-old male with chest pain during a MEE: The EC will verify the location and may utilize the PIMM to: select the correct response plan; verify the recommended units have the correct capabilities and personnel attributes; and, alert the proper stations (e.g. the ship's infirmary) or responding (medical) units.

<u>i. Response Plans</u>

A response plan is a plan that identifies the number, type or specific crew units that respond to an incident of a specific type, and the order in which they respond. Response plans are usually part of the ship's protocols including information such as personnel primary and secondary capabilities, routing-based recommendations, target hazards, response plans based on time of day, and other factors. The PIMM will utilize response plans (if exist) to allow dispatching by resource type (e.g. personnel with first aid training), capability (e.g. crew with Spanish speaking ability) and equipment (e.g. automated external defibrillator—AED).

Sample Requirements

In order to support the Response Plans sub-function, the PIMM:

- [Shall/Should] allow for dynamic and fixed/static response plans.
- [Shall/Should] allow for unlimited alarm levels.
- [Shall/Should] allow for the use of primary and secondary capabilities (attributes).
- [Shall/Should] allow for assignment to be by resource type, capability and equipment (e.g. AED).
- [Shall/Should] allow for the use of personnel capabilities (e.g. personnel with language speaking abilities).
- [Shall/Should] allow for the use of resource groups made up of individual units (e.g. an oil spill group made up of several units and dispatched as a single team, i.e. single unit).
- [Shall/Should] support multiple contingency response plans.
- [Shall/Should] allow for unit assignment based on time or distance to the incident.
- [Shall/Should] allow for adjustable plans that are based on time of day.

ii. Adjustable Dispatch Levels

Adjustable dispatch levels refer to changing dispatch levels to alternative sets of response plans in special circumstances, such as inclement weather, major incidents, acts of terrorism, and low resource levels. The PIMM should allow ECs to raise and lower the level on demand; for example, a first level of response reduction might be to remove one firefighter unit from a standard crew team. A higher level might be to remove the entire firefighting team.

An example of adjustable dispatch levels would be during special situations—a higher than normal activity levels (crowding) in a lower deck stairway—normal dispatch responses may be increased or decreased based on adjustable dispatch levels; for example, a normal two-crew response at the lower and upper part of the stairway may be changed to a single-crew response in a reduced dispatch level scenario—or, conversely, a normal one-crew response might change to a two-crew response if safety is an issue and the response level is raised.

The consequence of changing the dispatch level is that the resource requirements change according to pre-defined response plans. The PIMM should allow for changing one or all of the response plans to a different dispatch level. There is a difference between changing the type of the incident and changing the dispatch level since dispatch levels affect the entire response recommendations (e.g. a different set of incidents occurs when a structural damage incident changes to a fire in the same location versus a fire in a location that is upgraded to a higher alarm assignment).

Sample Requirements

In order to support the Adjustable Dispatch Levels sub-function, the PIMM:

- [Shall/Should] allow for adjustable dispatch levels.
- [Shall/Should] allow for an unlimited number of dispatch levels.
- [Shall/Should] have an easily viewable method to review current dispatch levels.
- [Shall/Should] alert the EC when the required number or type of units are not dispatched (e.g. one firefighting team instead of two, or two damage-control units instead of four).

iii. Conditional Availability

The conditional availability function allows crew with specific statuses to be recommended and dispatched to certain types of incidents; for example, a crew member that is responding to a low priority incident (e.g. lift assist) would be recommended for dispatch to a higher priority incident if closer than other crew. The lower priority incident would be automatically re-queued for dispatch.

Sample Requirements

In order to support the Conditional Availability sub-function, the PIMM:

- [Shall/Should] have the capability to code the conditional availability of crew units.
- [Shall/Should] be able to prioritize an incident and recommend the type of crew units based on the prioritization of that incident and the current status of the unit.
- [Shall/Should] have a unit recommendation feature with the flexibility to be overridden by the EC.

iv. Dispatch Units

The crew teams specifically recommended or selected for an incident will be dispatched and their acknowledgment recorded. All status changes associated with a team's involvement with an incident should be recorded by the PIMM and become part of the addressed incident. More specifically, the PIMM should allow for documentation of times, via mobile devices as documented by the responding personnel in their units, or by the EC or the call taker when the responding personnel verbalize their status via the radio (e.g. acknowledgement, en-route, on scene, leaving scene, arrived at destination, back in service). Other crew units not dispatched may be notified of an incident in-progress. When multiple units are dispatched, one unit will be designated as the primary responder responsible for the incident until it is completed and any reports associated with it. Other units responding to the incident will follow the direction of the "incident commander" for the incident.

