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PROJECT DELIVERABLE REPORT

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

D3.5 PALAEMON Weather Forecast Tool

A holistic passenger ship evacuation and rescue ecosystem

MG-2-2-2018

Marine Accident Response

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Responsible Author	Panagiotidis Panagiotis (KT)	Email	ppanagiotidis@konnektable.com	
		Phone		
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This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made

Contents

Abbreviations

DFB	Data Fusion Bus
DRF	Django Rest Framework
DSS	Decision Support System
IR	Information Retrieval
MF	Medium Frequency
NAVTEX	Navigational Telex
PIMM	PALAEMON Incident Management module
SOLAS	Safety of Life at Sea
VDES	VHF-Data Exchange System
WFT	Weather Forecast Tool

Executive Summary

Despite the wide variety of weather forecast tools existing in the marine industry, there are no existing tools to support the crew in acting during an incident based on the weather conditions. In any case, the weather conditions affect the evacuation process; for example, high waves slow down the process (Marina Balakhontceva, 2015). Furthermore, there are a lot of cases in marine incidents that the weather conditions, during the evacuation, result in deaths (Kjeldsen, 2000). The PALAEMON Weather Forecast Tool (WFT) aims to support crew members by providing the effective and ineffective actions that applied immediately after the incident occurrence based on the weather conditions at the time of the incident. In this case, the WFT constitutes a guide regarding the effective and ineffective actions that took place in similar past weather conditions (see Subsection 3.2.1). To achieve this target, a dataset that combines weather condition features and crew's actions is created. To the best of our knowledge, this is the first dataset with structured information about the weather conditions and the crew's actions. This attempt comes to cover the gap between the unstructured and structured marine incident datasets.

1 Introduction

1.1 Purpose & Scope

This document, named "PALAEMON Weather Forecast Tool v1", part of WP3 - PALAEMON Intelligence Framework - AI Services and Algorithms, presents a detailed description of the WFT, its role and purpose in the context of the PALAEMON project and, finally, describes its actual implementation. The WFT should be adaptive as vessels with very different sizes, and numbers of persons on board will use it, according to the project's scope (D2.6, 2020).

This document describes the procedure followed and the available sources used for the dataset creation. We also provide an outline of the proposed approach for the crew guiding during the evacuation considering the weather conditions. Furthermore, a demonstration of the actual functionality of the tool is a part of this deliverable. The second version of this document (D3.6 due to M30) will provide the finalized dataset, an empirical study for the proposed method and the actual implementation of the tool.

1.2 Relation to other WPs & Tasks

The T3.3 Weather Forecasting toolkit is strongly related to the WP3, WP6 and WP7. Several components may use the output produced by the WFT. Specifically, T3.3 is also related to T6.2, T6.4, T6.5 and T7.4. The WFT will retrieve the data (e.g. weather conditions) from the Data Fusion Bus (DFB) to provide the output suggested actions. The VDES (VHF-Data Exchange System) will possibly provide the weather conditions at the incident time through the DFB.

Furthermore, the PALAEMON Incident Management Module (PIMM) dashboard will display the WFT output. Moreover, the WFT will deliver to the PALAEMON Decision Support System (DSS) the course of actions for further analysis and will retrieve from the DSS the incident type (see Figure 1).

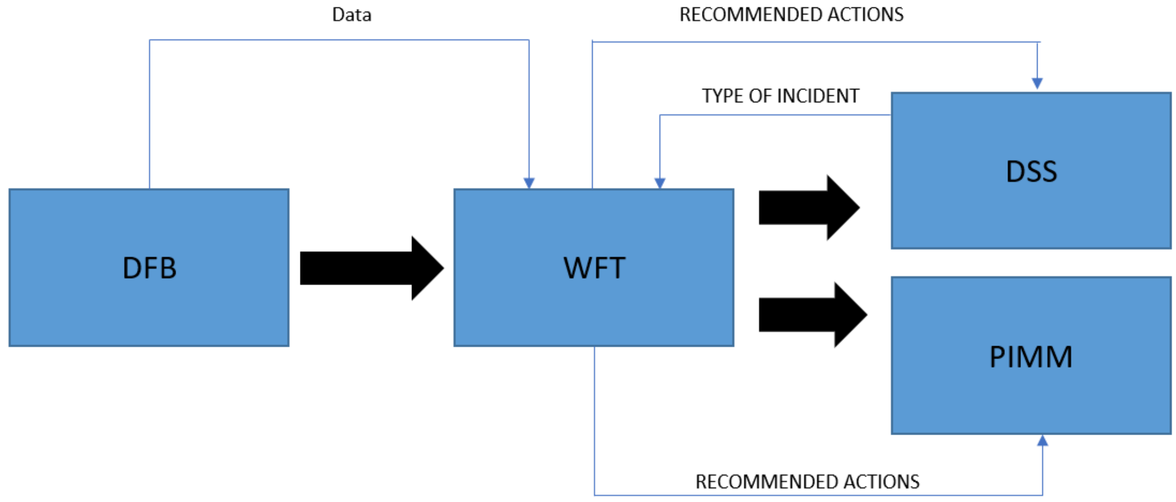

Figure 1 PALAEMON WFT information processing

1.3 Weather data providers onboard

Weather data is an essential and very critical information for ship's safe navigation, seaworthiness and solid condition. Elements of ship data consist of wind speed, wind direction, significant wave height, waves direction, pressure, temperature (air, sea), humidity, ice coverage and other.

