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

D6.4 Development of PALAEMON On-Board Decision Support System

A holistic passenger ship evacuation and rescue ecosystem

MG-2-2-2018

Marine Accident Response

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Version	Date	Responsible	Description/Remarks/Reason for changes
0.1	2021/09/08	KT	Report write-up
0.2	2022/02/14	KT	Inclusion of partners' contributions
0.3	2022/02/25	DANAOS, ITML	Internal Review
1.0	2022/03/09	KT	Release

Contents

Abbreviations

Acoustic Emission	AE
Decision Support System	DSS
Engine Control Room	ECR
International Safety Management Code	ISM Code
Inertial Measuring Unit	IMU
Main Vertical Zone	MVZ
PALAEMON Incident Management Module	PIM
Republic of the Marshall Islands	RMI
Safety Management System	SMS
Ship's Health Monitoring	SHM
Ship Structural Monitoring Ecosystem	SSME
Shipboard Legacy Systems	SLS
Smart Risk Assessment Platform	SRAP
Smart Safety System	SSS
Very High Frequency	VHF

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1 Introduction

1.1 Purpose and Scope

PALAEMON's vision is to support the safety of passengers by providing a total solution for the evacuation of high-capacity passenger ships. PALAEMON aims to address the increased need for advanced passenger ship evacuation methodologies by defining a new ICT framework and radical rethinking of mass evacuation systems with the introduction of MEVs with a wider scope than a sole technical proposition. Driven by the need to yield an end-to-end uniform approach, PALAEMON redefines the issue of passenger ship safety by taking into consideration issues about cost, complexity, vulnerability, societal acceptance, and ethics.

To support the PALAEMON's vision, we will improve a Decision Support System (DSS). The main object of the DSS is to help the Master take the proper actions after a grounding, fire or collision incident of the ship, in order to avoid the adverse consequences of the incident and avert the problem that may drive to an evacuation of the ship.

Therefore, the DSS is based on the International Safety Management (ISM) Code. The ISM Code provides an international standard for the safe management and operation of ships and pollution prevention. Also, it takes notice of the Shipboard Oil Pollution Emergency Plan, known as SOPEP. The purpose of the SOPEP is to guide the Master and officers on board the ship concerning the steps to be taken when an oil pollution incident has occurred or is likely to occur. So, the actions that the DSS displays to the Master of the ship have been checked to comply with the protocol of the protection of the environment.

The DSS will enrich the suggested actions with real-time data provided by other components. There is data from other components that are integrated into the DSS and are associated with the suggested actions. So, the DSS not only provides actions to the Master but also combines the proper data in a way that is useful to the Master.

Since maritime disasters in recent years are a stark reminder of the imperative need for timely and effective evacuation of large passenger ships during an emergency, this project aims to maximize the effectiveness of passenger evacuation, during an emergency and/or a serious incident. So, the PALAEMON DSS has been developed to be a part of the PALAEMON project for the achievement of this goal.

1.2 Structure of the Deliverable

The deliverable is organized as followed:

- Section 2 focuses on the System Overview of the PALAEMON DSS. It describes the scope of the DSS and analyses the Design Principles of the DSS's screen.
- Section 3 focuses on the data aggregation of the Decision Support System from other components of PALAEMON.

- Section 4 presents the Innovative Functionality of the DSS and how it will contribute to avoiding or delaying the evacuation of a ship.
- Section 5 focuses on the analysis of the technical specifications that are used in order to complete the DSS's functionality.
- The deliverable concludes in Section 6 with the last remarks and the upcoming plans.

1.3 Relation to other WPs and Tasks

In this subsection, all the related Work Packages and Tasks of the PALAEMON Decision Support System Component will be mentioned by name. The PALAEMON On-Board Decision Support System belongs to Work Package 6, which is called PALAEMON Back-End Infrastructure, specifically to Task 6.4.

First of all, the 6.4 - PALAEMON On-Board Decision Support System Task is related to other tasks in the same WP.

- Task 6.1 - Ship Structural Monitoring Ecosystem
- Task 6.5 - PALAEMON Incident Management Module (PIMM) has an immediate connection with the DSS, as the DSS is one of the components that are integrated with the PIMM.

Also, the WP3 - PALAEMON Intelligence Framework - AI Services and Algorithms has many tasks that are associated with the T6.4. The tasks are as follows:

- Task 3.4 - Safety Procedures
- Task 3.5 - Risk Assessment Platform Development

2 System Overview

2.1 Scope of the DSS

The PALAEMON project objective is to support the safety of passengers by providing a total solution for the evacuation of high-capacity passenger ships. Different toolkits have been deployed to achieve the PALAEMON project vision. One of these toolkits is the implementation of the PALAEMON Decision Support System (DSS).

A Decision Support System (DSS) has to be implemented to contribute to the PALAEMON project aim. The PALAEMON project needs a DSS that is able to eliminate the confusion that is caused when an incident occurs. The confusion that is caused affects the Master's way of thinking negatively. The master must be able to take matters into their own hands and handle the situation calmly and quickly as passengers and crew members' lives depend on him. So, the PALAEMON project needs a DSS that is able to provide safe and sure suggestions and actions to the Master to deal with the situation of the incident. The DSS, as it is a machine, cannot be affected by the confusion on the ship during the incident, so the Master can trust the DSS suggestions.

The scope of the PALAEMON Decision Support System (DSS) is to assist the Master and crew members to act in a proper way to avoid the bad consequences of an incident. Providing an immediate response and an innovative solution to the Master in a case of a grounding, fire/explosion, or collision incident, PALAEMON DSS's main aim is to avert an evacuation on the ship and save the life of the passengers and crew members. All the solutions that are provided to the DSS respect the sustainability of the environment and are related to the prevention of water pollution.

In addition, to make the PALAEMON DSS more efficient and provide to the Master solutions helping him to have a better assessment of the situation, the DSS combines different data from other components of the PALAEMON project. The main reason the DSS is preferable to be combined with other components of the PALAEMON project is to be fed with more data that will help the DSS to improve its suggestions and make the Master more sure of executing these DSS suggestions.

2.2 Design Principles

An effective DSS design should fulfill its intended function by conveying its particular message whilst simultaneously engaging the user. Several factors such as consistency, colors, typography, simplicity, and functionality all contribute to good DSS design. When designing a DSS many key factors will contribute to how it is perceived. A well designed DSS can help build trust and guide users to take action. Creating a great user experience involves making sure your DSS design is optimised for usability (form and aesthetics) and how easy it is to be used (functionality).

- **DSS Purpose**

The DSS needs to accommodate the needs of the user. Having a simple clear intention will help the user interact with what you have to offer. The purpose of the PALAEMON DSS is to assist the Master of the ship to come to a decision, depending on the type of incident that has occurred. For this reason, the PALAEMON DSS is simple and comprehensible in such a way that guides the Master to interact with it. So, the Master can use it easily.

- **Easy Navigation**

Easy Navigation is one of the most important features or a principle, and the key to a successful DSS. If a DSS is hard to navigate and nothing is easily available, then the mitigation might be hindered. The PALAEMON DSS ensures the ability to quickly and reliably navigate, making the Master sure about actions they should follow, without leaving any room for doubt.

- **Comfortable UI**

A user interface is an interface through which the user interacts with the system. It serves as a bridge between the system and the user. It is important to keep the interface simple, use consistent fonts and colors, make it minimalistic and keep only the relevant information. The PALAEMON DSS takes into account who the users are, what activities are being carried out, and where the interaction is taking place. So, the DSS's layout, component hierarchy, typography, and colors are made in such a way to fulfill its purpose.

- **Performance**

The performance of the DSS must be smooth and not slow. If the performance of the DSS is too slow, then it will create a bad impact on the incident mitigation. On account of this, the DSS is dynamically updated, so that every time an incident happens, it is immediately activated and displays the suggested actions in combination with all the useful information that the user has to know.

2.3 PALAEMON DSS

The PALAEMON DSS aims to restore the ship's condition to normal when an incident occurs. In case of a grounding, fire/explosion, or collision incident, the PALAEMON DSS is immediately triggered to avert the ship abandonment. It starts displaying lists of actions depending on the incident. These actions are based on the policies and practices of the ship operator of the International Safety Management (ISM) Code and are formed in compliance with it and according to the ship owner's policies. The objectives of the ISM Code are to ensure safety at sea, prevention of human injury or loss of life, and avoidance of damage to the environment, in particular, to the marine environment, and property. So, all the actions that are suggested through the PALAEMON DSS have been fully vetted and the Master can trust the actions that are suggested to him. Many times, in case of a maritime incident, confusion is caused between the Master, ship crew members, and passengers that leading to adverse consequences. As the PALAEMON DSS provides this solution and the Master can trust the action lists, it solves the problem of confusion as the only thing the Master has to do is to follow the DSS actions. The PALAEMON DSS, while being based on the ISM Code, also provides risk level data to the Master, helping to solve the problem of the decision uncertainty. These risk level indications describe the condition of the different parts of the ship and the situation assessment of the ship during the incident. The values of these indications are represented by a percentage indicator. The actions of the Safety Management System (SMS) that are related to the risk level indications have been combined and the Master can have a better understanding of the situation to be surer of the action they will decide to make. Also, the PALAEMON DSS will be fed data by the different systems of the ship. The data is provided by the Shipboard Legacy Systems (SLS) and it includes information about the situation of the ship, sensors, etc. The PALAEMON DSS displays the data with the actions that are related to the specific data points. In addition, the PALAEMON DSS gives the ability to the Master to be able to observe the situation of the fire sensors of the ship. In this way, the Master can be notified when a value of a fire sensor exceeds the maximum threshold and is able to declare a fire incident in order for the DSS and other PALAEMON components to be activated.

3 Input from other Components – Data Aggregation

3.1 Overview

3.1.1 Safety Management System

A Safety Management System (SMS) administrator tool, following International Safety Management (ISM) principles, for automation in controlling and updating emergency guides, was developed for the documentation of safety procedures with the least of human intervention (). Safety procedures modelling framework is digitally translated into PALAEMON SMS tool (ISM compliant SMS administrator, as per DOA). PALAEMON SMS tool is a component of the integrated PALAEMON system. SMS Tool comprises of three main components:

1 SMS ashore is a standalone program hosted in the offshore serves of the management company of the vessel (and all the fleet).
2 SMS on-board is a replica of the SMS ashore program hosted in a remote server on-board the vessel and integrated with the PALAEMON ecosystem.
3 SMS synchro engine is dedicated to activation of bridge connectivity between office ashore and vessel (SMS instances) for versioning control.

PALAEMON SMS tool spans across all phases of the incident management and evacuation process (see figure below)

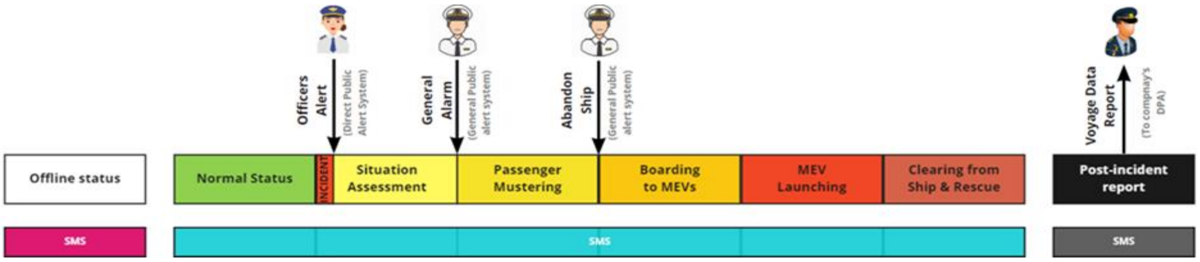

Figure 1 Ship Evacuation Stages

A more thorough description of the SMS tool functionalities, technologies and interfaces with the PALAEMON platform is provided in the relevant dedicated deliverable D3.8. “Modelling of Safety procedures (V2)”.

