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Human Factors Implication in Innovative Strategies for Containership Fires Prevention and Management

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ABSTRACT

Maritime transport historically represented the centre of global trade with about 90% of the goods' volumes and values worldwide. Nowadays, containerships are built with the same basic design principles as the older smaller container ships, without accounting for possible consequences that could impact safety. In this perspective, cargo fire represents one of the most important threats for ships. On one hand, fire causes large losses of humans and/or cargoes, on the other hand fire is impacting coastal zone and marine protected areas causing unvaluable damages to the flora and fauna. Often, seafarers underestimate the dangerousness of the situation. This because, sometimes people are not always well trained and some confusion on the correct procedures to be adopted might lead to in a catastrophic situation. In this perspective, the European Union funded a research project based on innovative strategies for containership fires prevention and management. the European research goal is to prevent, detect, manage and response to fire accidents on board of containerships paving special attention to seafarer Safety Culture (SC) to better understand how seaman people perceive safety onboard and the company's approach to safety management. Human Factors (HF) and Safety experts will closely work by setting a SC assessment framework which allows actors to identify, describe and structure their SC using a four-stage model of cognition. In particular, step 1 focuses on theoretical framework development. Step 2 focuses in identifying the overt parts of a safety system before focussing on the hidden layers of the system. In step 3 the hidden layers of the safety system will be scrutinised using exploratory systems constellations. Finally, step 4 encompassed the replication in other use cases (UCs). Furthermore, the research activity will develop a Digital Solution (DS) that will increase the overall situational awareness of accountable people to promptly react during fire accidents avoiding cascade effects. A novel training for seamen on fire management, based on the results of the project, will be executed to increase the readiness of first responders. Hence, the research activity proposes a truly new generation of digital fire management solutions to increase the safety and the SC of seafarers. The impact of the proposed solution will be initially evaluated by performing validation activities in simulated environment by utilising ad-hoc facilities in Italy and France respectively at Italian Maritime Academy Technologies (IMAT) centre and École Nationale Supérieure Maritime (ENSM) centre. Afterwards, demonstration activities will be executed in a real environment where the HF and safety will closely work on the field with the involved actors to gather as much results as possible. Finally, in order to provide evidences of HF and safety results, the research activity selected five scenarios in different European countries: Genova port (Italy), Brest port (France), Valencia port (Spain), Bremen port (Germany) and Gdynia port (Poland).

Keywords: Safety, Human factors, Safety culture, Fire management

INTRODUCTION

Nowadays, container ships are built with the same basic design principles as the older smaller container ships, without accounting for possible consequences that could affect safety. From reports of the European Maritime Safety Agency (EMSA) database, it is assumed that safety principles designed and applied decades ago for ships of much smaller capacity and sizes will work with the same efficiency and effectiveness on today's significantly larger ships (EMSA, 2021). The specific needs that triggered the Innovative strategies for containership fires prevention and management (OVERHEAT) project are to be researched into the number of fires recorded on containerships. In fact, vessels become larger every year – capacity has increased by 1,500% over 50 years – which can impact fire prevention and salvage in the event of an incident. Awareness of this problem has been growing but is still a major concern and a focus of insurers. Too much cargo is being loaded that is not properly documented and appropriately stowed, increasing the threat of fires and risking lives. In response, a number of major container ship operators are taking steps to tackle the issue, including more stringent cargo verification and inspections and higher penalties and fines for infringements. However, this is a problem that will only get worse if action doesn't continue, as vessels become bigger and the range of goods transported continues to grow. These aspects have led to consider an improved prevention and management of containership fires. In OVERHEAT, thanks to the use of cutting-edge technology and the development of new practices, it is possible to reduce the risk of fire on board vessels, including temperature monitoring of cargo, and more active firefighting on deck.

APPROACH AND METHODOLOGY

The project relies on the following novel approaches: (i) Methodologies for fire prevention (ii) technologies for fire prevention and/or management; (iii) design and development of a Digital Solution supporting the prevention, detection and management phases, last being shared with external parties (rescue teams).

The impact of the OVERHEAT solution will be initially evaluated by performing validation activities in simulated environment and then executing demonstration activities in a real environment.

Methodologies for on Board Fire Prevention, Detection and Management

Experts in the OVERHEAT project are strongly working to define effective firefighting capabilities on the container ships providing novel methods for the prevention of fire accidents. These methods will rely on safety goals provided by the studies conducted on the causes of container ship fires occurrence. Through a risk assessment, the risks that could lead into a hazard will be identified and mitigated. The key topic will be the execution of SC assessment to better understand how people perceive safety and if the company policies covers the aspects of safety management. In shipping, and especially on board ships the organization is hierarchic, due to tradition and the

need for clarity in emergency operations. Therefore, safety considerations strongly depend on the actions of the masters and the officers of the ships, and the interactions of the land-based organization. One typical feature of shipping is that ships are manned with crews of multiple nationalities, and the much of it is carried out in international setting, outside national legislations. These issues complicate the communication and interactions within the ships, between them, and with the land-based stakeholders. Safety culture can be assessed iteratively to determine if the situation has improved. As a result of the study, a best practice for firefighting will be produced.

