

Reducing ship evacuation time: the role of a rail platform for integrating novel LSA lifeboats on ship architectural structures

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ABSTRACT

Ship evacuation is a complicated process, when it comes to fire or flooding scenarios, which is facilitated by an increased availability of onboard systems. The present paper proposes a solution which aims at improving the availability and the accessibility of novel lifeboats in case of an unforeseen event on large passenger vessels. A detailed analysis of the required components and their technical specifications is performed, along with performance requirements, maintenance plan, operational profile, and preliminary cost estimation. The paper concludes with the solution's assessment by calculating the required evacuation time of a sample cruise vessel through simulations.

Keywords: availability, accessibility, ship evacuation, novel LSA, reducing evacuation time, SafePASS

1. INTRODUCTION

Evacuation of cruise vessels is a multi-variable process as it involves the interaction of a large number of passengers and crew with various systems under the effect of rapidly changing conditions (e.g., ship exposed to adverse weather conditions, occurrence of flooding or fire). An extensive literature analysing the potential problems during the evacuation process of large passenger vessels can be found, focusing on the required evacuation time and the possibility of encountering bottlenecks, among others (Vassalos et al., 2003). Nowadays, a series of alternative designs are introduced to address these problems

(SOLAS, 2005) (Bureau Veritas, 2010), while highly sophisticated software is widely used as well, as a mean to assess in a performance-based approach these alternatives that would promote safer evacuation strategies in case of an emergency (Guarin et al., 2014). In this sense, a novel solution is proposed which can be installed on large cruise ships allowing the relocation of the LSA away from a hazardous event (i.e., fire) and preventing its incapacitation during evacuation. Its effectiveness in terms of reduced evacuation time will be validated through relevant numerical simulations for a set of scenarios.

The solution has been conceptualized within the scope of the SafePASS Horizon 2020 Research Project, dealing with the integration of novel LSA lifeboats on novel ship architectural structures. It is one of the solutions proposed in the context of the project, all aiming at reducing the evacuation time, by integrating also novel LSA concepts on large passenger vessels and cruise ships. Focusing on the rail platform solution, it aims at improving the availability and the accessibility of the novel LSA lifeboats in case of an unforeseen event where the lifeboats are incapacitated or the movement of passengers and crew members within the aft-most and fore-most Main Vertical Zones (MVZ) may be restricted. In such emergencies, it is of vital importance that all LSA will be available in order for the total number of passengers and crew members onboard to evacuate safely. For this purpose, it is suggested that the container boxes carrying the LSA lifeboats could be placed on rail platforms that will be able to move longitudinally and relocate in a different position, where the embarkation of passengers and crew would be safe. The infrastructure that should be installed must follow a design in accordance with LSA regulations (IMO, 2017 and best human modelling practice (IMO, 2004) and maintain the vessel's elegance, as it mainly refers to cruise vessels.

Following the introduction, a detailed component and technical specifications analysis is performed. Afterwards, the operational and human analysis is demonstrated, along with an overview of the installation and system integration. A couple of restrictions are identified, while the assessment of the solution concludes the paper, regarding calculations of the evacuation time in several scenarios through simulations.

2. COMPONENT ANALYSIS AND TECHNICAL SPECIFICATIONS

To begin with, the container carrying the novel LSA should be secured on the rail platform with

specified arrangement. The platform shall move on wheels, using an electric motor, which will be powered by a power supply driven in an energy chain, or by mounted batteries in case of emergency, while a locking mechanism should be available as well for the deployment phase. Concerning the controls of operation, a button shall be available for on-site operation, as well as two remote panels and a wireless control. One control panel should be stationed locally, near the installation, for the crew to operate if needed, while another must be stationed at the bridge. The ability of hydraulic manual handling should be provided, as well. The entire conceptual design is illustrated in Figure 1, to enhance the solution's understanding. The solution is analyzed further into its subsystems, components, and parts.

LSA container. It contains the novel LSA lifeboats, and it shall be provided from the manufacturer. Twist locks and corner castings is suggested to be utilized in order to secure the container on the rail platform.