Crew skills and unit capabilities should be considered when units are recommended for dispatch. Based on the specific requirements of the incident, a unit or resource that is more appropriate may be assigned (dispatched) to the incident rather than the closest available unit. The PIMM will take into consideration the incident's requirements (e.g. type, location, priority), the units' service/responsibility area, and the skills and capabilities of the available personnel when recommending units for dispatch.

Sample Requirements

In order to support the Dispatch Units sub-function, the PIMM:

- [Shall/Should] have the optional ability to assign one incident number to each unit responding to the incident
- [Shall/Should] capture every time stamp associated with each unit's response and status change related to the incident
- [Shall/Should] capture all status changes and their times for statistical and research purposes (e.g. out of service versus in service to calculate "lost emergency unit hours").

<u>v. Resource Alerting</u>

Assigned crew units will be notified that they have been dispatched to an incident in a number of ways, including: the EC advising them by using a voice radio system; and/or sending resource alerting information in selected crew's mobile digital devices.

Assigned crew units will be notified that they have been dispatched to an incident, in a number of ways, in addition to the EC advising them by using a voice radio system. Additional information relating to an incident may also be relayed in ways other than by the EC vocalizing the information. Such resource alerting mechanisms include:

- Mobile digital devices
- Ship alerting systems (if exist) that activate features in crew posts (e.g. lights, tones and message boards) and announce incidents
- Alerting via Short Message Service (SMS) delivered to cellular telephones.

Sample Requirements

In order to support the Resource Alerting sub-function, the PIMM:

- [Shall/Should] alert via mobile digital devices.
- [Shall/Should] generate (automatically) information appropriate for use with SMS sent to a mobile device when units are dispatched or on demand by the EC.
- [Shall/Should] support sending SMS messages either directly via cellular modem or using a common carrier's SMTP interface.
- [Shall/Should] interface with ship's crew alerting systems.

5.2.3 Resource / Crew Management sub-functions

One of the fundamental and critical components of the PALAEMON PIMM is the ability to assign and track resources. Tracking of these resources is critical for the EC to know what crew units are available to send to a particular reported incident and what their status is at any given time.

Operational Example

A passenger injury call comes to the EC. Reportedly, the passenger has life-threatening critical injuries. The EC receiving the call from the call taker needs to assign resources—including medical personnel and an officer responsible for air rescue—as well as to call in for help and place a medical transport helicopter on standby. The EC relies on the PIMM to identify what crew of each type are available and which ones are closest to the incident.

i. System Status Management

System status management is a function of strategically pre-positioning resources to minimize response times. According to ship's evacuation plan, resources may be positioned at permanent or temporary post locations. The PIMM should have the ability to build system status plans (by hour of day, etc.) that define the levels of resource availability and what posts/stations should be prioritized for coverage. For example, if only one medical team is available onboard, then that team might be positioned in the most accessible part of ship. In this example, that post would be the "Priority 1 Post." The PIMM should be able to accommodate multiple priority posts in each system status plan, and posts may be designated as equal to or alternates to other posts in the plan.

The PIMM should continually monitor each system status plan in effect for the current time period and alert the EC if the plan goes "out of compliance" (e.g. priority units are not in their proper positions). The PIMM may allow all users (not only the EC) to view the out of compliance condition and provide a recommendation to the EC for how to position units to meet the requirements of the plan. The EC will be able to accept, override or ignore PIMM recommendations.