Most of vessels are equipped with basic weather instruments (anemometer, barometer, barograph, thermometer, etc.) to display, even digitally, actual weather condition for safe navigation. On top of that, WMO application of Meteorology Programme[1] constitutes a policy framework where ships in voluntary basis could become a mobile weather station to transmit weather observations and be a node in a network of weather data collection which works of ship benefit in return.

However, a display of actual weather condition is one side of the coin. Forecast is the other on and most important for safety on board and critical for ship route plan. **SOLAS** regulation IV/12.2 states that "Every ship, while at sea, shall maintain a radio watch for broadcasts of maritime safety information on the appropriate frequency or frequencies on which such information is broadcast for the area in which the ship is navigating". On that basis, **NAVTEX** is basic weather warning/forecast data source. NAVTEX is an international automated Medium Frequency (MF) service providing shipping with navigational and meteorological warnings, meteorological forecasts and other urgent safety-related messages by automatic display or printout from a dedicated receiver. It is suitable for use in all sizes and types of ships.

Figure 2 illustrates the way the service is typically structured.

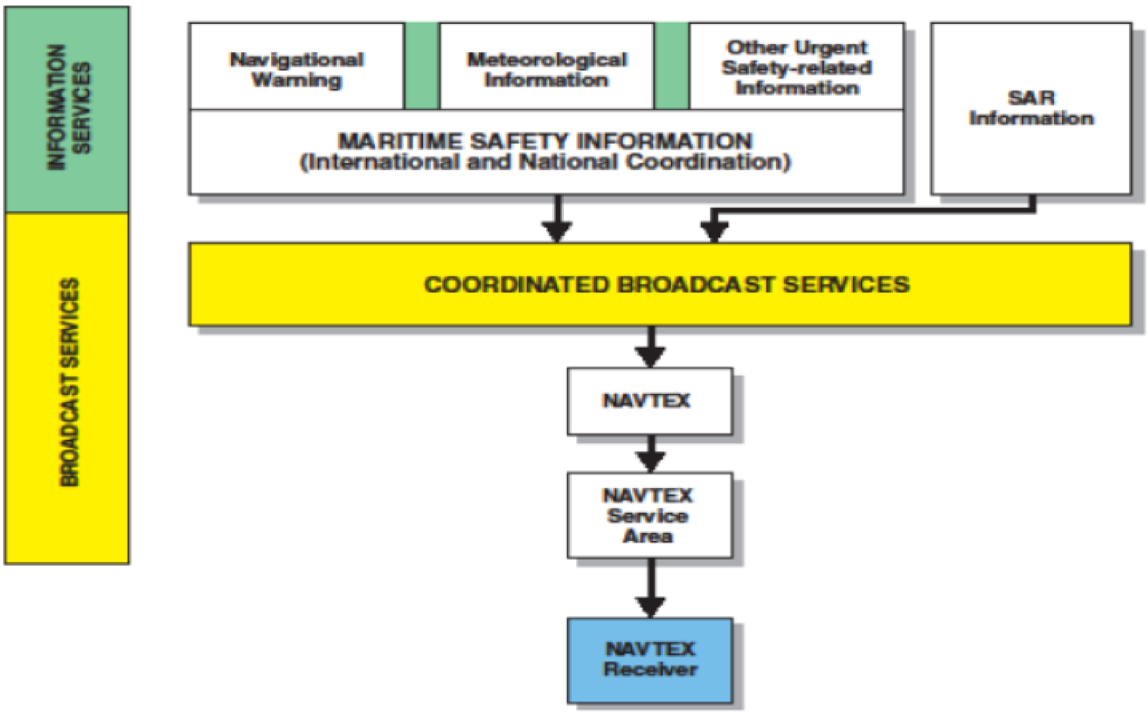

Figure 2 NAVTEX service structure

[1] https://www.wmo.int/pages/prog/amp/mmop/documents/GuideChp6.html#:~:text=A%20selected%20ship%20should%20have,%2C%20and%20possibly%2C%20an%20anemometer.

For the geographical regional distribution of weather information METAREAs[2] exist which represent geographical sea regions for the purpose of coordinating the transmission of meteorological information to mariners on international voyages through international and territorial waters. There are Identical to NAVAREAs which are used to coordinate the transmission of navigational hazards to the same mariners (see Figure 3). Mariners receive the meteorological and navigational information via NAVTEX as both NAVTEX and METAREAs are Part of the Global Maritime Distress Safety System (GMDSS). The Joint WMO/IOC[3] (Intergovernmental Oceanographic Commission) Technical Commission for Oceanography and Marine Meteorology is the responsible agency for the coordination of the dissemination of this information for METAREAs and NAVAREAs.