Technologies for on Board Fire Prevention and Management

OVERHEAT intends to develop automated systems to prevent fire accidents and for an early detection of the fire. At the first stage, automated system requirements will be identified to install them in the deck. Then, Internet of Things (IoT) sensors such as temperature sensors, Thermal Imaging Camera (TIC), smoke detector, sniffer smoke detector, CO/CO2 detector, gas detector will be installed and implemented on the containers. Data from these sensors will be fused and in case of fire the intelligent system will allow to accelerate time sensitive tasks and reduce the potential of human error. Furthermore, the digital system will also provide proper guidelines for critical operations in case of fire. For an early fire detection, Unmanned Aerial Vehicle (UAV) could be used: drones' specific cameras can provide images seeing through fumes and other low visibility conditions (e.g. fog) and in addition with thermal cameras will identify the most heated zones, preventing potential explosion risks, maintaining the safest conditions for personnel involved in fire management.

Design and Development of the Digital Solution for Fire Management

OVERHEAT intends to develop a Digital Solution (DS) to support the entire fire on board management process: from prevention to detection and intervention in case of accident. At the first prevention step, the DS will assist the loading process, registering the hazardous cargoes, and providing the best solution for their transportation (e.g. above weather deck). In this way they will be located into preferable segregated area for rapid fire fighting response. In the 2nd step, the DS (well-integrated in the vessel architecture) will receive the sensors data and will fuse them for a rapid-fire response, providing to intervention teams on board the overall augmented picture of the situation on board (seen by the UAV, fixed and mobile cameras on board). In the 3rd step (rescue case) the DS shall share this overall picture of the situation on board in real time with external parties: surveillance agency receiving the distress call, the rescue teams on land and at sea, the selected port and its service vessels (pilotage, tugs, firefighting etc). In return the captain on board is not isolated, receiving the up-to-date situational picture of the surrounding conditions (around and in front) of the vessel along its routing to the selected port of destination. The DS will allow teams on board, on rescue vessels at sea and on land to share the same overall picture of the situation. Joining both, the DS will behave as a digital assistant, at each stage of the firefighting

process, providing the guidelines for best practices and in case the fire starts the integrated picture of the area of interest on board and at sea for a much safer management of the interventions.

Scenarios Description

The following Use Cases, encompassing different European scenarios, are considered in the framework of OVERHEAT project: the Italian, French, Spanish, German and Polish Use Cases.

Italian Use Case

The Italian use case focuses on the on-board containership fires to prevent the negative cascade effects in and out the vessel. The operational scenario foresees a containership that is underway when a fire alarm sounds on the decks/bridge and smoke can be seen coming from a container. The ship is close to Genova port while the vessel is waiting for the clearance of the port authority for entering and start the port operations. Meteo and sea conditions are calm.

The general alarm is activated by a IoT sensor fixed on the container and the crew goes to the muster station. Approximately 5 minutes after the alarm, the UAS on board the ship starts the flight in order to check if it is a real or false alarm and if someone is locked on the deck. In addition, the UAV is able to real-time detect possible thermal anomalies on the containers (e.g. temperature of detected objects with respect to temperature of the surrounding scene) and provide an ulterior point of view of the scene (air view). Thanks to the collaborative use of IoT sensors and the use of the drone, the fire is detected at an early stage and the fire team, on board the ship, can promptly extinguish the fire.

The Italian scenario will be able to test two different situations:

1. Early Warning: the use of the collaborative systems (IoT sensors and UAS) will be for monitoring the containers on the weather deck. In case an alarm is raised by the sensors, the UAS using the AI algorithms, will return a temperature matrix able to detect if a container is warmer than the surrounding area.
2. Fire Monitoring: the use of the UAS will be for monitoring the fire and humans in danger in order to provide a good situational awareness to the rescue/fire teams.

Another goal of this use case is to use UAVs to replace humans in demanding and / or dangerous task such as fire detection.

UAV is able to detect if a human is locked/unconscious on the weather deck. At this stage, the fire/rescue team can promptly receive an assessment of the situational awareness. The above concept implies the use of a platform specifically designed for the purpose of combining the information resulting from IoT sensors as well as from UAVs. The project will benefit from existing simulators that will be upgraded for the purpose of the project. This will allow prototyping the basic IT components and the end-to-end services of the Italian scenario and thus to switch from a simulated world to the real

world within situ tests achieved in the port of Genova. Also, tests under real conditions will be carried out in order to demonstrate that the data obtained from the simulation activities are reliable.