Sample Requirements

In order to support the System Status Management sub-function, the PIMM:

- [Shall/Should] build multiple system status plans (e.g. by hour of day) that define the levels of resource availability and which posts/stations [Shall/Should] be prioritized for coverage
- [Shall/Should] monitor, on a continuous basis, each plan in effect and alert the EC if the plan goes "out of compliance" (i.e. units not in their proper position)
- [Shall/Should] include the capability for multiple plans by unit resource type.

ii. Geo-fencing

Geo-fencing refers to the function of providing alerts when automated location systems report crew or passengers entering or leaving a geospatially defined area. In PALAEMON the technology that will be used to support geospatial reporting from numerous devices will be 5G technology. The ability to alert, record and play back these actions is critical to evacuation planning, operations review and post action support.

Sample Requirements

In order to support the Geo-fencing sub-function, the PIMM:

- [Shall/Should] provide geo-fence creation tools that allow the use of polygons, circles, ellipses, and rectangles
- [Shall/Should] facilitate the creation of multiple, coexisting, overlapping geo-fences
- [Shall/Should] support unique geo-fence names and each geo-fence [Shall/Should] be visually distinct
- [Shall/Should] generate an alert whenever a passenger or crew member enters and/or exits a geo-fence
- [Shall/Should] include standard relative coordinates functions, such as exportation of parcel Information, data fields, and historic records from geo-fence
- [Shall/Should] be able to alert personnel and passengers though technologies such as text messaging
- [Shall/Should] provide informative and manageable alerts to appropriate personnel through visual and audible representation.

iii. Unit Routing

Automatic routing is the service provided by the PIMM to advise crew units of the best route to respond to an incident, based upon the responding unit's current location. Routing should take into consideration the ship's blueprints (stored in the system) and any possible exit closures or other impedances reported from the moment the evacuation alarm has gone off.

Sample Requirements

In order to support the Unit Routing sub-function, the PIMM:

- [Shall/Should] present the destination location visually for validation and acceptance
- [Shall/Should] provide a route that considers current impedances (e.g. corridor closures, smoke, damaged doors)
- [Shall/Should] provide a route that considers moving speed and other control variables
- [Shall/Should] provide a visual map that presents the entire route
- [Shall/Should] provide consistent route re-evaluation, and visually present alternate routes based on estimated arrival time at muster/embarkation stations without interfering with current route
- [Shall/Should] provide a directions list from unit current location to destination
- [Shall/Should] present visual and audible warnings about route impedances
- [Shall/Should] allow authorized units to create and clear impedances, which may be used for directing other units.

iv. Bypassed Units

ECs should be notified when a closer appropriate unit becomes available for dispatch to an incident to which another unit has already been assigned; for example, if unit 2 was responding to another incident when an incident was assigned in its service area and the unit that was assigned to the incident is still further from the incident than unit 2 when unit 2 goes back into service, the EC should be notified of unit 2's possible availability.

Sample Requirements

In order to support the Bypassed Units sub-function, the PIMM:

- [Shall/Should] alert (automatically) the EC in the case of a unit becoming available that is closer to an incident in which the currently assigned unit is still en-route and farther away.

5.2.4 Incident Management sub-functions

It is important that any treated incident is managed by continually updating the system record with any additional information reported by passengers or crew on scene. The resource recommendations may be revised based on additional information and may be added to or reassigned.

Operational Example

An original incident is a fire and a firefighting team is on the scene. The fire is growing, so the assigned team requests additional fire units. The EC requests a recommendation from the PIMM, so the system provides recommended, additional fire units based on proximity, unit type and availability.

i. Update Assigned Resources

If changes to the assigned resources are needed, then the updated recommended response complement should be adjusted and recorded based upon predetermined criteria.

Sample Requirements

In order to support the Update Assigned Resources sub-function, the PIMM:

- [Shall/Should] detect when a reduction in assigned resources is required.
- [Shall/Should] recommend readjusted resources that meet the requirements of the incident.
- [Shall/Should] record any changes to assigned resources as an update to the incident record.
- [Shall/Should] provide the capability to recommend additional resources based on response plans.

ii. Assign Units

The dispatcher will assign responders to an incident based on the incident type, location and user-defined response criteria. Based on priority levels and the resource needs of the incident, units assigned but available to other incidents may be pulled off of the current assigned status to handle a higher priority incident. If all units are pulled off of an incident, then the incident will be added back into the pending incidents queue to be re-assigned when resources are available.