3.1.2 Smart Risk Assessment Platform

The main goal of the SRAP is to enhance the situation awareness of the crew members and to assist in the incident/accident management lifecycle, by providing decision-making support during various phases of the evacuation process (Development of Risk Assessment Platform (v2)). Therefore, SRAP consists of three different models that are developed to maximize the situation awareness of the Master and Bridge Command Team for the three stages of evacuation, i.e. situation assessment, mustering assessment and pre-abandonment assessment. The role of each model is analysed below:

- **Situation Assessment**

  The situation assessment model is activated after the occurrence of an incident/accident. Its purpose is to evaluate the incident severity and provide an indication to the Master whether to raise the General Alarm (GA) or not.

- **Mustering Effectiveness**

  The mustering model aims at quantifying the progress of mustering in terms of whether it is carried out as intended or there are delays. The quantification is made per Main Vertical Zone (MVZ) and the specific ship deck under examination. The outcome of the assessment for each area is provided in color (according to the level of risk) on the PALAEMON Dashboard. The outcome of the assessment will assist crew members to identify which areas of the ship may need to take mitigative and/or corrective actions during the mustering.

- **Pre-abandonment**

  The Pre-abandonment model aims at increasing the situational awareness of the Master on whether the ship is no longer safe for the person on-board (i.e. passengers and crew) and thus the abandonment procedure shall be considered. The outcome of the assessment indicates the Master to order the abandonment of the ship or not.

3.1.3 Smart Safety System

The "Smart Safety System (SSS)" component of the PALAEMON project is intended to create an assisting safety system during evacuation. The system aims to improve the safety evacuation system on board passenger ships and to provide information on the condition and all relevant information during the evacuation process. All crew members on board should have access to this information. This also reduces the burden on VHF communication and provides a detailed overview of the situation on board. This Model of the SSS was built on the adapted similar System which is used at coordinating firefighters when they are proceeding with building evacuation. The needs and systematic changes are done and adapted within the system to meet the objective of T3.1 Evacuation Methodologies & Models Analysis and the whole process of WP3 PALAEMON Intelligence Framework - AI Services and Algorithms.

This module gives an overview of the evacuation status and the current status of the evacuation progress. It also provides an interface for the connection between the master and the evacuation team. The information is provided as a gadget in the PALAEMON Decision Support System (DSS). Officers and crew members provide information and can rely on sensors (e.g. wristbands) and also on communication devices (e.g. tablet or Bluetooth receiver).

3.1.4 Ship Structural Monitoring Ecosystem

The SHM (Ship's Health Monitoring) and AE (Acoustic Emission) systems are used for the monitoring of the Ship's response in normal but also adverse, e.g. accident, conditions. The SHM is comprised of IMUs (Inertial Measuring Unit) which are equispaced on one of the decks of the ship, from aft to fore. The numbers of the IMUs depend on the length of the ship. The data from the IMUs are collected from a central processing unit, e.g. laptop, with the SHM software, translated to useful data (angles, accelerations and displacements). The SHM software records the data, transmits alarms when a parameter has exceeded a critical value and also sends a status report at prearranged time intervals. The AE is placed at critical areas of the ship, where defects might form but also where damages are likely to occur. The AE systems also record real-time data ad can transmit alarms when a parameter exceeds a critical value. These values are hit counts and/or acoustic emission energy. These values indicate when a defect is forming or a defect propagating (getting bigger). The IMU and SHM software are used for ship global stability and structural strength monitoring, while the AE is used for local condition monitoring, to detect defects and damages while they are being formed or propagating.

3.1.5 Evacuation Coordinator

At this point, it is worth recalling that PALAEMON hinges around the concept of Maritime Evacuation Process. As illustrated in Figure 2, an incident may occur during a voyage, thus unleashing the whole evacuation process represented in the schema. Nonetheless, we must state that, if the situation gets solved (e.g., the fire extinguisher team puts out a fire and has the situation under control), the chain of events may be interrupted, getting back to the normal situation. As we can also appreciate in the figure, the actual elements that trigger the status changes are humans (i.e., officers/crew, Master), so we can consider the process as "analog".

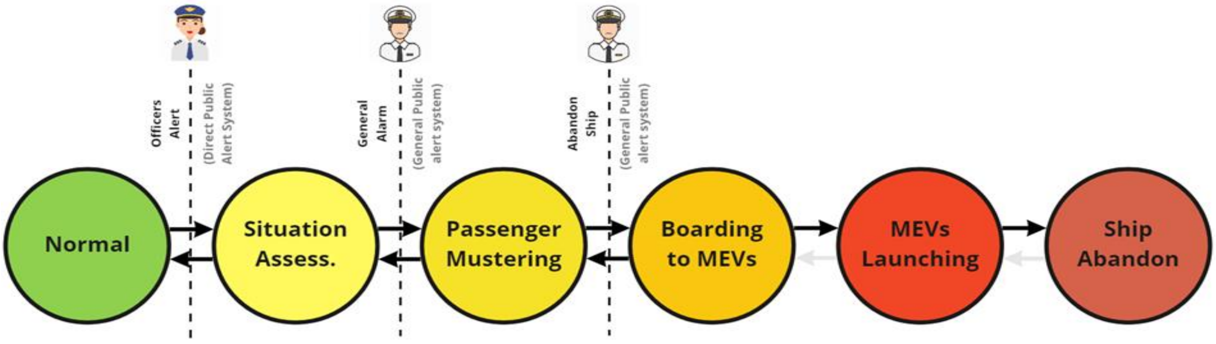

Figure 2 Ship Evacuation Stages and triggers

With the Evacuation coordinator, the idea is to translate these human-based commands to (simple) digital signals that are propagated across the PALAEMON system, in order to warn all software components (i.e., the ones that depend on the ship evacuation status) that something has occurred and they must react accordingly. As a matter of fact, some components (not all) do modify their operation mode as a function of the ship evacuation status, as shown in Figure 3. It is out of the scope of this deliverable to analyze the individual behavior of these components upon this status change notification.

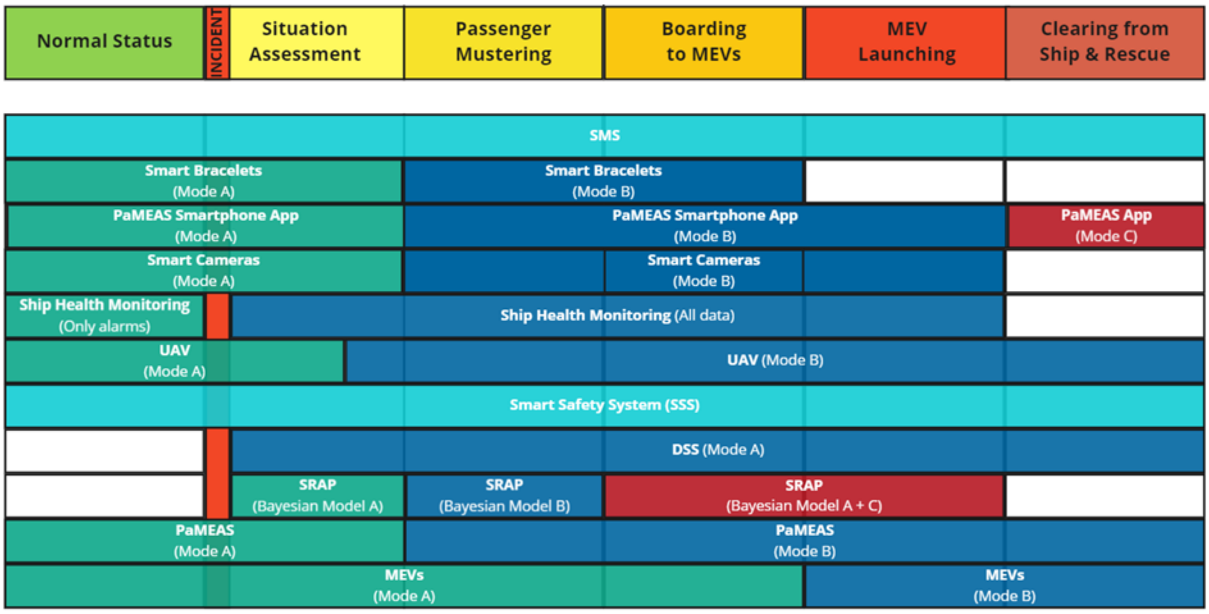

Figure 3 Component's operation mode dependency with Ship Evacuation Status

Technically speaking, the process goes as follows:

1. The PIMM displayed in the bridge permits the Master and Bridge Command Team to manually click on the upcoming status (as shown in Figure 4).
2. PIMM sends a message (i.e., HTTP) to the PALAEMON Evacuation Coordinator.
3. The PALAEMON Evacuation Coordinator broadcasts (i.e., via Kafka) a notification of the status shift to all (subscribed/interested) components. More information about the format of this message is in Section 3.2.6.

4 All affected components reply with an acknowledgment message back to the PALAEMON Evacuation Coordinator, notifying in the operation mode modification. As a side note, those without a direct dependency can directly ignore the message.

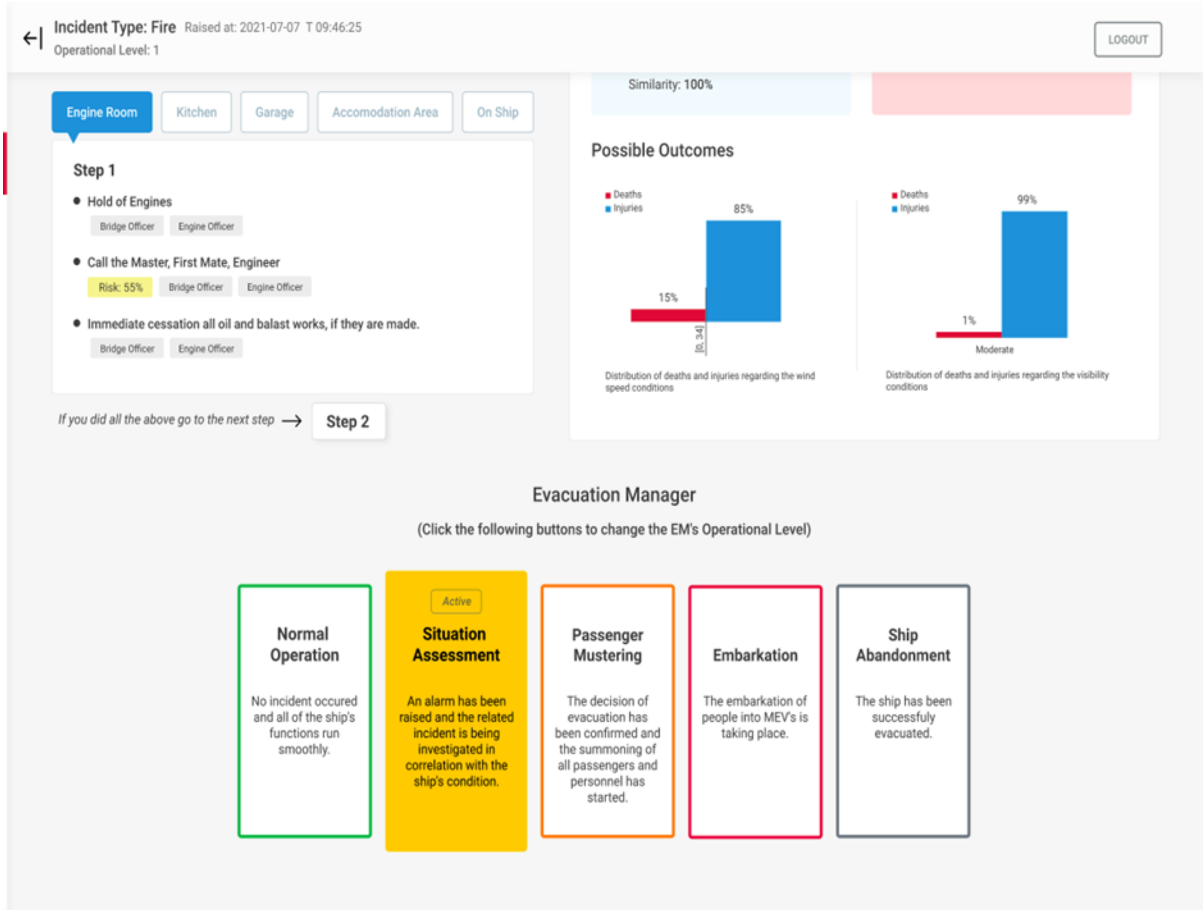

Figure 4 Evacuation Coordinator feature present as part of PIMM's layout

Under the hood, the PALAEMON Evacuation coordinator keeps track of all the status updates, whose traces are stored in the Data Fusion Bus for further (e.g., post-incident) analysis. The reader might refer to D7.1 (PALAEMON Communications Platform) to get more information about the process.