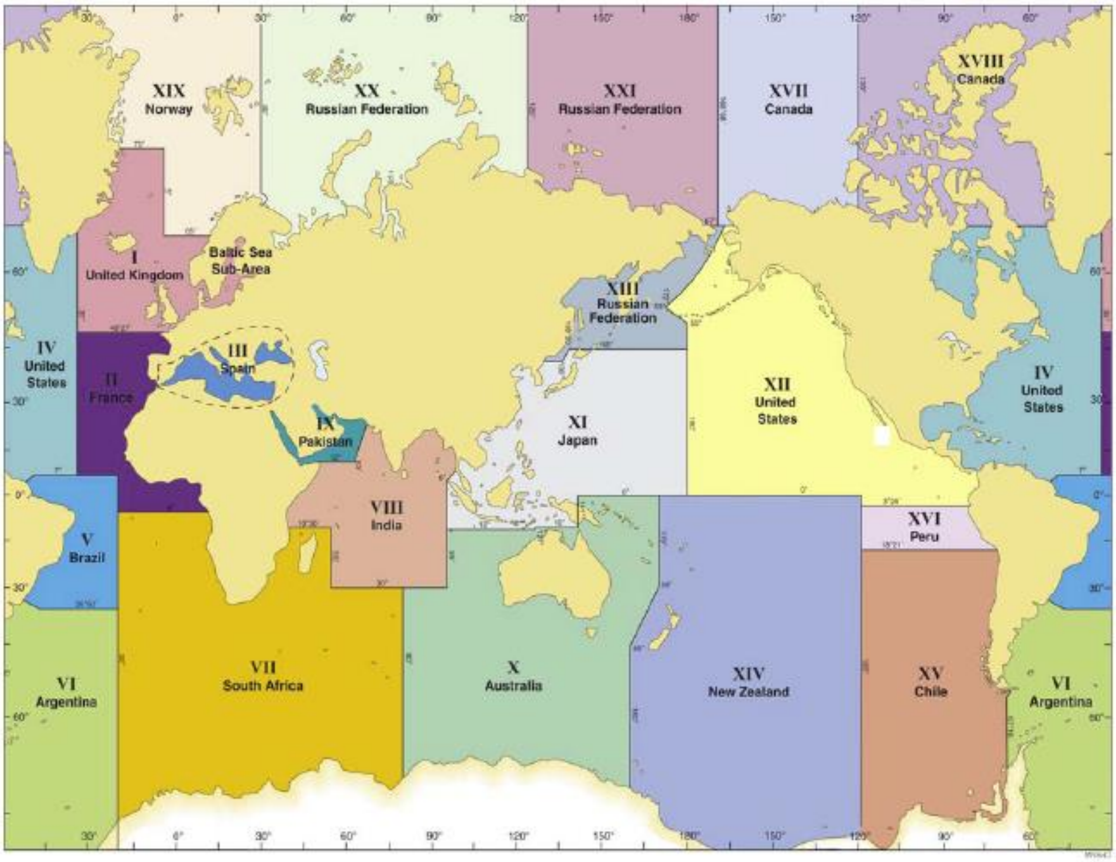

Figure 3: Map of all NAVAREAs. A similar map exists for METAREAs, with only slight changes to areas III and VII

NAVTEX meteorological messages part of urgent maritime safety information (MSI) to ships have the following characteristics:

- 24-hour forecasts
- Dedicated minute broadcast time slots, depending on the geographical location of the station, identified by an identification character.
- Each transmitter identification character is allocated a maximum transmission time of 10 minutes every 4 hours

[2] https://en.wikipedia.org/wiki/METAREA
[3] https://ioc.unesco.org/

- Usually only one-time slot is for meteorological data, with the rest are navigational warnings, search and rescue, piracy warnings, etc
- Meteorological warning for extreme phenomena (i.e. gale), allocated as important and repeated constantly. These messages should contain only the appropriate warnings and should be separate from the weather forecasts
- Weather forecasts (24-h) should be broadcast at least twice each day
- Routine ice reports, once per day

For coastal shipping and short sea shipping mostly, extremely important external sources of weather information and forecast are coastal VTS (vessel traffic service). VTS ensures that essential information becomes available in time for onboard navigational decision-making transmits. The information service is provided by broadcasting information (VHF radio communication) at fixed times and intervals or when deemed necessary by the VTS or at the request of a vessel, including reports for waterway conditions, forecasts and hazards conditions. In this context VDES-VHF data exchange system[4] is come into weather information sharing. The system is seen as an effective and efficient use of radio spectrum, building on the capabilities of AIS and addressing the increasing requirements for data through the system. New techniques providing higher data rates than those used for AIS is a core element of VDES. Furthermore, VDES network protocol is optimized for data communication so that each VDES message is transmitted with a high confidence of reception. VDES will decongest overloaded AIS frequencies and extend datasets of any critical information asset for safety shipping, including weather forecasts.

Other weather forecast sources are including but not limited to

- HF/Single Side-Band Radio
- Public service radio (i.e. BBC Shipping forecast on Radio 4). More modern ways tend to replace this.
- Internet
- Weather charts

Concluding, we should also highlight the ongoing trend in shipping industry of exploiting historical weather conditions while taking advantage of advanced technology and sophisticated computation to come up with meaningful and important information. Use case are directed to weather routing optimization (a computation engine, running in most of the cases ashore, combining historical information, e.g. as currents seasonality, and forecast datasets by international sources[5] to plot a safe passage for ship routing and send a route advice to captain on-board), to the evaluation of adding resistance to ship due to weather condition based on hydrodynamic modelling and operational profile for prediction on fuel consumption and energy optimization, to hull performance assessment and as in the case of PALAEMON to correlation with past incidents at sea for optimizing emergency advice.

[4] https://www.iala-aism.org/technical/connectivity/vdes-vhf-data-exchange-system/
[5] https://www.noaa.gov/, https://www.ecmwf.int/

2 Data

2.1 Data sources

According to the European Maritime Safety Agency only for the year 2018, 941 people injured and 53 died at marine incidents. Both the incident impact and the post-incident situation management are the reasons for human loses. Particularly, the focus on the post-incident situation management to identify the wrong decisions that lead to human loses would significantly reduce the size of the disaster. The need of open marine incident data is evident to tackle the challenges discussed above. Unfortunately, there are limited available sources of structured maritime incident data.

Regarding the marine incidents, there two existing categories of data, the unstructured data mainly into text format (e.g. reports)[6] and the structure data with limited accessibility[7]. In the literature review, the majority of the existing approaches uses the IHS Sea-web database[8]. This database provides limited access structured information for each incident, such as the number of injuries and fatalities, the date and its type. Furthermore, many of these approaches use the structured data for statistical analysis and also to identify the incident consequences (A. Papanikolaou, 2014).

