33rd European Modeling & Simulation Symposium
18th International Multidisciplinary Modeling & Simulation Multiconference

ISSN 2724-0029 ISBN 978-88-85741-57-7 © 2021 The Authors.
doi: 10.46354/i3m.2021.emss.055

Improving Safety in Ports & Harbor Facilities by MS2G

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Abstract

The paper addresses the definition of a scenario to be used by a Simulation based Virtual Lab adopting MS2G paradigm for the improvement of safety in seaports. This goal is based on Procedure Redesign, training and experimentation. The paper presents analysis of principal factors, influencing mthe evolution of crises. Consequently, reference cases used for development of evaluation and training scenarios are proposed, one at sea near the port and one inside the port area.

Keywords: Seaports, Virtual Laboratory, Simulation, Safety Training

1. Introduction

Seaports are critical infrastructures characterized by elevated number of risks. Indeed, while they are essential part of numerous supply chains, the presence of hazardous materials and bulky equipment could compromise their operation. Considering this, it is very important to ensure that key figures responsible for safety of seaport and adjacent sea area are capable to reduce risks and to handle crises in effective way.

Increasing attention to safety and emergencies management lead to more frequent and different exercises. For instance, based on the required goal, they could include (EPPR, 2020):

- Table–top exercise, which are mostly discussion-based and typically focused on understanding of roles and responsibilities, response process and interactions;

- Live exercise involving personnel, vessels, aircrafts, etc.;
- Communication tests aiming to ensure that means of communications work as expected;
- Simulation exercises involving computer simulation-based solutions;

Simulation is the newest and most promising kind of exercise in this field. Indeed, it could allow reducing gap between table-top and live scenarios, providing high assessment capabilities without excessive costs in terms of time and resources, enabling experimentation on the models (Bruzzone et al.2011a). In some cases, using also modern virtual and augmented reality solutions could be convenient, in order to make the experience even more immersive (Bruzzone et al., 2019). Considering this, the authors focused on computer-based simulation for training of decision makers who are involved in crisis management in seaports.

2. State of the Art

Crisis prevention and management are important tasks for decision makers. Indeed, complex systems are quite difficult to manage even in normal conditions, while in case of crisis they become even harder to control. Considering this, it is evident the necessity in tools capable to support such key players in most difficult activities. For example, some interesting models were developed to predict outcome of certain events and to support crisis management at city level, including critical infrastructures, transportation system and population behavior while considering even meteorological conditions; indeed, utilization of advanced models and intelligent agents allows replication of complex scenarios in multifunctional environments (Bruzzone et al., 2018; 2014; 2000). Some existing simulation-based solutions were created to assist in more specific tasks, such as port traffic control (Bruzzone et al.2008, 2012). Another advantage of simulation-based solution is the capability to integrate data directly from sensors and other useful information, capable to make the environment and its behavior even more realistic; for instance, data on hazardous materials/potentially dangerous goods as well as on security systems and adjacent to the port areas could be included (Bruzzone et al.2011b, 2011c).

3. Reference Cases

In order to develop the scenarios to be implemented in the model, it is essential to perform analysis of existing cases related to the framework of interest. Indeed, identification of key factors contributed in most characteristic accidents could be very useful for improvement of existing training procedures. Considering this, hereafter is present an overview of several cases of interest used as inspiration for development of training scenarios.

3.1. Moby Prince Disaster

One of most notable cases is Moby Prince disaster, which happened 1991 and lead to 140 casualties. In particular, Moby Prince ferry departed from the port of Livorno, Italy, for unknown reasons collided with anchored oil tanker Agip Abruzzo. As result, the tanker started spilling oil, which resulted in uncontrolled fire. Due to lack of reaction and poor coordination, all persons on board of the ferry except 1 died; according to the investigation, location of the tanker in prohibition of anchoring zone and complete incompetence in handling of emergencies by port authority contributed in collision and death of crew and passengers (Commissione Parlamentare, 2018). While since that case there were introduced various measures to avoid similar situations and specially to prevent such outcomes, number of collisions involving ships remains high while even modern vessels do not guarantee complete protection against leakage of material (Klanac et al., 2009; Lois et al., 2004). This case includes several factors particularly important for training of decision makers, such as involvement of passengers as well as necessity to conduct evacuation and coordination of rescue operation among different bodies.

3.2. Syn Zania Accident

In 2019 liquefied petroleum gas tanker Syn Zania was loading in Petkim plant in western Turkey (TSIC, 2020). At the beginning of the proceeding due to higher than expected pressure the loading hose ruptured and started to leak gas which in no time lead to the explosion and fire, causing necessity of evacuation and consequent death of the second engineer. While the adequate management of crisis allowed to avoid significant damage, this case is a very good example of a starting point for the training scenario; indeed, such event could potentially lead to domino effect and require involvement of different stakeholders for containment.