Rail platform. It is the main system of the proposed solution. It shall house the subsystems necessary for its operation inside a frame construction. These concern the following:

- **Frame construction:** It shall house all subsystems and ensure structural integrity.
- **Wheels and drivetrain:** The wheels of the platform must support the load requirements and follow certain standards. The drivetrain must be characterized by high reliability, with four wheels, two on each rail.
- **Hydraulic brake system:** A high reliability hydraulically powered brake system should cover the safety demands. The brakes should be strong enough to support any loads applied to the system (rotational loads, rolling hazard in seaway when moving to position, bowing arrangement, etc.)
- **Lock mechanism:** A locking mechanism is needed for securing the rail platform at a certain longitudinal position along the rails.

This can be achieved through the locking of the wheels or even hydraulically controlled support legs. The latter will also act as a

restraint of the whole structure against rotational loads in case of extreme rolling behavior of the vessel or other circumstances.

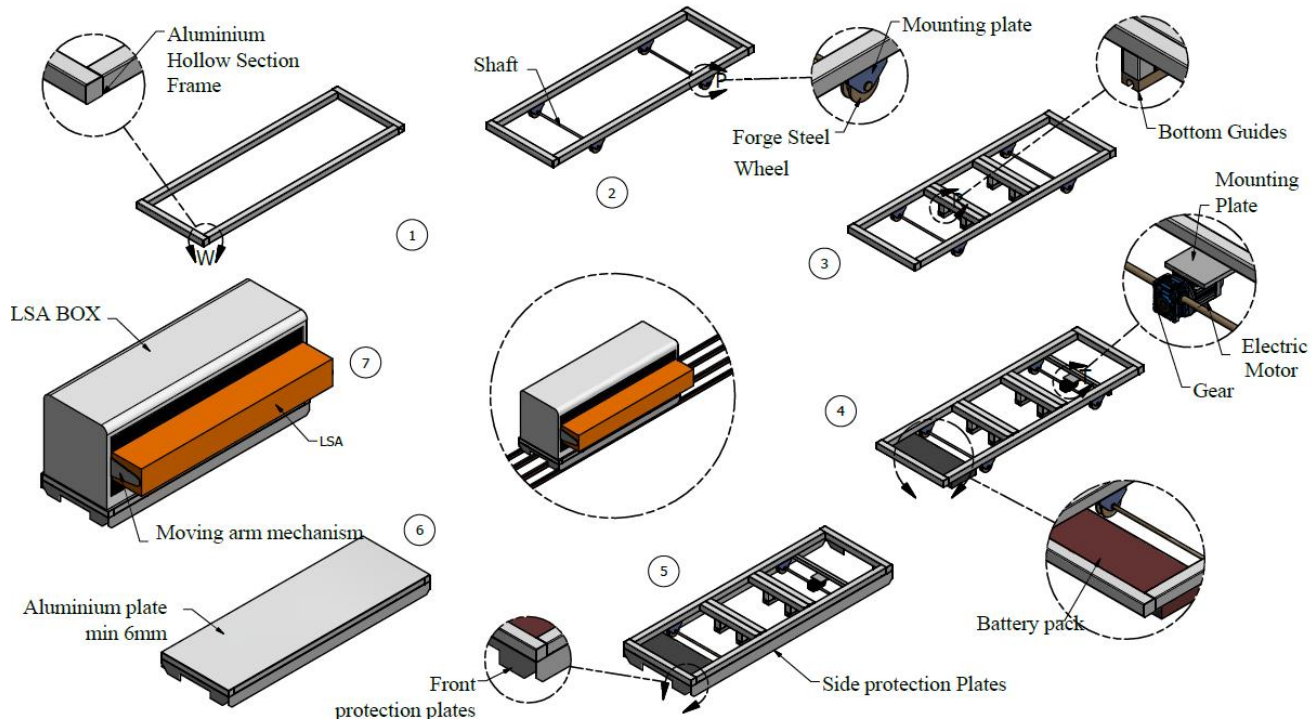


Figure 1: Conceptual design of proposed solution

- Batteries: To achieve autonomy in case of power outage, the rail platform must be equipped with a set of batteries to power the electric motor and enable its movement. The capacity will be instructed by the power demand of the motor, which depends on the overall weight of the assembly.
- Electric motor: The movement of the rail platform shall be achieved by an electric motor. The power demand depends on the overall weight and the speed of the platform.
- Manual hydraulic handling mechanism: If both the control panels and the mounted button fail to respond, the installation should allow the designated crew members to move the platform manually and avoid incapacitation, despite its significant weight.