Despite the wide variety of open sources with unstructured marine incidents data, there are no existing open-source structured datasets that include the crews' actions and the weather conditions during an incident. (Dongkon Lee, 2003) has motioned that the evacuation process takes more time when there are high waves in place, indicating that the weather conditions play an essential role in the evacuation process. All that mentioned earlier advocate the usefulness of a dataset that includes both the weather conditions and the actions that took place during the evacuation process. The following section describes in detail the procedure followed for the dataset creation.

2.2 Dataset creation

Multiple online open sources used for the creation of the dataset, such as the National Transportation Safety Board (NTSB)[9] and the Japan Transportation Safety Board (JTSB)[10] include marine incident reports with unstructured data (see Figure 4Figure 5). The information extraction from the reports was a collaborative process of three persons familiar to the field of safety. For each incident report, the participants in the creation process recorded the crews' actions and weather conditions at the time of the incident (see Figure 5).

The 363 marine incidents of the database of the NTSB have been converted into a structured format. The conversion into structured format of the 95 marine incidents of the JTSB database is still pending. The marine incidents without persons on board are not taken into consideration for the creation of the dataset but only used for statistical analysis (148 out of the 363 incident cases) (see Subsection 2.3). The proposed methodology will use the rest 215 incident cases and the cases from the JTSB database (see Section 3). The incidents from 1972 to 2019 include several types of vessels according to the project's scope (D2.6, 2020). The target is

[6] https://www.ntsb.gov/Pages/default.aspx
[7] https://ihsmarkit.com/products/casualty-and-events.html
[8] https://maritime.ihs.com/Account2/Index
[9] https://www.ntsb.gov/investigations/AccidentReports/Pages/marine.aspx
[10] https://www.mlit.go.jp/jtsb/marrep.html

to examine all the cases to identify the effective and ineffective evacuation actions and their correlation with the weather conditions.

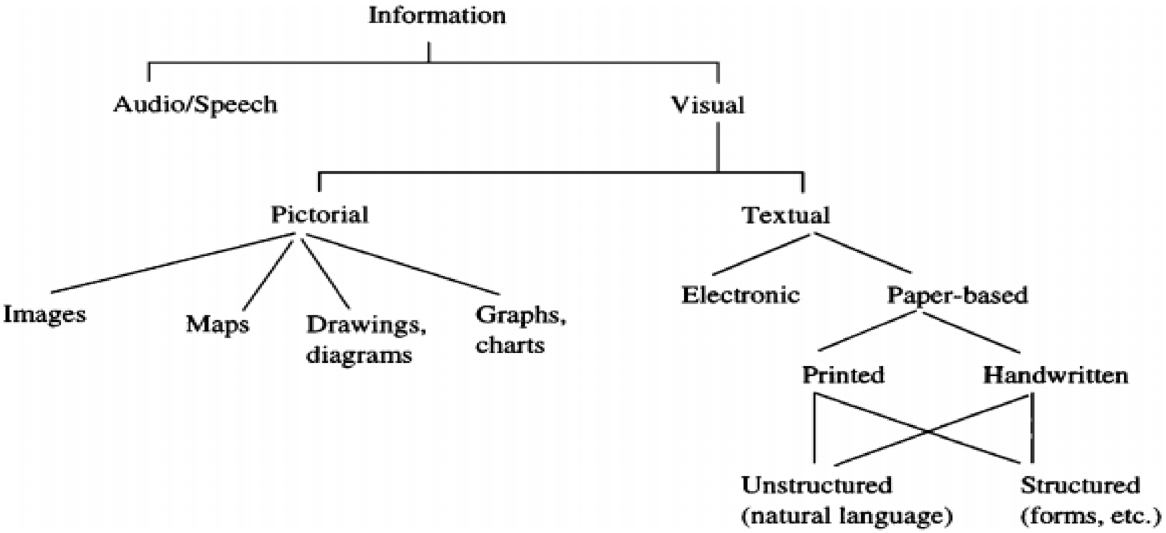

Figure 4 Different types of the available online sources (M. MITRA, 2000)

The attributes of each incident include the sequence of actions that the crew members proceed and a detailed recording of the weather features such as the wind speed, wind direction, visibility, etc. There are also features related to the ship characteristics (e.g. length, ship type), the number of the crew members, passengers, injuries and deaths (see Figure 5).

Vessel Name	Date	Ship Type	Ship Length (FEET)	Visibility (MILES)	Wind Dir.	Wind Speed (KNOTS)	Air Temp. (°F)	Water Temp. (°F)	Incident Type	Crew Member	Passenger	Injuries	Deaths	Action 1	Action 2	Action 3		Action N
SCANDINA VIAN SUN	1984	PASS ENG ER	441	7	158	5	79	77	FIRE	201	530	4	2	The captain activated the general alarm	None was in the position to take immediate action to close the automatic fire doors and to stop ventilation immediately	The captain decided to evacuate	...	...

Figure 5 The structured information for an incident

2.3 Statistical analysis of the dataset

In this section a statistical analysis is applied, the 363 incident cases are used to provide a first insight in the dataset. The analysis provides charts and their description.