Sample Requirements

In order to support the Assign Units sub-function, the PIMM:

- [Shall/Should] allow the assignment of units by using drag-and-drop and point-and-click pull-down menus.
- [Shall/Should] re-queue the incident that has had all units removed, but has not been handled.
- [Shall/Should] recommend a unit that is unavailable only if the ship's evacuation procedures permit units to be pre-empted for a higher priority incident.
- [Shall/Should] provide the ability to assign one or more units to an incident.
- [Shall/Should] provide the ability to dynamically, and without user intervention, change the unit recommendation if relevant incident information changes (i.e. type, location, alarm level).
- [Shall/Should] provide the ability to notify users that the unit recommendation has changed.
- [Shall/Should] provide the ability to cancel a unit from an assignment: If the cancelled unit is the only unit assigned, then the incident will be returned to the pending incident queue.
- [Shall/Should] provide the ability to assign a single unit to multiple incidents.
- [Shall/Should] allow the EC to override the system recommended units and assign other units.

<u>iii. Multiple Simultaneous Incidents to Single Crew Unit</u>

This sub-function refers to the ability to assign multiple incidents to a single crew unit. It provides a method of assigning multiple low priority incidents to a single unit (individual crew members or crew team) and allowing the unit to automatically receive information for the next incident upon closing the current incident. Although units can be assigned multiple simultaneous incidents, they can only act on one incident at a time.

If this capability is used, controls should be in place to avoid incidents being assigned to a unit, but then subjected to prolonged response times. The EC may need to monitor the overall incident loading on various units and re-allocate to other available units when required.

Sample Requirements

In order to support the Multiple Simultaneous Incidents to Single Unit sub-function, the PIMM:

- [Shall/Should] allow the EC to hold or stack events to a busy unit, as well as units that are in-service.
- If a unit is on an assignment, when the unit clears its assignment, then the system [Shall/Should] notify the EC the unit is available.

- [Shall/Should] allow several events to be placed on hold for a single unit.
- [Shall/Should] apply timers to all held incidents and alert the EC when a held incident has exceeded the allowable time in a held status.
- [Shall/Should] provide the EC with the ability to pre-empt a unit and dispatch the unit to another incident.

iv. Timers

Responding units will require additional timer functions, such as failure to respond (i.e. if a first unit does not respond, a timer alerts the EC to move to next due unit)—additional timers might include extended time at an incident location. Timers may be “connected” to or based on the PIMM’s incident type (e.g. every 5 minutes for elderly assistance, etc.). System timers allow for alerts for such things like a unit taking too long to an assigned incident.

Sample Requirements

In order to support the Timers sub-function, the PIMM:

- [Shall/Should] have, and allow configuration of, multiple timers based on unit status and incident type, such as time on a particular call, time since last check-in, etc.
- [Shall/Should] have, and allow configuration of, timers for incidents, such as a priority 1 unit overdue to be dispatched.
- [Shall/Should] allow for operators to manually place a timer alert on an incident or a unit.

6 PALAEMON Pilots Evaluation Setting: KPIs for the Evacuation Process

Although the unpredictable nature of MEE situations makes it difficult to know for certain if everything will go as planned until after a specific situation has occurred, relying only on “seeing what happens when the situation occurs” to assess design efforts in PALAEMON cannot provide all the ingredients needed to craft a good SEM system. It is therefore important to be able to measure how well the system is designed to perform, not just watch how well it performs after the fact. Though current measurement approaches provide information on many of the key inputs to a good design and have made some progress toward outcome assessment, they do not make it possible to reasonably anticipate the SEM system’s performance before incidents actually occur and the design is tested against reality.