French Use Case

The French scenario focuses on the rescue component of the overall "fire risk management" scenario addressed by the project. The operational scenario foresees that the crew of the containership has detected fire on board, causing damage to the propulsion system. Extinguishing a fire in a container is a very specific exercise and one possible option is to puncture the container. The ship is located in the Atlantic / British Channel, an intense traffic area linking South and North Europe, as well as trans-Atlantic traffic. The vessel is close to the coast. Meteo and sea conditions are rough. Decision is taken to ask for assistance. The captain alerts the French surveillance agency in charge of the area: the Cross. The Cross station "Corsen" is the closest. It takes the communication with the captain. Currently, the 1st exchange between uses VHF (channel 16 sending the key words "may day may day may day", adding the name of the vessel, its location, the nature of the accident). With this few verbal information, the CROSS must estimate the situation and coordinate the rescue, contacting concerned parties (the rescue vessel, the fire intervention teams and the PREMAR (regional maritime administration).

Decision is taken to join the next port: Brest. Exchanges are now initiated with the captain of the port and the pilots. They define a ship rescue strategy, taking in consideration the local traffic, weathercast and sea conditions, hydrographic conditions (tides, water level, under keel clearance etc.) to estimate the best operational conditions including arrival time to take in charge the vessel in the port approach and area. Five teams are now involved: the captain and the crew, the Cross; the rescue vessel, the harbor master, the pilots and PREMAR which takes in charge the overall coordination. The scenario ends when the vessel is at the quay of destination. Below is the port navigation chart of Port of Brest. The entry channel is 3.3 kms. The water level and currents and meteo (wind) are of high importance for piloting a vessel along the channel. The bathymetry along this channel, close to the cost is currently of 9m in the last zone of the channel.

French Use Case will investigate the Digital SAR assistance scenario. The main information sharing is provided is vocal, by VHF. Each team (on board, on land) has its own, partial, vision of the situation, built around the location of the vessel and surrounding traffic and hydrographic conditions; all other information transits through external channels (e.g., sea conditions). The situational picture is hardly set up and shared among all parties, real time is currently impossible. The goal of the French scenario is to test the OVERHEAT information sharing capacities of the DS which provides a global picture of the situation (of the fire on board, of all navigation/traffic/danger information at sea) all along the rescue operation and route to the port of Brest.

Spanish Use Case

The pilot scenario in Spain will take place in the port of Sagunto, north of Valencia. The aim is to assess the usefulness of the technological tools developed in the previous WPs. A container ship berthed at the port and carrying out loading and unloading operations of several containers. During this activity, the ship's captain identifies a smoke on board originating from one of the containers. The various sensors and fire mitigation tools are then activated. The cooperation will take place on the one hand between Valencia port and the Valencia fire brigade, to coordinate the different actions join to the technological partners. Port operations, port services, maintenance and upkeep are all centralised to ensure improved coordination to reduce fire to a large extent. Decisions that need to be made about safety and security issues and the management of emergencies will be taken during this pilot.

German Use Case

Formulating innovative strategies for containership fires prevention and management not only depend on suitable management tools, both digital as well as analogue, but also on an appropriate safety culture. The Gernab use case aims at developing an assessment framework for covert parts of the safety system in the port or coastal state. This is carried out on the basis of the port (or place-)-of-refuge concept which forms a vital element in ensuring maritime safety. However, this concept comes with several conflicts of interest that compromise the applicability of digital solutions intended to provide increased levels of maritime safety. In particular, the safety culture influences the application of a place-of-refuge concept in practice. The objective is to make hidden elements of safety systems explicit.

Polish Use Case

As the Italian scenario, the goal of this use case is to test the use of UAS from ashore to replace human in demanding and/or dangerous tasks such as fire/human detection. The system is composed of a self-charging drone, recovered on its hangar ashore, from which it takes off and executes its missions, mainly consisting in optical/thermal images and video stream acquisition coupled with a A.I. computer vision algorithm capable to detect possible thermal anomalies over the vessel/containers. This is a real-time operation and the UAV is able to detect if an human is locked/unconscious on the weather deck. At this stage, the fire/rescue team can promptly receive an assessment of the situational awareness.

HUMAN FACTORS AND SAFETY ASPECTS

Sharing the Situational Picture

The concepts of Situational Awareness picture (SA) and Common Operational Picture (COP) are closely related and well-acknowledged to be crucial factors for effective emergency management (Steen-Tveit et al., 2021). OVERHEAT will contribute to the generation of an enriched Common Operating Picture (eCOP) through integration of different information sources, and in compliance with related reference standards.