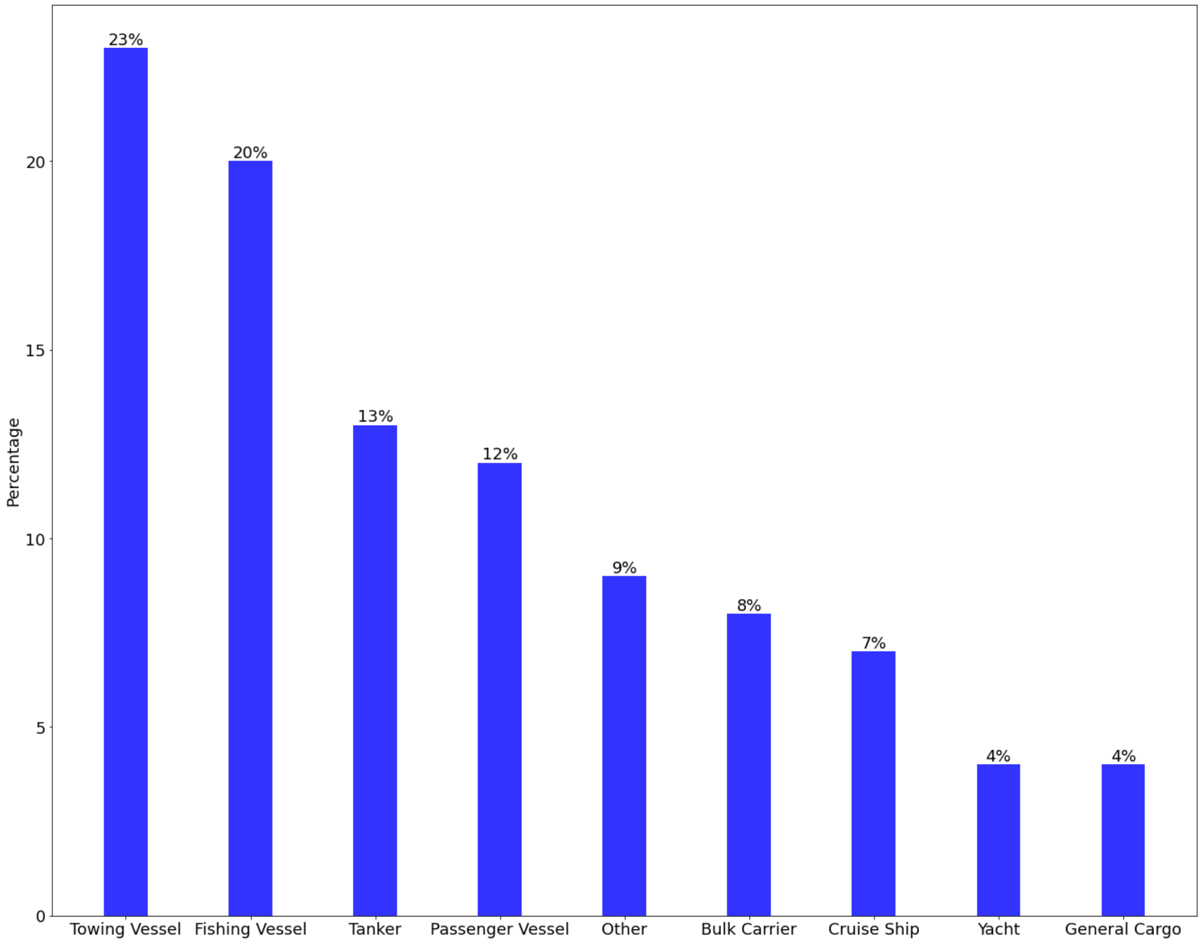

Figure 6 Distribution of ship types in the dataset

Figure 6 shows the percentages of each ship type that the dataset contains. 23% of the sample consist of Towing Vessels, 20% of Fishing Vessels, 13% of Tankers, 12% of Passenger Vessels, 8% of Bulk Carriers, 7% of Cruise Ships, 4% of Yachts, 4% of General Cargoes and other ship types are following with smaller percentages.