As already mentioned, the assessment of the SEM’s performance is linked to the measurement of the impact on MEE response reliability, which requires determining what might go wrong and anticipating what the impact of particular incidents would be on the success of the operation. In some cases, breakdowns of critical equipment (e.g. MEVs) will derail the entire evacuation response effort – they will cause catastrophic failures where there are limited options for adaptation or improvisation to reconstitute capabilities and effectiveness. For non-catastrophic failure modes (e.g. an embarkation point that has been cut off from a fire) there may be options for the crew to dynamically adjust "on the fly" and find ways around the failure. Depending on if and how rapidly such adjustments can be made, the overall impact of an incident possibly leading to a failure could be reduced to a minimal level. Understanding the scope of potential consequences of different incidents is important to the development of indicators for measuring the performance of SEM. Incidents that would result in failure of the entire MEE response (which pose much more risk) are treated in specialized ship evacuation protocols and are not considered in this analysis. Incidents that would just reduce the SEM's total capacity or effectiveness and should be taken into account in the development of the system's performance indicators are illustrated in the following Figure.

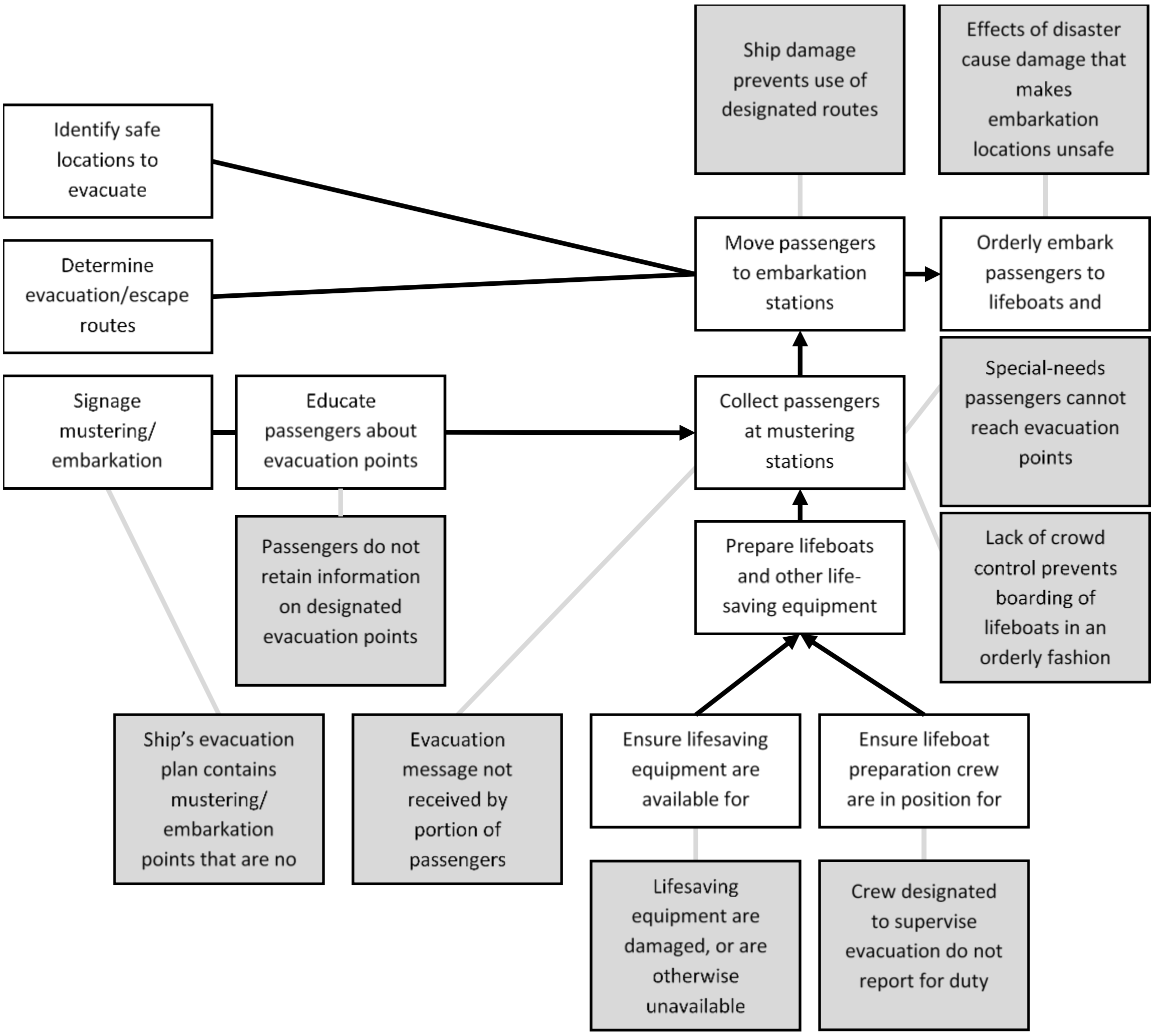

Figure 9: Incident analysis for identifying SEM performance indicators

The general steps of the MEE response operation, needed to actually trigger the evacuation and carry it out, are shown in the white boxes. Possible incidents that could occur that might disrupt the MEE operation are included in the gray breakout boxes linked to the steps of the response. Rather than being exhaustive, the incidents shown are intended to illustrate some of possible elements that would have to be considered in developing the PALAEMON SEM's performance indicators. For example, an identified incident-based failure is that, due to a fire, muster stations that are included in the ship's evacuation plan are no longer available. While this failure would not threaten the entire operation, it would disrupt it and could result in a significant reduction in effectiveness. With the SEM system in place, crew might find ways around the possible failure and evacuate passengers to other muster stations or temporary areas of refuge. Therefore, the "expected number of safe evacuees at time t" could be a good measure of performance as it could capture the effect that the system has on the overall MEE response. Another indicator could be the "expected time needed to evacuate k persons" that captures equally well the effect of incidents of lower priority (such as breakdowns in crowd control or damage at the designated points for evacuees embarking the liferafts) on the overall MEE response quality.