3.3. Influencing Factors

Apart from obvious common factors which could be observed in analysis of numerous accidents, in order to ensure realism, it is important to take care on some particular situations which were encountered during handling of emergencies; indeed, even if minor issues could seem irrelevant, they could change outcome of the situation, hence, decision makers must be ready to handle them. While it is possible to identify several common characteristics in the situations, such as lack of communication, following subdivision is done in order to focus attention on particular factor of interest; hereafter is present a list of such factors with reference to cases in which they were encountered.

Due to these reasons the simulator should include also representation of these aspects usually modeled as stochastic factors affecting the scenario evolution.

3.3.1. Difficulties in communications

First and very important class of factors is related to communication among stakeholders. Indeed, in some cases even familiar situation could start evolving in wrong direction due to poor or missing communication. For instance, it is necessary to consider language difficulties in order to ensure coordinated work, as is highlighted in Unalaska exercise after action report (ETS, 2012). Another factor is related to availability of equipment, for instance, when a temporary command center is established it could have insufficient connection capabilities to guarantee effective operation, as was identified in Black Swan rescue exercise (USA Coast Guard, 2016); there could also be present dead zones for radio communication in rescue area. Even worse situation could occur when contact information (e.g. phone number) changes without proper notification of partners, in such case it could require some time even to inform a body about ongoing accident, which is especially probable in case of responsibilities shared among several states as was identified in table top exercise conducted by Arctic Council (2017). Considering this, the scenario could include situations in which a stakeholder replies to emergency call only after some time and/or the actual actions do not fully correspond to the requested ones.

3.3.2. Conflicting operation

Improper reaction and lack of coordination could put at risk first responders themselves. For example, it could occur that unaware of each other's' actions entities deploy rescue units, causing interference or even accidents; one of studied cases describes accident with 1 casualty caused by collision of two motor boats related to different bodies and operated without coordination (MAIB, 2020). Very common example of this kind of situation is related to utilization of drones and firefighting, when privately deployed unmanned vehicles obstacle operation of airborne firefighting units; same thing could occur even during rescue operation and involve assets related to different bodies (Kolarich, 2017). Hence, in the simulation it should be possible to introduce similar situations; for instance, surveillance drone could prevent a helicopter from retrieval of injured persons; this situation could be a simple trap for the player, useful in order to highlight importance of proper coordination.

3.3.3. Countermeasures based on wrong evaluation

In some cases, damage could be caused not only by accident itself but also by application of countermeasures, often due to missing coordination. Indeed, in case of TAI YUAN accident, captain of the ship for scrap transportation failed to contain fire due to decision to employ water spraying instead of carbon dioxide when the fire started; fortunately, there were no casualties but the ship was destroyed (JTSB, 2018). Probably the worst example of lack of coordination and improper handling of fire is the Tianjin explosion, in which unaware firefighters poured water on containers with calcium carbide, provoking explosion and numerous casualties (Shen, 2016). In case of PYXIS (JTSB, 2011) the chief engineer of the ship died due to poisoning caused by Carbon Dioxide used to contain the fire; indeed, the crew did not ensure that he left the dangerous area in time.

Another example is related to environmental protection. In case of oil containment on the surface of water, efficiency of booms is limited by weather conditions; in some cases, their deployment could be ineffective and even potentially dangerous (Fingas, 2011; AMSA, 2000). Considering this, the player must have "possibility" to increase damage by improperly applying containment measures.

3.3.4. Lack of familiarization with equipment

Response to emergencies in maritime framework could require utilization of various types of equipment, for this reason, probability that personnel has insufficient experience with it must be taken into account. For example, after Pacific Adventure accident, multiple vehicles with 4-wheel drive (4WD) were deployed to the Moreton island in order to assist in response operation, however, lack of experience in guiding of 4WD, combined with rough terrain lead to numerous breakdowns which slowed down the procedures (AMSA, 2010). Considering this, the simulation would benefit from such factor, which could manifest also as stochastically occurring malfunctions.