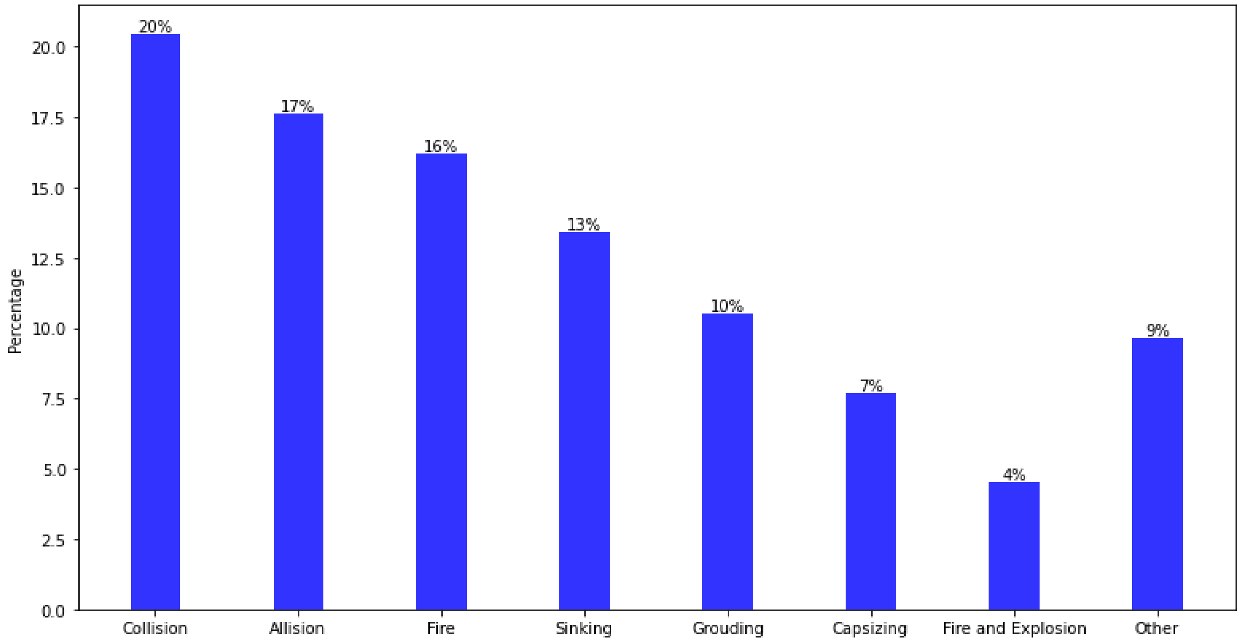

Figure 7 Distribution per incident type in the dataset

Figure 7Figure 7 shows the distribution per incident type in the dataset. 20% of cases are collisions, 17% are allisions, 16% are fire, 13% are sinking, 10% are groundings, 7% are capsizing, 4% explosions that led to a fire and the rest 9% of the cases are other types of incidents.

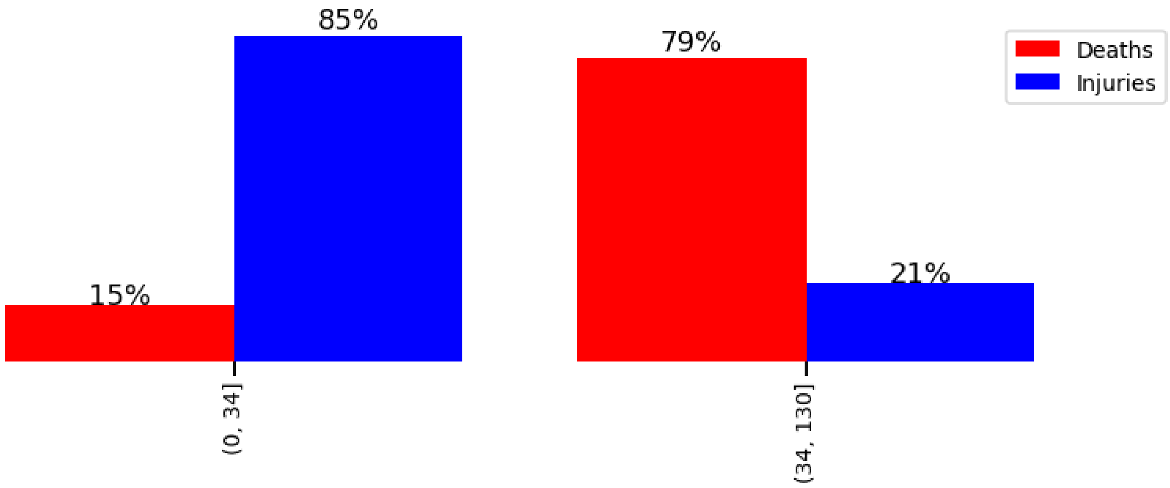

Figure 8 Distribution of deaths and injuries regarding the wind speed conditions

Figure 8 shows the distribution of deaths and injuries regarding the wind speed conditions revealed at the time of the incident. In this case, the dataset has been splatted into two categories, in the first category belong the incidents that during their occurrence revelled light or moderate wind speed conditions ((0,34] Knots) and in the second strong wind speed conditions ((34,130] Knots). For the first category, the majority 85% of the persons on board injured and only 15% of them suffering deadly injuries. This situation inverted for the second category, in this case, the majority 79% of the persons on board suffering fatal injuries and only 21% injured.

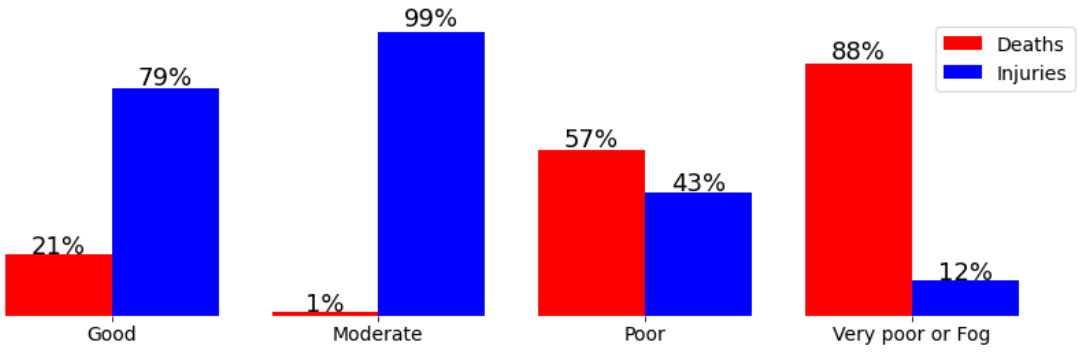

Figure 9 Distribution of deaths and injuries regarding the visibility conditions

Figure 9 shows the distribution of deaths and injuries regarding the visibility conditions during the time of the incident. In this case, the dataset has been splatted into four categories, good (more than 5 nautical miles), moderate (between 2 and 5 nautical miles), poor (between 1 and 2 nautical miles) and very poor or foggy visibility conditions (less than 1 nautical mile)[11]. For the third and especially for the fourth category, deaths have overcome the injuries percentage, 88% of persons on board suffering deadly injuries with very poor or Foggy visibility conditions.

[11] http://weather.mailasail.com/Franks-Weather/Marine-Weather-Forecast-Terms

Figure 8 and Figure 9 confirm the obvious, incidents that occur where in place reveals adverse weather conditions have more human causalities.