3.2 Data Description

3.2.1 Safety Management System

- **Short Description of the data being passed:**

Through the SMS tool, a list of responses to emergency actions based on SMS manuals and contingency plans are sent to DSS in a DATA representation format as JSON files. The transformation of unstructured information found in safety documents to structured tree-level data is post-processed in DSS to come up with a list of suggestions to crew for the right emergency response.

- **Dispatch interval:**

Upon request. Triggered by the DSS component during an emergency for the management of the emergency response. The JSON file is posted to DSS via DFB core for post-processing.

- **Data description:**

```
{
"incident type": "Fire at Sea",
"incident stages": [{
    "incident stage": "Situational Assessment",
    "actions": [{
            "actor": "Crew",
            "actions": [{
                    "id": 1,
                    "name": "Attempt to extinguish fire, if it is possible",
                    "check": true
                },
                {
                    "id": 2,
                    "name": "Report to the bridge that fire is off",
                    "check": true
                },
                {
                    "id": 3,
                    "name": "Push the nearest fire alarm button",
                    "check": true
                }
            ]
        },
        {
            "actor": "Master/Bridge",
            "actions": [{
                    "id": 1,
```

```
                    "name": "Make analysis of the situation, assess the extin-
guishing method",
                    "check": true
                },
                {
                    "id": 2,
                    "name": "Monitor progress of firefighting measures",
                    "check": true
                },
                {
                    "id": 3,
                    "name": "Collect information. Consider early reporting",
                    "check": true
                },
                {
                    "id": 4,
                    "name": "Consider vessel's stability. Consider ballast oper-
ations",
                    "check": true
                },
                {
                    "id": 5,
                    "name": "Prepare for transmission of distress call (use pre-
pared format)",
                    "check": true
                }
            ]
        }
    ]
},
{
```

```
    "incident stage": "Incident Response",
    "actions": [{
            "actor": "Crew",
            "actions": [{
                    "id": 1,
                    "name": "Check the surroundings for any persons in immediate danger, alert/      rescue them keeping in mind your own safety.",
                    "check": true
                },
                {
                    "id": 2,
                    "name": "If immediately possible, stop the air/fuel supply to the fire",
                    "check": true
                },
                {
                    "id": 3,
                    "name": "Inform the bridge about location and details of fire",
                    "check": true
                }
            ]
        },
        {
            "actor": "Master /Bridge",
            "actions": [{
                    "id": 1,
                    "name": "Master to establish the emergency response centre on the bridge (if possible).",
                    "check": true
                },
```

```
                {
                    "id": 2,
                    "name": "Send firefighting squad to assess and fight the
fire and report progress",
                    "check": true
                },
                {
                    "id": 3,
                    "name": "Maneuver vessel to minimize air flow",
                    "check": true
                },
                {
                    "id": 4,
                    "name": "Raise alarm in passenger compartments",
                    "check": true
                },
                {
                    "id": 5,
                    "name": "Close watertight/fire compartments",
                    "check": true
                },
                {
                    "id": 6,
                    "name": "Instruct the fire patrol to check adjacent compart-
ments",
                    "check": true
                },
                {
                    "id": 7,
                    "name": "Inform the passengers about the fire via public ad-
dress system",
```

```
                    "check": true
                },
                {
                    "id": 8,
                    "name": "Prepare for transmission of distress call (use pre-
pared format)",
                    "check": true
                },
                {
                    "id": 9,
                    "name": "Consider abandoning the vessel",
                    "check": true
                },
                {
                    "id": 10,
                    "name": "Call for external assistance",
                    "check": true
                },
                {
                    "id": 11,
                    "name": "inform the company, authorities and parties con-
cerned as necessary",
                    "check": true
                }
            ]
        }
    ]
},
{
    "incident stage": "Passenger Mustering",
```

```
    "actions": [{
            "actor": "Crew",
            "actions": [{
                    "id": 1,
                    "name": "Muster/Assist passengers on muster stations.",
                    "check": true
                },
                {
                    "id": 2,
                    "name": "Head count",
                    "check": true
                },
                {
                    "id": 3,
                    "name": "Search for missing persons",
                    "check": true
                }
            ]
        },
        {
            "actor": "Master/Bridge",
            "actions": [{
                    "id": 1,
                    "name": "Muster crew on muster stations",
                    "check": true
                },
                {
                    "id": 2,
```

```
                    "name": "Instruct the passengers via pa-system about actions required from passengers (muster or stay in cabins or assemble in restaurant, head count, etc.)",
                    "check": true
                },
                {
                    "id": 3,
                    "name": "Keep passengers well informed about the process of firefighting",
                    "check": true
                }
            ]
        }
    ]
},
{
    "Incident stage": "Embarkation-Abandon Ship",
    "actions": [{
            "actor": "Crew",
            "actions": [{
                    "id": 1,
                    "name": "On hearing the general alarm muster at the desig-nated boat or life raft station with lifejackets and immersion suite.",
                    "check": true
                },
                {
                    "id": 2,
                    "name": "Complete assigned tasks as per the muster list",
                    "check": true
                },
                {
```

```
                    "id": 3,
                    "name": "Preparing documents to be saved",
                    "check": true
                },
                {
                    "id": 4,
                    "name": "Rigging of lifeboat embarkation ladder for possible
re-entering of the vessel",
                    "check": true
                },
                {
                    "id": 5,
                    "name": "If missing, provide the lifeboats with communica-
tion equipment, i.e., Walkie-talkies, radio transponder, EPIRB, SART",
                    "check": true
                },
                {
                    "id": 6,
                    "name": "Prepare for marshalling a number of inflated,
manned life rafts",
                    "check": true
                },
                {
                    "id": 7,
                    "name": "Release boats from hook and stay in vicinity of the
vessel",
                    "check": true
                },
                {
                    "id": 8,
```

```
                    "name": "Prepare for transmission of distress call (use pre-
pared format)",
                    "check": true
                }
            ]
        },
        {
            "actor": "Boat leaders",
            "actions": [{
                    "id": 1,
                    "name": "Final head count",
                    "check": true
                },
                {
                    "id": 2,
                    "name": "Searching for missing crew members/passengers",
                    "check": true
                },
                {
                    "id": 3,
                    "name": "Maneuvering lifeboats clear of the vessel and stay-
ing together, towing of life rafts away of the ship by lifeboat",
                    "check": true
                }
            ]
        },
        {
            "actor": "Master/Bridge",
            "actions": [{
                    "id": 1,
```

```
                    "name": "Sound Abandon Ship alarm",
                    "check": true
                },
                {
                    "id": 2,
                    "name": "Order launch of boats/life rafts and Instruct the boat leaders to embark",
                    "check": true
                }]
            }]
      }]
}
```


3.2.2 Smart Risk Assessment Platform

- **Short Description of the data being passed:**

SRAP provides input to the DSS the results of the core nodes from the three models that are comprised of. The vast majority of the data are probabilities for the main aspects/factors that affect the evacuation process. All data along with a short description and their type are presented in Table 1 (the detailed description of the nodes is provided in D3.10 Development of Risk Assessment Platform (v2)).

- **Dispatch interval:**

The data are provided at an asynchronous rate. The output rate of SRAP is depending on the rate of the data input. In particular, every time SRAP identifies input data will produce a revised input to DSS.

- **Data description:**

Table 1 The nodes from all the models of SRAP that will be provided to DSS.

#	Node			Variable	
	Name	**States**	**Description**	**Name**	**Type**
1	Effectiveness of mitigation measures on-site	Effective Not effective	Likelihood of mitigation measures being effective.	effectivenessOfMitig	Double
2	Passengers	Low	Probability of passengers being close	passengerProxToHaz	Double

	proximity to hazards	Medium High	to danger, which determines the probability of being directly exposed to and affected by hazards.		
3	Status of passive containment	Effective Not Effective	Indicates whether passive containment of the incident is effective given the status of the detectors and the containment doors.	statusOfPassiveCont	Double
4	Spreading	Contained Not Contained	Probability of incident spreading to other parts of the ship other than the incident location.	spreading	Double
5	Structural Integrity	Not Compromised Compromised	Probability of ship structural integrity being compromised.	structuralInt	Double
6	Stability	Sufficient Not sufficient	Probability of ship stability being sufficient.	stability	Double
7	Hull status	Safe Unsafe	Probability of hull being in a safe or unsafe state.	hullStatus	Double
8	Ability to communicate	Fully operational Degraded Not operational	Indicates the ship's ability to communicate, within the ship and with the outside world.	abilityToCom	Double
9	Critical systems status	Fully operational Degraded Not operational	Probability of critical systems being operational.	criticalSystemsStatus	Double
10	Vessel status	Safe Unsafe	Probability of vessel being in a safe or unsafe state.	vesselStatus	Double
11	Incident severity	Low Moderate High	Probability of the incident resulting in adverse/ unacceptable consequences for the	incidentSeverity	Double

			crew and passengers.		
12	Sound the GA	Sound GA NO Sound GA	This is an indication to assist the Master to decide to sound the GA or not	sound	String
13	Risk of Delay	Low Medium High	The risk of delay will be provided for all the areas of the vessel per MVZ and deck	riskOfDelay	Double
14	Situation Severity	Low Medium High	Probability of the severity regarding the condition of the ship given the abandonment readiness level, the risk of the abandonment and the vessel status.	situationSeverity	Double
15	Abandon vessel	Abandon ship Do Not Abandon ship	This is an indication to assist the Master to decide to abandon ship or not	abandonVessel	String

3.2.3 Smart Safety System

- **Short Description of the data being passed:**

The Smart Safety System will generate Kafka messages in JSON form, based on the events, which are entered manually by the Bridge Team and Crew.

- **Dispatch interval:**

On event generation.