Summarizing, the PALAEMON SEM system should satisfy certain safety requirements all of which fall in three typical categories:

1. Qualitative requirements, e.g. evacuation should be safe.
2. Quantitative requirements on system level, e.g. the total evacuation time should be below 60 minutes (Ro-Ro).
3. Detailed requirements to component solutions, e.g. doors should be wider than 1.2 meters, etc.

The first category of requirements is too vague to consider for the needs of this document. The third category of requirements, frequently used (in the past) to evaluate evacuation simulation models, are easily evaluated, but one does not have any guarantee that good components necessarily compose a good system. Based on these observations this analysis will focus on the second category of requirements, which can better highlight the performance of the PALAEMON SEM system. To evaluate if the system copes with these requirements it is necessary to measure the performance of the system during the pilot phase.

In the literature, little has been written about performance measures of evacuation management systems. Several sources have discussed different measurement methods albeit in the context of network flow models, either deterministic[40,41,42,43] or stochastic[44,45,46,47], or simulation methods[48,49,50,51]. The cited references are concerned with a few performance measures only, and some of them are mainly oriented towards optimization of an evacuation management system with respect to some small subset of the performance measures.

The performance measures suggested below for the PALAEMON SEM describe the likely performance of the system, i.e. how it is likely to affect the overall marine evacuation process and do not address any technical issues such as system throughput, latency, etc. which is subject to the performance engineering solutions that will be adopted by the individual development teams. These indicators are shown in Table below:

40 Chalmet, Luc & Francis, R. & Saunders, P.. (1982). Network Models for Building Evacuation. Management Science. 18. 90-113. 10.1007/BF02993491. Available at: https://www.researchgate.net/publication/225411643_Network_Models_for_Building_Evacuation

41 Choi W., Hamacher H.W. and Tufekci S. (1988). Modeling of building evacuation problems with side constraints. European Journal of Operational Research 35 98-110. Available at: http://www.sciencedirect.com/science/article/pii/0377-2217(88)90382-7

42 Francis, Richard. (1981). A "Uniformity Principle" for Evacuation Route Allocation. Journal of Research of the National Bureau of Standards. 86. 10.6028/jres.086.023. Available at: https://www.researchgate.net/publication/266532010_A_Uniformity_Principle_for_Evacuation_Route_Allocation

43 Hamacher H. W. & Tufekci S., 1987. On the use of lexicographic min cost flows in evacuation modeling," Naval Research Logistics (NRL), John Wiley & Sons, vol. 34(4), pages 487-503, August. available at: https://ideas.repec.org/a/wly/navres/v34y1987i4p487-503.html