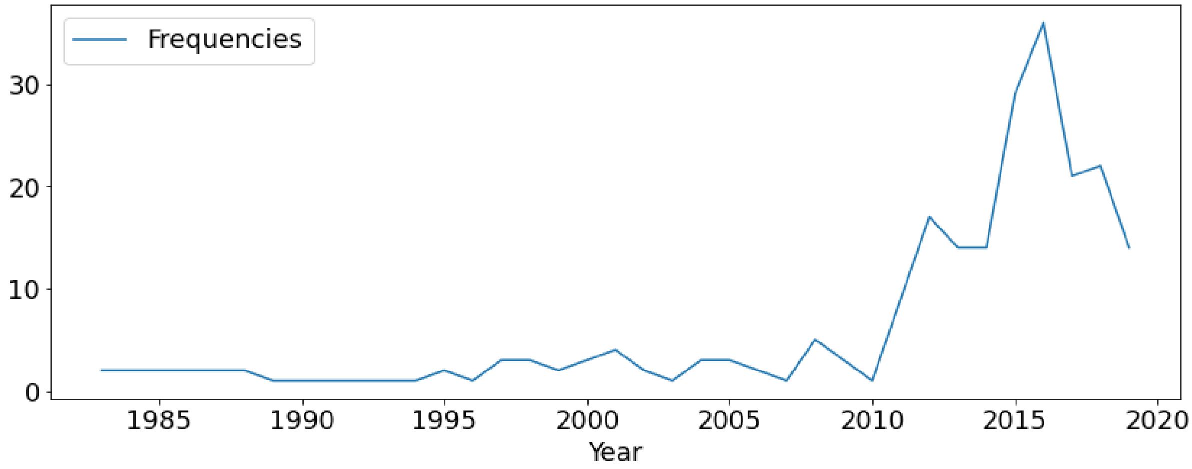

Figure 10 Timeline for the total number of incidents for the period 1985-2019

Finally, Figure 10 shows the number of incidents for the period 1985-2019. There is a clear increasing trend to the number of incidents from the year 2010 to 2017. The rising trending may be due to the improvement of the reporting procedures, resulting in an increased number of reports. Meaning, that this increase caused since more incidents reported compared to the previous decades (N. P. Ventikos, 2014).

3 Weather Forecast Tool

3.1 Related work

To the best of our knowledge, the majority of existing approaches provide weather conditions forecasts for long/short-term periods, e.g., regarding the wave hight (K.G. Sandhya, 2014), fog forecast (Darko Koračin, 2017), etc. Other approaches (Scavia, 2003) inform the crew for the current levels of the environmental pollution and issues related to the marine ecosystem management (Scavia, 2003). The proposed forecast tool follows an alternative path by investigating the correlation between the current weather conditions and the crew's actions during the evacuation.

3.2 Our approach

The initial dataset consists of 363 marine incident cases; 148 incidents are excluded, as they do not involve persons on board. The rest 215 cases serve the purpose of the project. These cases are categorised into two groups, the "effective" and "ineffective" ones. The "effective" incident cases are those that have no injuries, whereas the "ineffective" ones are those that at least one person was injured. This information is encoded by adding an extra Boolean feature to the dataset called "Effective" (see Figure 11). The goal of the WFT is to identify the most appropriate set of actions that meet the needs of the corresponding evacuation case considering the weather conditions and utilizing the group of the "effective" incident cases (see

Annex I, II). Moreover, the WFT identifies potential risky actions for human life using historical data coming from the group of "ineffective" cases to raise the awareness of the crew members.

	Ship Length (FEET)	Visibility (MILES)	Wind Dir.	Wind Speed (KNOTS)	Air Temp. (°F)	Water Temp. (°F)	Incident Type	Crew Member	Passenger	Action 1	Action 2	Action 3	Action 4	Effective
Row 1	441	7	157	5	79°F	77°F	FIRE	201	530	The captain activated the general alarm	None was in the position to take immediate action to close the automatic fire doors and to stop ventilation immediately	The captain decided to evacuate	-	0
Row 2	50	10	292.5	10	59	55	FIRE	6	198	A fire alarm activated	The crew members secured the fire doors to prevent the fire spreading	The crew members applying CO2	The captain decided to evacuate	1

Figure 11 A sample from the dataset

3.2.1 Modeling our approach

The WFT aims to recommend a proper set of actions that satisfy the demands of an evacuation case, taking into account the weather conditions and employing the group of the "effective" cases. Besides, the WFT recognises possible unsafe actions for human life using historical data from the group of "ineffective" incidents. For this purpose, in the first place, Information Retrieval (IR) techniques are used. Such IR systems comprise of three main steps: the representation of the documents' content ("effective"/"ineffective" incident cases), the representation of the user query (current/future weather conditions and ship features) and, finally, the comparison between these representations to retrieve the most related document(s) (e.g., cosine similarity) (see Figure 12). Gerard Salton and his colleagues considered the index and the query representations as vectors embedded in a high dimensional Euclidean space, where the dimensions correspond to the features of the query and the index representations (Roohparvar, 2015). Specifically, every time an incident occurred, the WFT calculates the similarity between the vector of weather conditions along with the ship features (i.e., query vector) $q = (w_{1,q}, w_{2,q}, w_{3,q}, w_{4,q}, w_{5,q}, w_{6,q}, w_{7,q}, w_{8,q}, w_{9,q})$ and the dataset vectors $d_j = (w_{1,j}, w_{2,j}, w_{3,j}, w_{4,j}, w_{5,j}, w_{6,j}, w_{7,j}, w_{8,j}, w_{9,j})$, where d_j with *j=1,…,215*, the vector representation of the weather conditions along with the ship features for each dataset incident. The features of the vectors used for the similarity computation are the ship length, the visibility, the wind direction, the wind speed, the air temperature, the water temperature, the incident type, the crew members and the passenger's number on board (i.e., the darker columns of Figure 11Figure 11). The similarities are computed based on the cosine similarity function:

$$\mathrm{sim}(d_j, q) = \frac{d_j \cdot q}{\|d_j\| \cdot \|q\|} = \frac{\sum_{i=1}^{N} w_{i,j} w_{i,q}}{\sqrt{\sum_{i=1}^{N} w^2{}_{i,j}} \sqrt{\sum_{i=1}^{N} w^2{}_{i,q}}} \quad (1)$$