- **Data description:**

A JSON form

```
{
      "Id": 1,
      "Type": "Fire",
      "Timestamp": "2020-11-09T10:42:58.790517+00:00",
      "Deck": 3,
      "Position": ["x": 55, "y": 85]
```

```
}
```

3.2.4 Ship Structural Monitoring Ecosystem

- **Short Description of the data being passed:**

The SHM and IMU systems generate data regarding angles and heave, which is translated to deflection of the ship. These data are recorded real-time on the SHM software database and the file that is described as follows:

Table 2 SHM Data

Timestamp	Roll angle	Pitch angle	Yaw angle
Fri May 28 06:37:55 2021	-0.3	2.8	-133.5
Fri May 28 06:37:55 2021	-0.3	2.8	-133.5
Fri May 28 06:37:55 2021	-0.3	2.8	-133.5
Fri May 28 06:37:55 2021	-0.3	2.8	-133.5
Fri May 28 06:37:56 2021	-0.3	2.8	-133.4
Fri May 28 06:37:56 2021	-0.3	2.8	-133.4
Fri May 28 06:37:56 2021	-0.3	2.8	-133.4
Fri May 28 06:37:56 2021	-0.3	2.8	-133.4

- **Dispatch interval:**

The SHM and IMU system transmits an alarm when a parameter, e.g. roll or pitch angle or deflection, exceeds a limiting value. For instance, if we have an asset with a limiting value for roll angle the value 25 degrees when the SHM system records a roll angle of 26 degrees the SHM system automatically sends a file with all the values of the parameters to the PALAEMON core system. Furthermore, it keeps sending real-time data with a frequency of 1 Hz until the value of the critical parameter drops below the limiting value, i.e. roll angle below 25 degrees. Lastly, the SHM also sends a status report file at predetermined time intervals, e.g. every 10 minutes. The AE system also works by sending alarms when a parameter has reached a critical value.

- **Data description:**

The SHM is connected to the PALAEMON core through Kafka and transmits a JSON file as described above. In particular, it sends JSON files as alarms, when a critical event has occurred and as status reports at predetermined time intervals.

3.2.5 Evacuation Coordinator

- **Short Description of the data being passed:**

Messages forwarded by the PALAEMON Evacuation Coordinator are straightforward, as illustrated below, which represents an arbitrary notification captured by the system.


```
{
    "current": 1,
    "previous": 0,
    "timestamp": "2020-11-09T10:42:58.790517+00:00",
    "originator": "PIMM",
    "incident_type": "fire / grounding"
}
```


Where:

- **Current**: New evacuation status
- **Previous**: Past status (NOTE: if the current status has a value of “N”, the previous one can only be either “N-1” or “N+1”. No other option is possible)
- **Timestamp**: Exact moment where the signal was generated (to keep track of the whole evacuation process)
- **Originator**: Software element that triggered the event. At the time of writing this proposal, the only actor capable of generating this is the PIMM; however, during the execution of the Application Field Trials (WP8), we may detect the need for new originators.
- **Incident type**: With the help of additional components (e.g., Smart Safety System, Smart Risk Assessment Platform, etc.), the system may detect the actual source that has given rise to the incident (e.g., Fire, grounding, etc.). In case this happens, the PALAEMON Evacuation Coordinator will share this with the rest of the components.

- **Dispatch interval:**

These messages are completely asynchronous since they are generated upon human intervention (i.e., the Master manually pointing at the new status on the PIMM dashboard).

- **Data description:**


```
{
    "current": 1,
    "previous": 0,
    "timestamp": "2020-11-09T10:42:58.790517+00:00",
    "originator": "PIMM",
    "incident_type": "fire / grounding"
}
```

3.3 Integration to the PALAEMON Incident Management Module Body

The PALAEMON Incident Management Module aims to connect all the components the PALAEMON project consists of. The scope of the PALAEMON project is to provide a total solution for the evacuation of high-capacity passenger ships. The reason for the implementation of the PIMM platform is to achieve the purpose of the PALAEMON project. So, the PALAEMON PIMM integrates the components of the other partners of the PALAEMON project in order to provide a complete solution to the Master/Bridge and crew members. The communication between the components becomes through the PIMM. The PIMM is the brain of the PALAEMON project and the toolkits that are used are the body of the PIMM. The data is gathered from the components into the PIMM and exchanged information and data through PIMM.

One of the components that are integrated into the PIMM is the PALAEMON Decision Support System. The PALAEMON DSS provides to PIMM's dashboard the actions-suggestions that the Master has to make depending on the incident that has been occurred. So, lists of actions are displayed to the DSS through the PIMM. Also, the actions are accompanied by the target (Master, engineer, etc.) that every action is referred to and risk level indications for the assessment of the situation. The indication is shown on the DSS to assist the Master to assess and monitor the condition of the vessel better as he knows the risk of taking a decision. Furthermore, the values of fire real-time sensors that are installed into the ship are provided from the DSS to PIMM in order for the Master to be able to observe the condition of the sensors.

The DSS is triggered every time an incident occurs. When the Situation Assessment state is enabled from the Evacuation Coordinator through PIMM the DSS is triggered and started to assist the Master until to return again to the Normal Operation state.

Here is a sample of JSON that contains information the DSS sends to the PIMM in case of a grounding incident:

```
defaultSuggestion: [
{
incident: "Grounding",
actions: {
suggestions: [
{
 id: "GRD_001",
 sug: "A visual inspection must be performed. All fuel tanks,
 ballast tanks, and hulls must be counted.",
},
{
 id: "GRD_002",
 sug: "All other apartments that are in contact with the sea
```

```
 should be inspected to ensure that they are intact.",
},
{
 id: "GRD_003",
 sug: "The measurements of tanks, fuel and ballast and hulls
 must be compared with the latest measurements of the same areas to detect any
leaks.",
},
{
 id: "GRD_004",
 sug: "Every inclination of the ship must be noted and
 included in the report.",
},
],
final_text: "Did you do all of the above?",
actions: [
{
action: "YES",
first_text: "Master should consider the following:",
suggestions: [
{
 id: "GRD_005",
 sug: "The danger to the ship crew if the ship slips
 from the grounding position",
},
{
 id: "GRD_006",
 sug: "The risk of ship breaking due to rough sea or
 big waves.",
},
{
 id: "GRD_007",
 sug: "The risk to the health of the crew and the population of the area from
 the escape of dangerous loads in dangerous quantities.",
},
{
 id: "GRD_008",
 sug: "The prevention of fire due to the escape of flammable materials in
 combination with uncontrolled sources of ignition.",
},
```

```
],……….
………………}]

suggestionDataMap: {
"GRD_001": {
 target: ["Master"],
},
"GRD_002": {
 target: ["Master"],
 info: [["Risk", "this.$store.getters.getHullStatus"]],
},
"GRD_003": {
 target: ["Master"],
},
"GRD_004": {
 target: ["Master"],
 info: [
  ["Risk", "this. $store.getters.getStabilityLikelihood"],
  ["Inclination", "this.$store.getters.getStabilityToolkit"],
 ]
},
"GRD_005": {
 target: ["Master"],
 info: [["Risk", "this.$store.getters.getIncidentSeverity"]],
},
"GRD_006": {
 target: ["Master"],
 info: [
["Risk", "this.$store.getters.getStructuralIntegrity"],
]
},
"GRD_007": {
target: ["Master"],
info: [
[
"Risk referred to the crew only, and not for population of the area",
"this.$store.getters.getIncidentSeverity",
],
],
},
```

```
"GRD_008": {
target: ["Master"],
},………..}
```

4 Functionality

4.1 Literature Review

Every year there are many maritime incidents with serious casualties. RMI issued its Annual Report on marine safety investigations for 2020, recording a total of 726 very serious marine casualties, marine casualties, marine incidents, and occurrences, 80 fewer than reported during 2019. Although every year there is a decrease in the percentage of ship incidents, the number of incidents is still large. So, the importance of the DSS is significant to decrease the number of ship incidents.

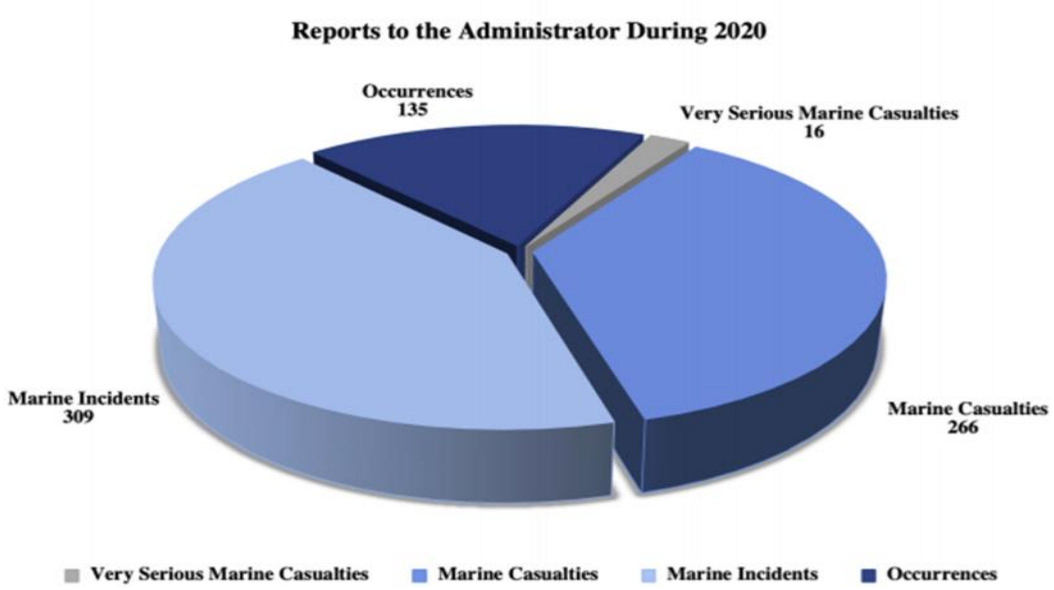

Figure 5 Maritime Incident Historical Data

In this section, some existing DSS solutions to maritime incident emergencies will be mentioned. It is an important part of the PALAEMON DSS's research objective to search, read and analyze other DSS solutions to find ideas and adjust them into PALAEMON DSS, always in conjunction with the data that other components of the PALAEMON Project provide.

- **Emergency Evacuation Decision Support**

A result of work in the EU-supported research and development project **DSS_DC: Decision support for ships in a degraded condition**. The work has been done under EU-contract TCT3-CT-2003-506354 for DG Research. [5]

The above research comes up with the use of electronic emergency management and decision support systems in the handling of passenger ship incidents. The focus is on support for evacuation, mustering and abandonment of the ship. All the ships are controlled by the International

Safety Management (ISM) Code that defines principles for emergency preparedness, planning, training, and execution. Important principles in the ISM Code are:

1 Planning and preparedness.
2 Clear definition of roles and responsibility, also for external actors, e.g., onshore.
3 Drills and training to ensure knowledge of procedures and deterministic responses to commands.

The International Safety Management (ISM) Code is being used to feed information to this DSS.

The DSS takes into consideration the incidents that are referred to the ISM Code and depending on the incident types, the DSS actions appropriately.

- **A maritime safety on-board decision support system to enhance emergency evacuation on ferryboats.**

This paper contributes to the related literature by providing a comprehensive methodology including simulation and statistical analysis along with a three-module decision support system (DSS) for ferryboat emergency evacuation. Emergency evacuation and fire environment are simulated via Maritime EXODUS V5.1 and SMARTFIRE V4.3, respectively. The methodology is applied to a real-life Ro-Ro ferry, and the results not only revealed significant factors on emergency evacuation performance but also demonstrated the validity of the developed decision support system. [3]

A three-module DSS for MEE is developed. Since the modules of the DSS are developed using different methods, it will be meaningful to give introductory information about these techniques.