44 Karbowicz, C. J., and J. MacGregor Smith. 1984. "A K-Shortest Paths Routing Heuristic for Stochastic Network Evacuation Models." Engineering Optimization 7 (4): 253–280. available at: https://www.tandfonline.com/doi/abs/10.1080/03052158408960642

45 Smith, J.M. (1991). State-dependent queueing models in emergency evacuation networks. Transportation Research. B 25B/6 373-389 available at: https://www.sciencedirect.com/science/article/pii/019126159190031D

46 Smith, J.M. (1992). Multi-objective routing in stochastic evacuation networks, in: J. Sullivan (ed.), Proc. of the 1992 Int. Emergency Management and Engineering Conference, Florida, April 1992, The Society for Computer Simulation, 113-117. available at: http://www.sciencedirect.com/science/article/pii/S0377-2217(08)00744-3

47 Talebi, K., and Smith, J. 1985. Stochastic Network Evacuation Models. Comput. Oper. Res., 12(6), p.559–577. available at https://dl.acm.org/doi/10.1016/0305-0548%2885%2990054-1

48 Drager K.H., Loves, G.G., Wiklund, J., et al. "EVACSIM. A comprehensive evacuation simulation tool", in: J. Sullivan (ed.), Proc. of the 1992 Int. Emergency Management and Engineering Conference, Florida, April 1992, The Society for Computer Simulation (SCS), 1992, 101-108. available at https://www.semanticscholar.org/paper/EVACSIM-A-comprehensive-evacuation-simulation-tool-Drager-L%C3%B8v%C3%A5s/f34375769827d8b07c375736b619ad7e776c4896

49 Glowacki A. (1992). Using simulation to prepare for emergency mine fire evacuations, in: J. Sullivan (ed.), Proc. of the 1992 Int. Emergency Management and Engineering Conference, April 1992, The Society for Computer Simulation, 79-83

50 Kisko T.M. and Francis R.L. (1981). EVACNET+: A network model of building evacuation, in: Computer Simulation in Emergency Planning, The Society for Computer Simulation (SCS).

51 Ozel F. (1992). Simulation modeling of human behavior in buildings. Simulation 58/6 377-384 available at https://journals.sagepub.com/doi/abs/10.1177/003754979205800604

Table 5: The list of performance indicators/measures with operationalization

Field	Indicators/ Measures	Operationalization
General evacuation process performance	Process complexity	• Number of elementary operations to complete the evacuation process*
	General process information	• Available time for evacuation* • Nr of passengers to be evacuated* • Ship's occupancy rate (%)* • Nr of incoming calls for help per time unit*
	Level of response	• [Nr of handled incidents] / [total nr of incidents*] * 100
	Perceived response performance	• Qualitative scale (e.g., Likert) on the successful application of response plans
	Resource utilization	• % of crew actively involved in the evacuation to total crew ratio
Time-related evacuation process performance	Throughput	• Expected time needed to evacuate k persons • Nr of processed incidents during evacuation per time unit
	Process efficiency	• Expected number of safe evacuees at time unit • [Σ(finish time − start time) of all handled incidents] / [number of all handled incidents]
	Process cycle time, process effort, process lead time	• Time for handling the evacuation process end-to-end • Aggregated personnel-time of all activities associated with the evacuation process • [Evacuation alarm time] − [crew response time]
	Processing time	• Time actually spent on a request for help (crew ingress/egress time excluded)
	Average incident lead time, incident lifecycle	• [Σ(Dispatch time – call-in time)] / [total number of handled incidents]
	Average incident handling time (lifecycle)	• [Σ([incident call-in time] + [information collection time] + [crew sourcing, response units' assembly and follow-up time] + [response unit's time to incident site + processing time + time back to post]) / [total number of handled incidents]
	Evacuation process waiting time, set-up time	• Average time lag between evacuation sub-processes, when an incident is waiting for further processing • Time between the receipt (by crew) of the order to evacuate and the start of passenger evacuation
	Value added	• [Average incident handling time] / [Average incident lead time]
	Error prevention	• Number of mistakes