3.3.5. Hostile and non-collaborative behavior

When illegal activities are involved, crew of the ship could put itself at risk trying to destroy evidences. For example, crew of poaching vessel Thunder was saved after the captain deliberately sink it after unsuccessful for the poachers 110-day chase (Watson, 2019). Hence, in the simulation the user could be required to assist in accident in which the rescued try to avoid the SAR assets. In some cases, the "rescue" could be performed by non-governmental organizations (NGO) or other autonomously acting bodies. For example, there are cases in which such vessels assist human traffickers' boats before they even send distress call, sometime interfering with official rescue operations, and causing overall number of accidents to grow, as happens in the Mediterranean Sea (FRONTEX, 2017); obviously, even if such activities are presented as SAR, they true purpose remains doubtful, while relationships with authorities and bodies is sometime tense. Considering this, the scenario could include presence of this type of uncontrolled assets characterized by unclear goals.

4. Simulation

ALACRES2 is devoted to create a Virtual Lab based on an innovative model using MS2G (Modeling, interoperable Simulation and Serious Games) paradigm and it adopt discrete event stochastic simulation agent driven approach within a Synthetic Environment to guarantee immersive intuitive interactive interoperable framework. One major issue is related to scalability from computers down to smartphones and Hololens considering different capabilities based on specific computational power of the platform. The Verification and Validation of these models is based on testing specific scenarios with a Champion Team composed by simulation experts, scientists, engineers, port operators, authorities and responsible of the different partners.

5. Developed Scenarios

Based on brainstorming with stakeholders of the ALACRES2 project, there was proposed a set of key factors of common interest to consider during simulation of emergency situations. Indeed, ports involved in the project have different destination and are characterized by distinct hazards; in fact, one of objectives is exactly to identify common scenario interesting for all stakeholders as well as to extend it with particular details. Considering this, following factors were identified as essential:

1. Fall of vehicles in water during loading and unloading of ferry ships. People in water;
2. Fire and explosions;
3. Leakages and contamination of sea surface and of air, debris in seabed;

Furthermore, it is identified list of bodies and units which must be included in the simulation in order to reproduce properly governance of emergencies. Indeed, the user of the virtual laboratory is expected to have direct or indirect control over following entities:

1. Equipage of ships and personnel of the port;
2. Coast guard and port authority units;
3. Firefighters and other first responders, including unmanned surveillance vehicles;
4. Administration of nearby cities;

Obviously, in all cases there is present influence of weather conditions, population, passengers and other factors. Considering this, there was developed a common scenario logic which includes following phases

1. Initialization of the environment and of the scenario. In particular, it is loaded a specific seaport model, set of assets and generated an accident, which could be caused by weather conditions, human error or even by hostile action; some of the causes could persist during all execution, e.g. meteorological situation.
2. The user takes control over some of the assets and starts analysis of the situation based on arriving information. As in real cases, the data could be incomplete or even erroneous, while orders to the staff could be executed with errors.
3. Once the crisis is under control or after the deadline, the simulator analyses performance of the players in terms of employed time, consequences of crisis and efficiency of utilization of resources.

Based on this there were proposed following scenarios to be employed in the simulation.

5.1.1. Collision of ships in proximity to a seaport

In this scenario there are involved 2 collided ships, causing one or several of following consequences:

1. Sinking;
2. Man in water;
3. Fire and/or explosion;
4. Release of toxic or contaminant agents in air or in water.

The scenario involves ships' captains and crews, coast guard, port authority, firefighters, tugboats and municipal authorities as well as autonomous vehicles. One of ships could carry passengers, increasing necessity to rapid response. Hence, goal of the player(s) is to ensure safety of people and limit damage using, with caution, available resources.

This scenario is inspired by the Moby Prince case study.

5.1.2. Accident in seaport

In this scenario there could be involved a passenger and/or cargo ships, tanks and/or containers with dangerous materials, while the main difference respect to the previous scenario is related to elevated possibility of domino effect due to presence of materials and equipment in the yard, higher risk to the port's infrastructures as well as possibility to affect residential areas of a nearby city, e.g. by creating panic. While the main causes could be similar to that ones of the previous case, involved bodies include additionally personnel of the terminal and of the customs. This scenario is inspired by the Syn Zania case study.

6. Conclusions

Emergency management in seaports is challenging framework which requires extensive periodic training. Based on experience of the authors it is proposed to address it using immersive and interactive simulation solution, capable to engage stakeholders in problem solving. In this paper it is identified a set of key factors determining efficiency of rescue operations, proposed a set of secondary factors which would make situation more realistic and improve quality of training; finally, 2 base scenarios and player evaluation criteria are presented.

The Virtual Lab based on the development of ALACRES2 project now is going soon into the experimentation campaign involving the Champion Team composed by the authors to Validate and Verify the models.

7. Acknowledgements

The presented research is carried out under the EU research funding program Italy – France INTERREG Maritime14-20 (http://interreg-maritime.eu/) which supports the development of the project named ALACRES2.

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