The clos

Finally, we keep the top-scored case of each group. This way, the WFT will suggest to the crew to follow an effective set of actions and avoid the ineffective ones.

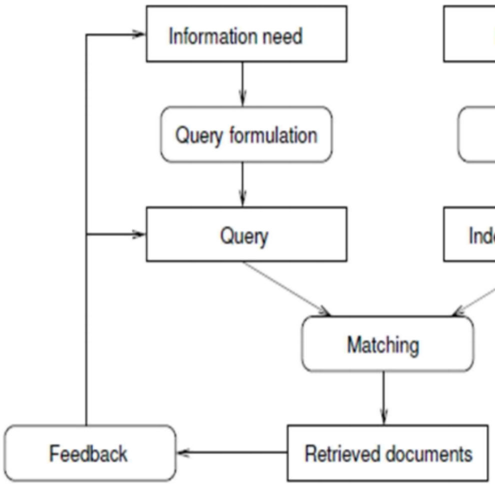

Figure 12 Information retrieval process (Roohparvar, 2015)

4 Technical specifications

Django:

Django is a high-level Python Web framework that encourages rapid development and clean, pragmatic design. Built by experienced developers, it takes care of much of the hassle of Web development, so you can focus on writing your app without needing to reinvent the wheel. It's free and open source. Django is used to develop the PIMM's Backend[12]. REST API Provider: Django Rest Framework (DRF)[13].

Vue JS:

Vue is a progressive framework for building user interfaces. Unlike other monolithic frameworks, Vue is designed from the ground up to be incrementally adoptable. The core library is focused on the view layer only, and it is easy to pick up and integrate with other libraries or existing projects. On the other hand, Vue is also perfectly capable of powering sophisticated Single-Page Applications when used in combination with modern tooling and supporting libraries. Vue is used to develop the PIMM's Frontend[14], where the WFT's output will be displayed.

Kafka:

Apache Kafka is an open-source project for a distributed publish-subscribe messaging system rethought as a distributed commit log. Kafka stores messages in topics that are partitioned and replicated across multiple brokers in a cluster[1]. Producers send messages to topics from which consumers read. Kafka can monitor operational data, aggregating statistics from distributed applications to produce centralized data feeds. It also works well for log aggregation, with low latency and convenient support for multiple data sources. Kafka will be

[12] https://www.djangoproject.com/
[13] https://www.django-rest-framework.org/
[14] https://vuejs.org/

used for communications between the WFT and several components, such as DSS and DFB[15]. Furthermore, the WFT sends data to the PIMM via a REST API.

[15] https://kafka.apache.org/uses

5 Conclusions

5.1 Conclusions

This document provides the initial approach of the specifications of the WFT. The functionalities of the WFT and a first version of the dataset are described in detail, highlighting their contribution to PALAEMON project. Furthermore, an early demonstration accompanies this deliverable.

5.2 Future plans

The second version of this deliverable (D3.6 due to M30) will provide all the agreed functionalities and the developing specifications. Also, the second version will try to identify the performance of machine learning/information retrieval techniques to provide effective and ineffective crew's actions. Furthermore, the second version of this deliverable will provide the final version of the dataset and a detailed demonstration of the component.

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Annex I: Effective action plans for fire

Action Plan 1	Action Plan 2	Action Plan 3	Action Plan 4	Action Plan 5
The vessel's fire-detection system activated and indicated the specific place of the incident	A fire alarm activated	The captain activated the fire alarm	A fire alarm activated	The crew members tried to extinguish the fire for about 8 minutes
The bridge crew activated the general alarm and crewmembers reported to their emergency stations	The crew members identified from where the smoke originated	The captain made an announcement over the public address system requesting passengers to don lifejackets, proceed to the outside decks, and follow the instructions of the crew members	The captain sounded the general alarm and radioed vessels in the area for assistance	The crew members immediately call the authorities
The crew members prevent the fire spreading by closed the engine room ventilation dampers and the fuel, oil valves	The bridge crew activated the general alarm and crewmembers reported to their emergency stations	The crew members passed out lifejackets to each passenger and assembled the passengers on the open decks	The crew members secured the fire doors to prevent the fire spreading	The captain decided to evacuate
	Approximately, a quarter later the captain re-sound the general alarm	The crew members controlled the passengers and kept them informed of the status of the situation	The crew members applying CO_2	
	All the water tight doors were closed		The captain decided to evacuate	

Annex II: Ineffective action plans for fire

Action Plan 1	Action Plan 2	Action Plan 3
The captain activated the general alarm	The lifeboats were through against the wind direction and were hit to the ship's side	The crew members began assisting the passengers to jump into the water
The passengers and crew members did not hear the general alarm or confused by other sounds from the ship	The evacuation was made from the deck in which the wind direction blows the smoke	The crew members did not distributed lifejackets because the entire event took place too quickly
None was in the position to take immediate action to close the automatic fire doors and to stop ventilation immediately		