As the first method used within the DSS, a heuristic algorithm is a set of general rules that are independent of the particular data case being considered in solving the problem.

Case-Based Reasoning, the next method considered in the DSS, is similar to the decision-making mechanism used by humans. Case-Based Reasoning involves two main steps, namely finding similar cases in memory and adapting previous solutions to current problems.

The other method used in the DSS (i.e., Rule-Based Reasoning) generates a set of outputs by applying a set of IF-THEN rules based on the information from a scenario.

As far as the type of the DSS is concerned, the first and third modules can be regarded as model-driven since they include an algorithm for crew assignment modelling (the first module) and a rule-based model for evacuation plan suggestion (the third module). The second module has a hybrid (model-data driven) characteristic due to the fact it attempts to assess emergency state-oriented evacuation performance metrics via a forecasting model using a database.

- **Predictive Maintenance Decision Support System for Enhanced Energy Efficiency of Ship Machinery**

The above project aims to tackle the issue of ship inspection by enhancing the cooperation of maritime stakeholders aiming to avoid ship accidents, promote maritime safety and protect the environment. The project introduces innovative solutions to the ship inspection regime. The proposed solution establishes a flexible framework by taking into account both ship structures and machinery and equipment. Ship machinery risk assessment involves designing and implementing a reliability tool for probabilistic failure case scenario analysis. The presented tools facilitate specific inspection tasks and provide input to the Decision Support Systems (DSS) for both structures and machinery. [1]

This developed DSS is separated into three main areas. These are the current performance area, the predicted warnings, failures and the analysis tabs. The Information presented to the user through the GUI includes predicted emergencies and advised actions that can be flowed by the crew on board the ship. This allows for better-informed decision-making concerning inspection and maintenance.

All the monitored systems, subsystems and components on the ship and their current performance as a percentage are presented by the DSS in the format of a list using traffic light color coding to draw the user's attention to the areas where reliability is low. Also, when warnings or failures are predicted by the application, they are presented to the user in the relevant lists of the GUI. Every time the performance of a system is deteriorating the DSS automatically recalculates the predicted performance and based on the returned values it will estimate the predicted failure of that system. Afterward, according to the listed warning/failure was predicted, the DSS displays some more analytical results. The four tabs are 'Cost Analysis', 'Actions', 'Prediction' and 'Symptoms'. The cost analysis tab presents the predicted costs associated with a warning or failure or a specific system, subsystem or component. The actions tab suggests maintenance activities be taken. The prediction tab lists the performance values of the selected and the failure probabilities calculated by the DSS application. Finally, the symptoms tab presents both the historical data recorded by the sensors and the predicted data.

4.2 Proposed Methodology

Since maritime disasters in recent years are a stark reminder of the imperative need for timely and effective evacuation of large passenger ships during an emergency the aim of this project (PALAEMON) is to maximize the effectiveness of passenger evacuation, during an emergency and/or a serious incident, from large Cruise and RoPax ships by combining the expertise of stakeholders from the field of cruise ship manufacturing, large cruise ship operators, classification societies, sensor and technology organizations, with a multidisciplinary group of innovators. An important part of this aim achievement is the development of a Decision Support System that helps the Master to take the proper actions after a grounding, fire or collision incident of the ship, in order to avoid the adverse consequences of the incident and avert the problem that may drive to an evacuation of the ship.

Data Collection

The Safety Management System (SMS) is the main source of data that feeds the DSS. The purpose of the ISM Code is to provide an international standard for the safe management and operation of ships and for pollution prevention. The ISM Code provides guidelines on how to script, verify, implement, certify and investigate compliance of safety procedures. Standards are tailored by each company policy/operational objectives/ vessel type etc. The PALAEMON DSS expertise is only for grounding, fire/explosion, and collision incidents so it uses the action lists of these incidents. Another source of data the DSS uses is from the Smart Risk Assessment Platform PALAEMON component. The SRAP component provides a risk level indication for the assessment of the situation. The indication is shown on the DSS to assist the Master to assess and monitor the condition of the vessel better as he knows the risk of taking a decision. In this way, the Master will be able to reconsider the action he wants to take. Additionally, ANEK Lines Company will feed the DSS with the Shipboard Legacy Systems (SLS). Shipboard Legacy Systems provides data from all the already used systems of the ship such as sensors, info about the situation, the position of the ship, etc.

Data analysis

Regarding the International Safety Management (ISM) Code, ANEK Lines company sent us its adjusted Safety Procedures/policies on its ship in a PDF file. All the data that referred to the grounding, fire/explosion, and collision incidents were divided into three categories. Also, each category was divided into subcategories. For example, the fire incident is divided into Fire in the engine room, Fire in the kitchen, Fire in the accommodation areas, etc. After the separation into these categories, a JSON format file was created inserting all the useful data of the ISM Code. This data is being loaded automatically to the DSS by the Safety Management System (SMS) tool, as soon as the incident is confirmed. In this way, the PALAEMON DSS is able to search the action lists depending on the ship incident and display them to the Master on the DSS monitor.

As far as the data that the SRAP provides the PALAEMON DSS, there are risk level indications for the assessment of the situation. These data points are separated into three categories: a. Situation Assessment, b. Mustering Assessment, c. Ship Abandonment. The data values that help to improve the DSS' efficiency and make it more innovative are those that belong to the Situation Assessment and Mustering Assessment category. For example, hull status, ability to navigate, critical system status are some of the data values that the SRAP provides the DSS. Providing these data values, all the safety/emergency actions have been read and combined with the SRAP data. So, the DSS will display the action lists depending on the ship incident and the Master will be able to read suggested actions followed by the value of risk expressed on a percentage that has the suggested action. For instance, when a grounding incident occurs there is an action for the Master to consider that is displayed on the DSS monitor "The risk of breaking the ship due to rough seas or big waves". This suggested action is followed by the Structural Integrity node from SRAP data. The Structural Integrity node is the probability of ship structural integrity being compromised. Compromised structural integrity means that the ship structure may be in danger of (partially) collapsing.

The Shipboard Legacy Systems (SLS) data values that ANEK Lines will provide the PALAEMON DSS, are useful data values that support the DSS to be more inventive. The SLS will feed the DSS with the values of fire sensors that the ship contains, their labels, and maximum values which a fire sensor must not surpass. There is a certain field on the DSS providing a Fire Sensors Button. When the Master clicks this button, they are able to observe all the values of fire sensors. When a value of a sensor surpasses the maximum threshold then the Fire Button changes in red color in order for the Master to understand that there is a possibility of a fire incident. Then, the Master has the capability, for each fire sensor that has surpassed the maximum threshold, to declare a fire incident or ignore the situation after manual inspection of the sensor (in case of a malfunction). If the Master declares a fire incident, then the DSS is triggered and displays the action lists depending on the place of fire that the incident happens.

Problems that the PALAEMON DSS Solves

The PALAEMON DSS has been designed and implemented in a way that combines helpful data and provides to the Master all the necessary actions to do, in case of a maritime incident. As the PALAEMON DSS is fully compliant with the International Safety Management (ISM) Code for grounding, fire/explosion, collision incidents, it solves the problem of confusion. There are many times that the Master, because of the criticality of the problem, makes wrong decisions although these certain actions don't make sense. For example, the Investigation Report of the grounding of the cruise ship Hamburg in the Sound of Mull in Scotland and the Fire incident aboard the Roll-on / Roll-off Passenger Vessel Caribbean Fantasy are two cases that Masters, due to confusion of the incident, did not take into consideration simple actions that must be done, as they are described at the next section, Incident Identification (4.3). As a result, these incidents had adverse consequences because of the confusion.

Additionally, the combination of the actions of the SMS and data coming from the SRAP, which are risk level indications solves the problem of the decision uncertainty. So, the actions of the SMS that are displayed through the DSS monitor to the Master are followed by the percentage of risk of making this action. The Master is able to observe the actions, the seriousness of the situation and how each of the actions will affect the incident that has occurred. Along these lines, the confusion that is caused by the consequences of the incident is eliminated to the minimum. The problem that the Master faced on the grounding accident of the cruise ship Hamburg in the Sound of Mull in Scotland and the fire accident of the Caribbean Fantasy (as described on 4.3 Incident Identification) would not have affected them, were they using the PALAEMON DSS. Also, providing the SRAP data to the Master, makes him more sure about his decision-making as he knows the danger of the situation at any moment of the incident depending on the action they decide to do.

Furthermore, providing data from the Shipboard Legacy System (SLS) of ANEK Lines to the PALAEMON DSS helps the master to estimate the situation of the incident better. The SLS will provide data from most of the components and systems of the ship and the PALAEMON DSS combines the data with the related actions of the SMS. Also, PALAEMON DSS will be fed by the fire sensors of the SLS data that the ship contains. So, the Master is able to observe the values of fire sensors at any time and they are notified by the DSS for every value of the fire sensor that exceeds the maximum value. Consequently, the Master can trigger the DSS to a fire incident situation. This means that the PALAEON DSS can also help actively prevent fire incidents before they are even declared.

4.3 Incident Identification

A Decision Support System for ship incidents is a system that helps the Master to decide and take the proper actions depending on the situation of the incident in order to avoid the casualties that may occur. So, it is a significant factor for every ship to provide a DSS. There are Maritime incidents involving ships that do not provide a DSS. In most incidents, confusion prevails because the severity of the situation makes it difficult for people to think. So, the Master is incapable of thinking calmly about the situation and this has the impact of making wrong decisions. Many times, the incident has taken adverse evolutions because the master decides that under normal circumstances, he would never make it.

During this section, three maritime accidents will be discussed with negative impacts on passengers, crew, and the ship. We will also discuss how the PALAEMON DSS would resolve the situation before it becomes an accident.

Report on the investigation of the grounding of the cruise ship Hamburg in the Sound of Mull, Scotland

On 11 May 2015, the Bahamas registered passenger's vessel Hamburg grounded on charted rocks near the New Rocks buoy in the Sound of Mull, Scotland. The accident caused considerable raking damage to the hull and rendered the port propeller, shaft, and rudder unserviceable. There were no injuries and the vessel continued on its passage to Tobermory. [6]

The investigation found that having been unable to enter Tobermory Bay on arrival, the passage plan was not re-evaluated or amended. Combined with poor bridge team management and navigational practices, this resulted in the vessel running into danger and grounding. Despite the loud noise and vibration resulting from the grounding, the bridge team did not initiate the post-grounding checklist, no musters were held and neither the vessel’s managers nor any shore authorities were notified of the accident.

Upon arrival at Tobermory Bay, the master made an ill-considered and poorly executed attempt at anchoring just within the bay’s entrance instead of the planned position in the south of the bay. This had to be aborted to avoid a second grounding when Hamburg dragged its anchor. The passenger's vessel was then taken back out to the open sea with unknown damage to its structure, before diverting to Belfast where a dive survey revealed the extent of the damage. The vessel was withdrawn from service for 3 months for repairs.

In this case, we notice that the master after the grounding incident of the Cruise Ship Hamburg dismissed the bad situation of the ship. He decided to continue the ship’s voyage without considering the handling problems the incident caused, despite the loud noise and vibration when the ship grounded. In a hurry to arrive at Tobermory Bay, the Master became more confused as the situation worsened. Also, he did not consider the weather conditions to continue to Tobermory port. So, as the vessel had handling problems after the grounding incident, adverse weather conditions were determinative for the safety of the vessel and the passengers.