In OVERHEAT, will be used UAV systems and IoT sensors that will collect data at very high frequency allowing to build a complete picture of the Area of Interest (AoI) for the different fire prevention and management phases. The intelligent image analysis algorithms provided by the UAV allows to reduce the human supervision time. The information provided by UAV and IoT systems will be integrated within the proposed DS allowing a timely intervention to mitigate the impact, allowing an attempt to early extinguish the fire automatically without the need for human intervention, guaranteeing full situational awareness picture to actors involved in the operations.

If the fire can't be self-managed, the DS behaves as a digital rescue assistant, enhancing the currently used human-human communication by VHF (radio) with a shared, near real time, picture of the situation on board and at sea around the vessel, up to a port of refuge.

Finally, within OVERHEAT, the data provided by the considered simulators/systems can be fused to create a knowledge-based navigation safety of fire occurrence. The output of the near-real simulation is expected to be confirmed by demo activities in real environment.

Setting a Safety Culture Assessment Framework

A SC assessment is a method used to evaluate the values, beliefs, and behaviors within an organization that influence safety. It helps in understanding the existing SC, identifying areas for improvement, and tracking changes over time. The assessment can be conducted using various methods such as surveys, focus groups, interviews, and document reviews (Ellis et al., 2023). Of course, the SC can be applied also in the maritime sectors due to the high flexibility.

The maritime sector represents a critical sector in which the safety plays a vital role. Furthermore, crew are often represented by people coming from all the word. This aspect of course reflect the importance to assess and evaluate the level of SC on board the ships.

Indeed, the entire crew operating on board ships should pay a critical attention to the safety aspects especially on cargo ship during the handling operation such as charge or discharge of goods. For these reasons, all the crew, should be aligned regarding the aspect of the SC.

Within the OVERHEAT project, a SC assessment will be conducted in order to understand how people perceive safety and their behavior in case of management of a critical situation.

Being SC a proactive stance to safety (Lee et al., 2000), organizations with a high level of safety culture are able to significantly reduce the occurrence of accidents and occupational diseases. A positive Safety Culture is in fact considered able to influence (Gadd et al., 2002) several aspects (i.e. the success of safety initiatives, employees working safety, employees taking work related risks.

According to the (DUCA et al., 2022) a SC assessment consist of 3 steps here listed:

Step 1: Understanding: define the Safety Culture model fitting the organization nature, define the suitable indicators for the specific safety culture;

Step 2: Assessing: measuring the Safety Culture, analysing collected data;
Step 3: Improving: defining a roadmap to improve weak points.

Finally, the analysis is mainly based on the evaluation of the observable and discussed problems in the real context of the organization, that is the results and safety performances, as well as the national culture and the productive and social context in which the organization operates. The results of the survey can be reported expressed by the organization as a whole or for groups of the company population, always paying attention to not stigmatize groups or categories of people. The quantitative data can be represented with histograms, pie charts or use of radar charts, where it is easy to read the strengths and weaknesses of the analysed SC. Data collected through qualitative methods, such as workshops and interviews, can be used to understand the causes of any weaknesses and therefore represents a valuable source for the definition of improvement initiatives.

Training Plans and Best Practices

It is important to highlight that International Maritime Organization (IMO) is most involved in the ship's firefighting. IMO requires through the Standards of Training, Certification and Watchkeeping (STCW) convention that all seafarers have a specific training about firefighting (STCW, 1978). Specifically, two IMO courses are mandatory for all seafarers:

1) Fire prevention and fire fighting – IMO model course 1.20;
2) Advanced training in fire fighting – IMO model course 2.03.

OVERHEAT project will provide a training course that integrates the courses mentioned above. This new course has the scope to illustrate the seafarers the new technologies provided by the project and how to use them in the possible way in the case of ships firefighting. Technology as sensors, drones and so on, can provide a big support to the seafarers and their company to ships firefighting, and can properly work as fire early warning systems.

As the technologies provided by the project are crucial also for the shipping companies foresees in the OVERHEAT project as such training plans will be welcomed as they will result as additional training for their seafarers.

The training course will be provided by project partners responsible for the technologies and will be held when technologies development will reach a good level of readiness and validation has not yet started. The duration of the entire course will be 8–10 hours in total.

CONCLUSION

This paper outlined the motivations and objectives of the OVERHEAT project and summarized the activities to be carried out and the results to be achieved. In particular, the paper outlined the considerations emerged from the work carried out in the project about: 1) the definition of scenarios and use cases for the prevention and management of fires on board; 2) the related safety and human factors aspects.

Future work will be devoted in the project to the refinement of the overall ConOps. Finally, recommendations emerging from the project studies will be provided in order to open up vast prospects for research and advances in the knowledge of human factors and the response to complex situations and crises, such as the fire management.

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