Field	Indicators/ Measures	Operationalization
Evacuation process performance related to quality		• [Nr of tasks with errors] / [Total nr of tasks per evacuation instance/process] • Nr of repeated problems
	Evacuation/response plans compliance, due time performance	• % of evacuation sub-processes' cycle times realized according to the evacuation plan or response plans • [Number of completed sub-processes on time] / [number of all completed sub-processes] * 100
	Rework time, evacuation efficiency	• Time to redo work for an evacuation problem that was solved partially or totally incorrect the first time • Average time spent on solving problems occurring during the evacuation process
	Integration capability	• Time to access and integrate information
Passenger performance	Perceived passenger satisfaction	• Qualitative scale on general satisfaction (e.g., Likert), possibly indexed as the weighted sum of judgements on satisfaction dimensions (e.g., satisfaction with the PaMEAS interfaces and services, perceived value, satisfying end-user needs, responsiveness, friendliness, availability, security)
	Perceived passenger easiness	• Qualitative scale (e.g., Likert) on the degree of easiness to understand broadcasted advice and instructions, and to navigate oneself in the ship following illuminated markings and public address system notifications
	Passenger query time, resolution time, response time	• Average time between receiving and responding to a passenger problem or inquiry for information
	Passenger waiting time	• [Time for receiving information about an evacuation sub-process or incident] + [time for following status updates] • Max nr of passengers in the queue asking for instructions • [Handled requests] / [total requests]
	Reliability	• [Late response on instruction requests] / [total nr of requests]
Crew performance	Perceived crew satisfaction	• Qualitative scale on general satisfaction (e.g., Likert), possibly indexed as the weighted sum of judgements on satisfaction dimensions (e.g., satisfaction with the PaMEAS interfaces and services, perceived value, satisfying end-user needs, responsiveness, friendliness, availability, security)
	Average crew saturation, resource	• [Time spent on response assignments] / [time waiting at evacuation posts]

Field	Indicators/ Measures	Operationalization
	utilization to perform duties	• % of evacuation time that a resource is busy
	Process users	• Nr of crew actually involved in the evacuation process
	Workload	• Average Nr of response assignments handled per crew

Of the above indicators/measures only those marked with an asterisk (*) should be expressed as an absolute figure. The rest will be measured differentially, with respect to the free SEM case, which requires two sets of measurements, one when the SEM is used and another one when it is not.

All the above indicators/measures will be related to the specific set of scenarios described above during the pilot application phase of the PALAEMON SEM System.

7 Conclusions

This report has presented the results of the definition of Reference Scenarios (Use Cases) for the management and monitoring of a Smart Evacuation and requirements a Smart Evacuation Management System that can *de facto* deliver the operational functionality needed for the realization of the Reference Evacuation Scenarios. This Report provides the first version of Use Cases Definition & Operational Requirements (V1). A second version (V2) that will be delivered at the end of the 2nd Year of the project will include a refinement of V1, as well as additional background analysis and more specific functional requirements that may be identified as the project evolves through life-cycle stages.

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PALAEMON D2.6, 2020, PALAEMON architecture

PALAEMON D2.6 (Deliverable 2.6, op. cit.), SEM is described, in technical terms, as follows: Atop the core of the platform, PALAEMON will come up with a number of heterogeneous services that will help stakeholders (e.g., Master, Bridge, crew in general, passengers, etc.) improve their response when it comes to proceed to evacuate the ship. It works with other systems (Smart Risk Assessment Platform-SRAP, DSS, Safety Management System-SMS, Weather Forecast etc.) to provide a "smart evacuation service".

PALAEMON WP2 Evacuation Scenarios v2.2 See: https://drive.google.com/file/d/1oLx100pTv_46_VW53EA2i6-T1Gt9f2B9/view?usp=sharing | Sheet D2.2

PALAEMON WP 8: PALAEMON Application Field Trials, Evaluation and Outcomes. WP8 points to three specific pilots (Field Trials): a) Mass Evacuation Vessels (MEV) Prototype Validation Demo, b) Passengers Evacuation Demo and, c) Passengers Mustering Demo.

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