When a ship grounding occurs, a DSS specializing in such incidents often can provide excellent guidance to the Master that would help for the safety of the passengers, the crew, the pollutants in the water, and the ship itself. Below, it will be explained the way that the PALAEMON DSS would deal with the grounding incident of the Hamburg Cruise Ship and how it would assist the Master. We will show some of the suggestions that the DSS displays that would help the current situation, accompanied by a percentage of risk, showing the danger of taking this suggestion and other useful information.

Table 3 A sample of the PALAEMON DSS suggestions on a grounding incident

States	**Some Actions Would Help the Situation**	**Situation Risk Assessment Data and other Information**
After a grounding incident, the DSS is activated and a list of actions is displayed.		
	A visual inspection must be performed. All fuel tanks, ballast tanks and hulls must be counted.	
	All other apartments that are in contact with the sea should be inspected with that they are intact.	1 Hull Status
	Every inclination of the ship must be noted and included in the report.	1 Stability Likelihood 2 Inclination Ship Stability Toolkit
Then, the DSS will suggest actions to prevent the pollution of the sea.		
The Master must estimate.	The transfer of oil from the damaged fuel and ballast	

	tanks.	
	The hermetic isolation of oil tanks to ensure that the hydrostatic height of the tanks is intact during tidal changes in sea level.	
	The assessment of the probability of rejecting oil.	
Next, the DSS will suggest actions about unhooking the ship from the mooring point by his own means		
	If the ship has such damage that after detachment is in the danger of sinking, breaking or capsizing.	1 Structural Integrity
DSS States	**Some Actions Would Help The Situation**	**Situation Risk Assessment Data and other Information**
	If the ship, after detachment, has handling problems with its own means and can not leave the dangerous area.	1 Ability to navigate
	If there is damage to the engines, rudder or propellers or if they occur during the ship's detachment attempt.	1 Critical systems status
	The weather condition, ie when it is preferable to attempt detachment. Is it preferable to wait for the weather or tide to improve.	1 Weather Forecast Toolkit

The main causes that lead the Hamburg Cruise Ship to a series of problems, fortunately without passengers and crew casualties, but making the ship incapable to continue voyages about 3 months was that the Master did not consider the damage the ship had suffered to the hull, port propeller, shaft, and rudder. Also, he did not consider the forecasted weather conditions that are important to check, especially after an incident. The PALAEMON DSS through the above-suggested actions would have led the Master to make a visual inspection of the hull and the other underwater components of the ship. Following that, it would suggest certain actions to prevent the pollution of the sea since it is inseparably connected to all the other actions the Master must take after an incident occurs aboard a ship. Lastly, if the Master decided to continue the Hamburg Cruise Ship voyage after consideration of all previous suggested actions, then the PALAEMON DSS would also suggest some other prerequisite actions before continuing the voyage with all the helpful information of the condition of the ship, including also the forecasted weather conditions.

Fire aboard Roll-on / Roll-off Passenger Vessel Caribbean Fantasy

About 0725 on August 17, 2016, a fire broke out in the main engine room of the roll-on/roll-off (Ro/Ro) passenger vessel Caribbean Fantasy when fuel spraying from a leaking flange came in contact with a hot surface on the port main propulsion engine. The fire could not be contained, so the master ordered the ship to be abandoned. US Coast Guard and other first responder vessels and aircraft, along with good Samaritan vessels, helped transport all 511 passengers and crew to the port of San Juan, Puerto Rico [7]. Several injuries, non-life-threatening, occurred during firefighting and abandonment efforts. The burning vessel drifted in the wind and grounded on the sandy bottom outside the port. Three days later, the vessel was towed into the harbor, where shore-based firefighters extinguished the last of the fire. The accident resulted in an estimated $20 million in damage to the Caribbean Fantasy, which was eventually scrapped in lieu of repairs.

The National Transportation Safety Board determines that the probable cause of the fire aboard the roll-on/roll-off passenger vessel Caribbean Fantasy was Baja Ferries’ poor safety culture and ineffective implementation of their safety management system on board the vessel, where poor maintenance practices led to an uncontained fuel spray from a blank flange at the end of the port main engine fuel supply line onto the hot exhaust manifold of the engine [4]. Contributing to the rapid spread of the fire were fuel and lube oil quick-closing valves that were intentionally blocked open, fixed firefighting systems that were ineffective, and a structural fire boundary that failed. Contributing to the fire and the prolonged abandonment effort was the failure of Panama.

The motorman and the wiper noticed the smell of fuel in the main engine room before the fire broke out. The chief engineer, motorman, and wiper investigated further and found fuel discharging from an end flange on the port main engine fuel supply line, located on the aft outboard side of the engine. The chief engineer proceeded to the engine control room (ECR) and he called the bridge to inform the Master of the leak. The chief engineer told the master that

repairing the leak required shutting down the fuel system and isolating the fuel supply line, which would also shut down the port main engine propulsion. But, poorly, the Master informed the chief engineer to “Reduce the speed.” With the permission of the master, the chief engineer took control of the main propulsion in the ECR and he reduced the load on the main engines.
Reducing the load on the engines had decreased fuel consumption and thereby increased the fuel supply line pressure, which in turn had increased the fuel spray. So, there was an increased amount of fuel spraying from the fuel end flange in the direction of the engine’s exhaust manifold casing and turbocharger. Then, the fire broke out in the main engine room as fuel spraying came in contact with a hot surface on the port main propulsion engine.
The PALAEMON DSS specialized in the different fire incidents depending on the placement where a fire broke out. In this case, the PALAEMON DSS would deal with the Caribbean Fantasy fire incident in the main engine room (ECR) as referred to in the below table.
We will show some of the suggestions that the DSS displays that would help the current situation, accompanied by a percentage of risk, showing the danger of taking this suggestion and other useful information.

Table 4 A sample of the PALAEMON DSS suggestions on a fire incident

States	**Some Actions Would Help The Situation**	**Situation Risk Assessment Data and other Information**	**Fire Sensors**
Assessment of the situation		1 Incident Severity 2 Spreading	
	Hold engines		
	Call the master, first mate, engineer.	1 Ability to Communicate	
	Immediate termination of all work oil, sailing ballast.		
	Stop the power supply or electrical power supply. Maybe quick closing valves are required. Activate EMERGENCY FIRE PUMP if required.		

Then, after the fire broke out.			
	Stop mechanical ventilation, close all fire and waterproof doors from the bridge or locally.		
	Emergency signal pan (PAN-PAN) via GMDSS to RCC/ coastal authorities / nearby ships.		
The DSS informs the Master to check if there are any types of leakages.			
States	**Some Actions Would Help The Situation**	**Situation Risk Assessment Data and other Information**	**Fire Sensors**
	Control for the threat of pollution - treatment of pollution if existing. Call trailers if required		

The main cause that led the Caribbean Fantasy Ship to a series of problems with passengers and crew casualties during firefighting and abandonment efforts, causing damage to the ship that costs 20 million dollars was that the Master, although the fuel discharging from an end flange on the port main engine fuel supply line, ordered to reduce the speed of the ship. As a result, there was fuel supply line pressure and the fuel started spraying more and more. The PALAEMON DSS would suggest the Master stop the supply of engines or power engines. Consequently, if the Master had taken this decision, the fire accident would not have occurred because the fuel spray would not have reached the hot surfaces of the exhaust manifold casing and the turbocharger.

4.4 Action Acquisition, Action Enrichment

- **Action Acquisition**

This section will be mentioned what kind of data the PALAEMON DSS receives, the way that it receives the data and the process of them in order for the DSS to suggest actions to the Master / Bridge and Crew members.

First of all, the PALAEMON DSS is based on the company's Safety Management System (SMS). The SMS provides all the actions that the Master/ Bridge and crew members have to follow in case of an incident. Depending on the incident that occurred, SMS provides certain actions to deal with the incident. All the actions of the SMS have been anatomized and assayed in order to assure the safety of the passengers and the environment of their actions. The PALAEMON DSS has digitized the actions of the SMS. Also, the DSS has separated the actions depending on the incident. So, a JSON file has been created that contains all the data.

Below there is a sample of the JSON file for the grounding incident.


```
defaultSuggestion{
        "incident": "Grounding",
        "actions": {
            "suggestions": [
                {
                    "id": "GRD_001",
                    "sug": "A visual inspection must be performed. All fuel tanks, ballast tanks and hulls must be counted."
                },
                {
                    "id": "GRD_002",
                    "sug": "All other apartments that are in contact with the sea should be inspected to ensure that they are intact."
                },
                {
                    "id": "GRD_003",
                    "sug": "The measurements of tanks, fuel and ballast and hulls must be compared with the latest measurements of the same areas to detect any leaks."
                },
                {
                    "id": "GRD_004",
                    "sug": "Every inclination of the ship must be noted and included in the report."
                }
            ],
            "final_text": "Did you do all of the above?",
            "actions": [
```

```
                {
                    "action": "YES",
                    "first_text": "Master should consider the following:",
                    "suggestions": [
                        {
                            "id": "GRD_005",
                            "sug": "The danger to the ship crew if the ship slips from the grounding position"
                        },
                        {
                            "id": "GRD_006",
                            "sug": "The risk of ship breaking due to rough sea or big waves."
                        },
                        {
                            "id": "GRD_007",
                            "sug": "The risk to the health of the crew and the population of the area from the escape of dangerous loads in dangerous quanti-ties."
                        },
                        {
                            "id": "GRD_008",
                            "sug": "The prevention of fire due to the escape of flammable materials in combination with uncontrolled sources of ignition."
                        }
                    ],
                    "final_text": "Did you consider all of the above?",
                    "actions": [....
```


There is the incident key that contains the cases of incidents, the actions key that contains what the Master and Crew member have to do with the suggestions and the ID of every action, a final text key that asks the Master if all the actions have been done in order to continue, and action key that contains the answer of the Master (For example, unhook the ship or remain)

Below there is an example of the JSON file for a fire-explosion incident (Fire at the engine room).


```
    defaultSuggestion{
        "incident": "Fire-Explosion",
        "actions": {
            "suggestions": [],
```

```
                "final_text": "Which is the point of the fire or explosion that broke out?",
            "actions": [
                {
                    "action": "FIRE AT THE ENGINE ROOM",
                    "suggestions": [
                        {
                            "id": "FRE_001",
                            "sug": "Stop the engines."
                        },
                        {
                            "id": "FRE_002",
                            "sug": "Call the Master, First mate, Engineer."
                        },
                        {
                            "id": "FRE_003",
                            "sug": "Immediate cessation of all oil and ballast works, if they are made."
                        },
                        {
                            "id": "FRE_004",
                            "sug": "Notice DPA and all stakeholders/interested parties."
                        },
                        {
                            "id": "FRE_005",
                            "sug": "Status report."
                        },
                        {
                            "id": "FRE_006",
                            "sug": "Stop oil supply or electrical power supply of engines. If QUICK CLOSING VALVES are required. Activate the EMERGENCY FIRE PUMP if required."
                        },
                        {
                            "id": "FRE_007",
                            "sug": "Activation of HI-FOG LOCAL PROTECTION SYS-TEM."
                        },
                        {
```

```
                            "id": "FRE_008",
                            "sug": "Stop ventilation. Close all fire doors and
watertight doors from the bridge or locally."
                        },
                        {
                            "id": "FRE_009",
                            "sug": "Control operation of EMERGENCY OPERATOR."
                        }
                    ],
                    "final_text": "Did you do all of the above?",
                    "actions": [....
```

There is the incident key that contains the cases of incidents, the actions key that contains what the Master and Crew member have to do with the suggestions and the ID of every action, a final text key that asks the Master if all the actions have been done in order to continue, and action key that contains the answer of the Master (For example, what type of fire incidents occurred, Fire at the engine room, Fire at the garage, etc.)

Secondly, the PALAEMON DSS receives input data from the Smart Risk Assessment Platform (SRAP). The data of the SRAP are risk level indications for the assessment of the situation. These risk level indications assist the Master to assess and monitor the condition of the vessel better as they indicate the risk of taking a decision. The risk level indications used by the DSS to solve the problem of decision uncertainty will be analyzed in the next subsection - Action Enrichment.

Below there are some indications that the SRAP provides to the PALAEMON project.

- Hull Status

The Hull Status indication indicates the probability of the hull is in a safe or unsafe state.

- Spreading

The Spreading indication indicates the probability of the incident spreading to other parts of the ship other than the incident location.

- Stability

The Stability indication indicates the probability of ship stability is sufficient.

- Ability to communicate

The Ability to communicate indication indicates the ship's ability to communicate, within the ship and with the outside world.

- Incident severity

The Incident severity indication indicates the probability of the incident resulting in adverse/ unacceptable consequences for the crew and passengers.

Find all the risk level indications of the SRAP component that are used by the DSS in the 3.2.2 “Smart Risk Assessment Platform Section”.

Also, ANEK Lines as the pilot of the PALAEMON project will provide the Shipboard Legacy Systems (SLS). The Shipboard Legacy Systems provides data from all the already used systems of the ship such as fire sensors, info about the situation, position of the ship, fire doors and watertight doors status etc.

- **Action Enrichment**

In this section will be mentioned the data enrichment of the actions the DSS suggests. How the actions of the Safety Management System (SMS) will be connected with other relative data in order to provide a complete solution to the Master in case of an incident.

As we have already mentioned the PALAEMON DSS is based on the Safety Management System (SMS). The PALAEMON DSS has digitized the actions of the SMS. Also, the DSS has separated the actions depending on the incident.

All the actions of the SMS have been checked, analyzed, and connected with relative data that the SRAP provides to PALAEMON DSS for all types of incidents. SRAP has developed three models that produce risk level indications. These risk level indications are separated into three categories: a. Situation Assessment, b. Mustering Assessment, c. Ship Abandonment. The risk indications values that help to improve the DSS’ efficiency and make it more innovative are those that belong to the Situation Assessment and Mustering Assessment category. The data that the PALAEMON receives from SRAP has been analyzed to the 3.2.2 Smart Risk Assessment Platform subsection.

Also, data from Shipboard Legacy Systems (SLS) will be provided by the ANEK Lines in order to provide useful information to the suggested actions.

So, has been developed a new JSON File called suggestionDataMap that is connected to the defaultSuggestion JSON file described above, and contains all the useful information referenced to every action of the defaultSuggestion JSON file. Also, there is the target which shows who is responsible to make every action.

- Below there is an example of the JSON file for the grounding incident.

```
suggestionDataMap: {
        "GRD_001": {
             target: ["Master"],
          },
        "GRD_002": {
               target: ["Master"],
               info: [["Risk", "this.$store.getters.getHullStatus"]],
         },
        "GRD_003": {
               target: ["Master"],
         },
        "GRD_004": {
             target: ["Master"],
```

```
            info: [
              ["Risk", "this.$store.getters.getStabilityLikelihood"],
              ["Inclination", "this.$store.getters.getStabilityToolkit"],
            ]
        },
       "GRD_005": {
             target: ["Master"],
             info: [["Risk", "this.$store.getters.getIncidentSeverity"]],
        },
       "GRD_006": {
            target: ["Master"],
            info: [
                  ["Risk", "this.$store.getters.getStructuralIntegrity"],
            ]
        },
       "GRD_007": {
               target: ["Master"],
               info: [
                       [
                 "Risk referred to the crew only, and not for population of the
area",
                  "this.$store.getters.getIncidentSeverity",
                      ],
               ],
        },
        "GRD_008": {
             target: ["Master"],
         },
```

- Below there is an example of the JSON file for a fire-explosion incident (Fire at the engine room).

```
suggestionDataMap: {
   "FRE_001": {
       target: ["Bridge Officer", "Engine Officer"],
    },
   "FRE_002": {
       info: [
               ["Risk"this.$store.getters.getAbilityToCommunicate"],
            ],
```

```
       target: ["Bridge Officer", "Engine Officer"],
    },
    "FRE_003": {
                target: ["Bridge Officer", "Engine Officer"],
    },
    "FRE_004": {
                target: ["Master", "First Mate"],
    },
    "FRE_005": {
                target: ["First Engineer"],
    },
    "FRE_006": {
                target: ["First Engineer"],
    },
    "FRE_007": {
                target: ["First Engineer"],
    },
    "FRE_008": {
               target: ["Bridge Officer"],
    },
    "FRE_009": {
               target: ["Electrician"],
     },
        "FRE_010": {
               info: [
                    ["Risk", "this.$store.getters.getEffectiveness"],
               ],
               target: ["Master"],
         },
        "FRE_011": {
               target: ["Master", "Radio-broadcast Officer"],
         },
        "FRE_012": {
               info: [
                 [
                   "Risk",
                   "this.$store.getters.getPassengersProximityToHazards",
                 ],
              ],
              target: ["Master"],
```

```
        },
}
```

The suggestionDataMap JSON file contains the target key which shows who is responsible for every suggested action of the defaultSuggestion JSON file and the info key that contains all the useful information that is associated with every action of the defaultSuggestion JSON file.

The main purpose of the PALAEMON DSS is to avoid the adverse consequences of a grounding, fire/explosion, or collision incident and avert the problem that may drive an evacuation of the ship. The way that PALAEMON DSS achieves this is by providing the Master and crew members with proper suggested actions and all the useful data depending on the incident.

4.5 Suggested Actions Approach

4.5.1 International Code and Procedure Compliance

The International Safety Management (ISM) Code was adopted by the IMO as Resolution A.741(18), in November 1993. It came into force on 1 July 1998 through SOLAS Chapter IX, ‘‘Management for the Safe Operation of Ships’’. The ISM Code provides an international standard for the safe management and operation of ships and pollution prevention. The origins of the ISM Code go back, internationally, to the late 1980s when there was mounting concern about poor management standards in shipping. It is estimated that a high proportion of maritime accidents (80%–90%) are attributable to human error. Investigations into accidents highlighted shortcomings on the part of ship management both at sea and ashore. In 1987 the IMO Assembly adopted Resolution A.595(15) which called upon the Maritime Safety Committee to develop guidelines concerning shipboard and shore-based management to ensure the safe operation of roll-on/roll-off (Ro-Ro) passenger ferries. [8]

Given that no two shipping companies or ship managers are identical and that ships operate under a wide range of different conditions, the ISM Code is expressed in broad terms and based on general principles and objectives. This provides companies with the scope to develop their safety management system (SMS) whilst meeting the provisions of the ISM Code. The Code imposes no prescriptive measures and takes a holistic view of a company and how it operates its ships. The objectives of the ISM Code are to ensure safety at sea, prevention of human injury, loss of life and the avoidance of damage to the environment, in particular to the marine environment.

The Code aims to support and encourage the development of a safety culture within the shipping industry whilst improving compliance with the requirements of international conventions. The Code requires that Companies establish safety and pollution prevention objectives and develop, implement and maintain a SMS and a systematic approach to the safe management of ships by those responsible, both ashore and afloat.

Audits are carried out to verify compliance with the ISM Code following the ‘‘Guidelines on Implementation of the ISM Code by Administrations’’, IMO Resolution A.1022 (26). In addition, the International Chamber of Shipping, in association with the International Shipping Federation, has produced ‘‘Guidelines on the Application of the IMO International Safety Management (ISM) Code’’ and IACS has produced PR 09 on “Procedural requirements for ISM Code certification”. It is recommended that surveyors become familiar with these publications as they establish underlying principles for verifying that a shipping Company’s SMS complies with the ISM Code.

4.5.2 Decision Support System in PALAEMON

The PALAEMON DSS aims to restore the ship's condition to normal when an incident occurs. In case of a grounding, fire/explosion, or collision incident, the PALAEMON DSS is immediately triggered to avert the ship abandonment. It starts displaying lists of actions depending on the incident. These actions are based on the Safety Management System (SMS) and are formed in compliance with it and according to the ship owner’s policies. ANEK Lines, as a pilot of the PALAEMON project, provides its safety framework for the DSS to be compiled with it. The PALAEMON DSS has digitized the actions of the Safety Management System (SMS) depending on the type of incident. So, when an incident occurs the DSS is triggered and displays the proper suggested action lists to the Master/Bridge and crew members.

Also, the Smart Risk Assessment Platform (SRAP) is a PALAEMON toolkit that provides risk level indications for the assessment of the situation. These risk level indications describe the condition of the different parts of the ship and the situation assessment of the ship during the incident. The values of these indications are represented by a percentage indicator. The actions of the SMS that are related to the risk level indications have been combined and the Master can have a better understanding of the situation to be more sure of the action they will decide to make.

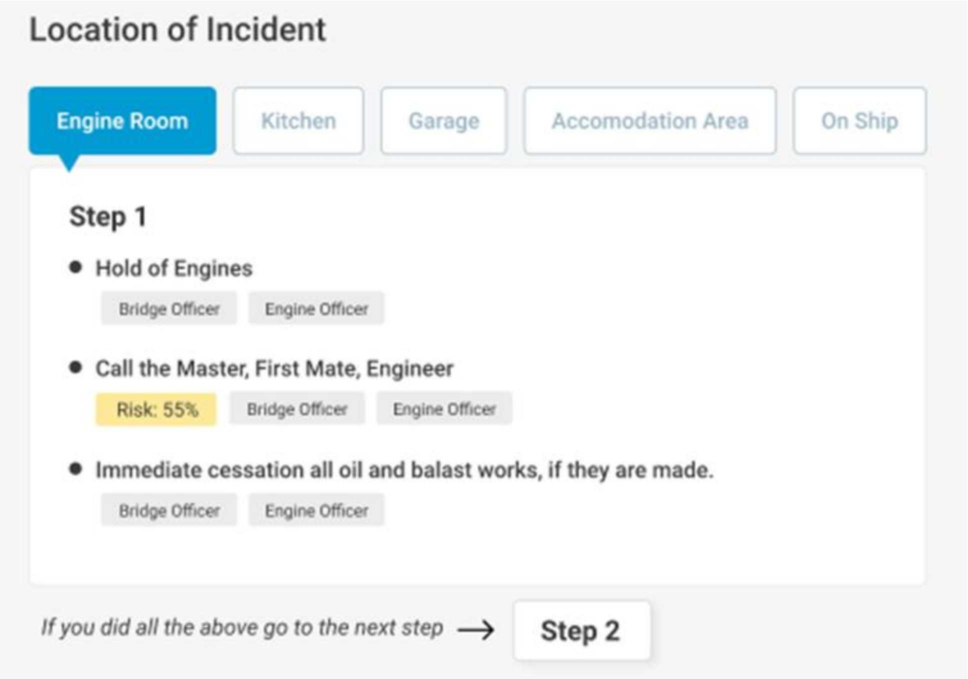

Figure 6 Decision Support System

The above image is the screen of the PALAEMON DSS when a fire/explosion occurs that will be displayed to the Master/Bridge. The master has to choose where the location of the fire incident is and depending on that the DSS displays the suggested actions. Under the suggested actions are displayed the risk level indications from the SRAP toolkit of the PALAEMON project and to whom the action is addressed to.

Furthermore, the PALAEMON DSS provides the condition of the fire sensors of the ship. The Master can be notified when a value of a fire sensor exceeds the maximum threshold and is able to declare a fire incident in order for the DSS and other PALAEMON components to be activated.

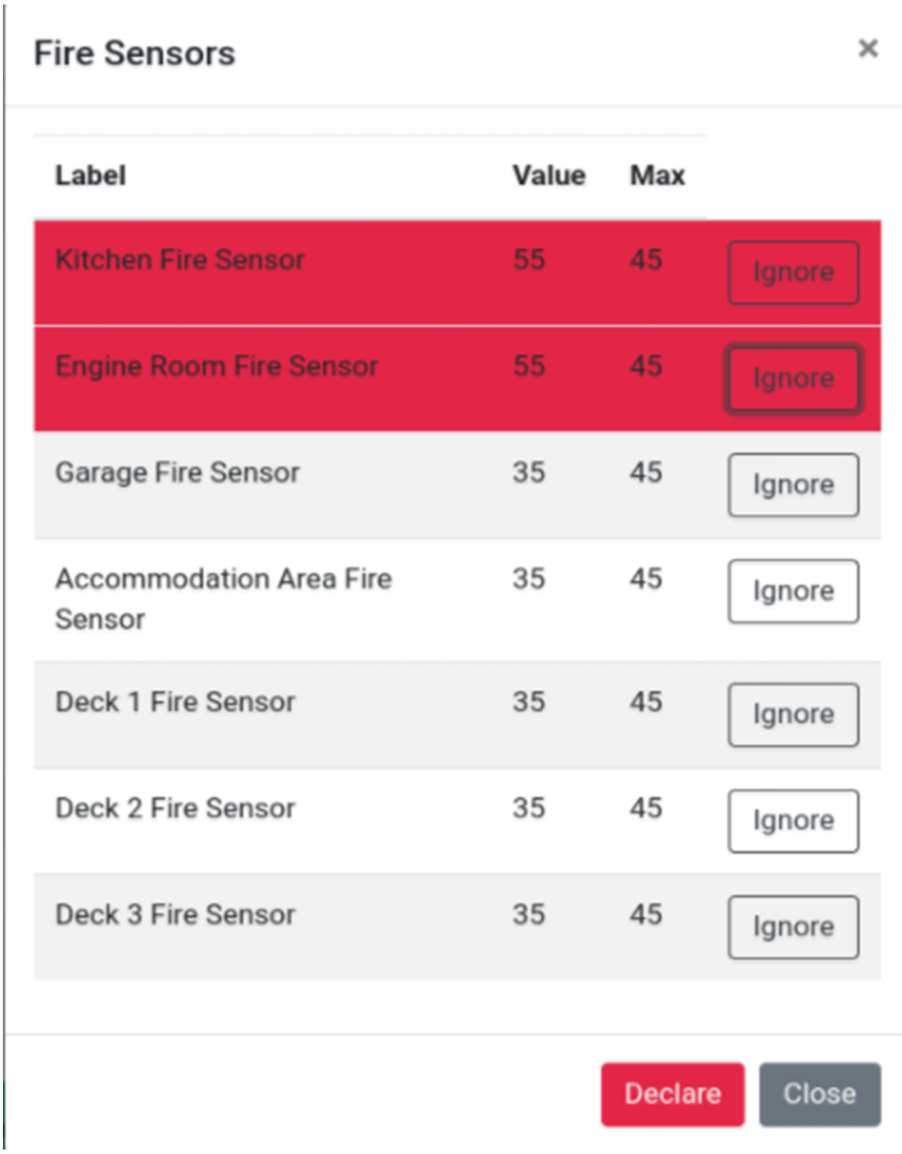

Figure 7 Fire Sensors Condition

As it is shown in the above image, when a value of a sensor surpasses the maximum threshold then it changes in red color in order for the Master to understand that there is a possibility of a fire incident. Then, the Master has the capability, for each fire sensor that has surpassed the

maximum threshold, to declare a fire incident or ignore the situation after manual inspection of the sensor (in case of a malfunction). If the Master declares a fire incident, then the DSS is triggered and displays the action lists depending on the place of fire that the incident happens.
Until now, the PALAEMON provides testing scripts using dummy data for this functionality. So, whenever the PALAEMON DSS will be provided by data such as fire sensors, it will be easily adjustable.

5 Technical Specifications of the DSS Module

In this section, the technical specifications that the PALAEMON Incident Management Module uses to achieve the implementation will be described.

For the backend, the PIMM is based on the Django Framework, Python, and Kafka.

Django Framework

Django is an open-source framework for backend web applications based on Python — one of the top web development languages. Its main goals are simplicity, flexibility, reliability, and scalability. [11]

Django has its own naming system for all functions and components (e.g., HTTP responses are called “views”). It also has an admin panel, which is deemed easier to work with than in Lavarel or Yii, and other technical features, including:

- Simple syntax
- Its own web server
- MVC (Model-View-Controller) core architecture
- “Batteries included” (comes with all the essentials needed to solve solving common cases)
- An ORM (Object Relational Mapper)
- HTTP libraries
- Middleware support
- A Python unit test framework.

Additionally, Django provides a dynamic CRUD (create, read, update and delete) interface, configured with admin models and generated via introspection. CRUD is used to describe the basic database commands, which means the interface facilitates viewing, changing, and searching for information.

The reason why we use Django for the implementation of the PALAEMON Incident Management Module (PIMM) is that it is fast and simple. One of Django’s main goals is to simplify work for developers. To do that, the Django framework uses:

- The principles of rapid development, which means developers can do more than one iteration at a time without starting the whole schedule from scratch;
- DRY philosophy — Don't Repeat Yourself — which means developers can reuse existing code and focus on the unique one.

As a result, it takes a lot less time to get the project to market. Also, Django has one of the best out-of-the-box security systems out there, and it helps developers avoid common security issues. In addition, Django can tackle projects of any size and capacity, whether it's a simple website or a high-load web application.

- It's fully loaded with extras and scalable, so you can make applications that handle heavy traffic and large volumes of information;
- It is cross-platform, meaning that your project can be based on Mac, Linux, or PC;
- It works with most major databases and allows using a database that is more suitable in a particular project, or even multiple databases at the same time.

Lastly, Django is time- and crowd-tested. It has a big, supportive community accessed through numerous forums, channels, and dedicated websites. It's easy to find help when there's a problematic function in the code and to find developers if your company is looking to base the next project on Django. Django started off with great documentation, the best of any other open-source framework. And it's still maintained on a high level, updated along with the new functions and fixes, so you can easily adapt to changes. You can trust that any issues with the framework will be solved as soon as they arise. The software is constantly updated and new packages are released to make working with Django more convenient than it already is.

Python

The Django framework is based on the Python programming language. Python is a general-purpose and high-level programming language. You can use Python for developing desktop GUI applications, websites, and web applications. Also, Python, as a high-level programming language, allows you to focus on the core functionality of the application by taking care of common programming tasks. The simple syntax rules of the programming language further make it easier for you to keep the code base readable and the application maintainable. The syntax rules of Python allow you to express concepts without writing additional code. At the same time, Python, unlike other programming languages, emphasizes code readability and allows you to use English keywords instead of punctuations. [10]

Apache Kafka

The PALAEMON Incident Management Module (PIMM) interconnects the PALAEMON toolkits between them. The PIMM is the bridge that transfers data between the components. Therefore, the PALAEMON components can communicate and exchange data. So, we use Apache Kafka.

Apache Kafka is a distributed data store optimized for ingesting and processing streaming data in real-time. Streaming data is data that is continuously generated by thousands of data sources, which typically send the data records in simultaneously. A streaming platform needs to handle this constant influx of data, and process the data sequentially and incrementally.

Kafka is primarily used to build real-time streaming data pipelines and applications that adapt to the data streams. It combines messaging, storage, and stream processing to allow storage and analysis of both historical and real-time data.

It is important for the achievement of the PALAEMON project vision, the data that are entered into PIMM and are transferred between the PALAEMON Components to be very promptly responded to. When an incident occurs the PALAEMON components must communicate and exchange data rapidly with reliability on high performance.

For the frontend, the PIMM is based on the VueJS framework.

VueJS

While JavaScript is its own beast, the ecosystem it exists within is more important than the programming language itself. Frameworks and libraries make the developer’s life so much easier by providing a solid platform – culminating in fewer bumps in the development road. [12]

VueJS is one such framework. Vue is an open-source progressive framework that is designed to be incrementally adoptable, as the core library is focused around the view layer only. That being said, it’s more than capable of powering sophisticated single-page apps with the help of modern tools and if there are libraries to support them.

Originally, VueJS was developed as a way to take the best parts of Angular, and build a custom tool around it. The data binding and data-driven way of dealing with an HTML-based Document Object Model or DOM were favored in lieu of working with the DOM directly.

VueJS is really easy to pick up, and it’s been this characteristic that has been the main driver behind its widespread and increasing adoption amongst programmers. Also, VueJS has accumulated a powerful set of tools for unit and end-to-end testing, as well as a plugin installation system.

As we touched on, a DOM is a representation of HTML pages with styles, elements, and page content shown as linked objects. This generates something that looks like an upside-down family tree, with the document branching off into its various parts, linked by lines that demonstrate the relations.

As the user interacts with the HTML-based web page, the browser has to update the information and render it to the user's screen as objects change their state. This process is normally cumbersome and slow, as the whole page has to refresh even if just one object changes. VueJS uses a virtual copy of the original DOM that figures out what elements require updating, without re-rendering the entire DOM – greatly improving app performance and speed. Even better than React JS and Angular.

Lastly, Because of this flexibility, VueJS is able to integrate with almost any existing application. It's JavaScript-based and doesn't really need any other tools to work. Switching from React or Angular to VueJS doesn't really cause any issues, as essentially Vue is a mash-up of the two and can talk to both Model View Controller and Component Based Architecture.

6 Conclusions and Future Plans

6.1 Conclusions

Issues regarding maritime evacuation of passengers and crew have received increasing attention due to the significant losses caused by major maritime disasters and the boost in the number of large-capacity passenger ships. The PALAEMON DSS project introduces innovative solutions, whenever a maritime incident occurs, to the Master and crew members gathering information from different components in order to have a better understanding of the situation. The PALAEMON DSS is able to eliminate the confusion that is caused when an incident occurs. The confusion that is caused affects the Master's way of thinking negatively. The main priority of the PALAEMON DSS is to assist the Master and crew member of the ship to deal with a grounding, fire/explosion, collision incident that may occur, with scope to protect people's life and prevent the pollution of the sea due to oil extraction. The ultimate aim is to contribute to the decrease in the number of maritime accidents and maritime casualties.

6.2 Future Plans

The PALAEMON Decision Support System (DSS) provides solutions to help the Master and crew members how to avoid adverse consequences when an incident occurs. The upcoming plans of the PALAEMON DSS are the followings:

First of all, the DSS needs to be able to adjust to different types of passenger ships. The implementation of this DSS aims to be adjusted with the ANEK LINES ships as it is a pilot of the PALAEMON Project. It would be really useful for PALAEMON DSS to be able to help other types of passenger ships just as efficiently. So, one of the upcoming plans is to achieve this.

Secondly, the PALAEMON DSS could be improved by integrating an identification system to gain a real-time specification of passengers and crew flows during an emergency.

Thirdly, it would be very practical if the DSS could analyze the evacuation performance considering the psychological aspects of passenger behavior via agent-based simulation.

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