Rail installation. The rail platform shall move on a pair of rails. The installation must be secured on deck, with a suitable assembly, while an

installation of energy supply is also needed. These are described below:

- Rails: Depending on the load specifications and the wheel dimensions, the model of the rails shall be chosen, respectively. The rails can be embedded on the deck (in case of newbuildings) in an elegant manner or can be installed through an assembly with a steel plate placed above the deck (for existing ships). In both cases, the rails should be placed in a way that they are not considered a hazard for passengers in every-day life of the vessel.
- Energy supply chain: To supply electrical energy on the rail platform, an energy supply chain shall be arranged at the side of the railway, with all necessary cabling.
- Linear slide assembly: A slide assembly should be arranged accordingly under the platform (or at its side), in order to allow longitudinal movement only. This

arrangement restrains the platform to move in any other direction and out of tracks. A conceptual design is illustrated in Figure 2. This is important, especially when ships are exposed to rough weather.

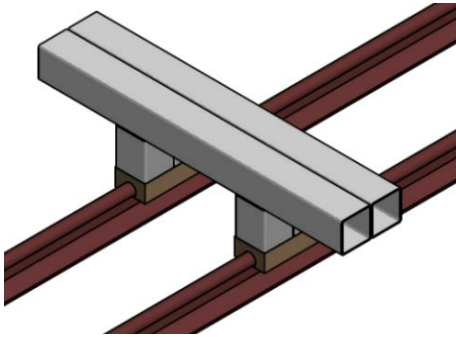


Figure 2. Indicative linear slide assembly

Controls. For the deployment and operation of the rail platform a set of controls should be available:

- **Mounted button:** A control button should be available to control the rail platform if the remote panels are out of order.
- **Remote control panel:** Placed locally, a control panel should be available for on-site deployment by the designated crew member(s).
- **Bridge control panel:** A control and monitoring panel should be placed at the bridge for controlling the platform, in association with crewmembers on site, in order to avoid incapacitation. This serves the evacuation process if quick decision making is required.
- **Wireless control:** For on-the-move control of the platform.

After presenting the main components, an analysis of the technical requirements of a case study rail platform follows. Assumptions are taken for the design approach, regarding dimensions and operational characteristics. The below technical specifications were assessed and validated by a group of experts, including LSA

and equipment manufacturers, as well as shipyard engineers, within the context of the project.

2.1 Dimensions, weight, and materials of the rail platform

The basic characteristics are specified for the considered case study, several of which are assumptions. Firstly, the rail platform has an overall length of approximately 12 meters, and approximately a width of 3 meters, following the novel LSA's dimensions. The weight of a conventional lifeboat of 50 persons capacity is over 3 tons (SOLAS, 1974), and thus, since the novel LSA is inflatable, the weight of the novel LSA lifeboats container is assumed to be approximately 500 kg to 1 ton. Consequently, the total weight of the cart would be 300 kg or less, according to the load demand. In any case, the cart should be able to carry at least a 20% surplus of the LSA's weight. The materials are mainly aluminum, regarding the frame construction, for achieving low weight, and steel for the rails and the wheels, in order to enhance their structural integrity.

2.2 Wheels, bearings, rails, and slide assembly

The wheels shall be of double flange cylindrical treads type and fabricated from forged steel. The wheels shall be tested using ultrasounds and shall be mounted in such a manner to facilitate their replacement.

The rails will be A-Shape according to DIN 536 standard of steel material. The profile would be of minimum A-45 with dimensions 55x125x45 and weight 22.00 kg/m. Their design, along with the wheels, is illustrated in Figure 3. They shall be fixed on deck with bolted connections, in order to be easily replaced for maintenance. In this case study, the length of the rails is taken as 50 meters (i.e., equal to the longitudinal distance of a fire

zone), as not to interfere with the fire protection transverse configuration (refer also to section 6). Thus, an overall weight of the rail installation is calculated as 2.2 tons.

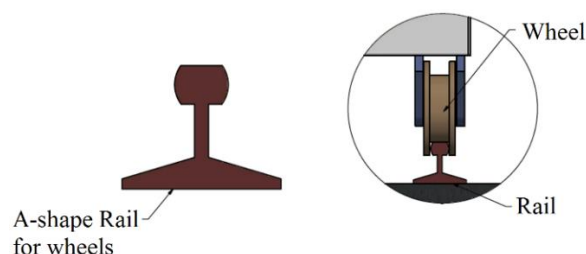


Figure 3. Rails

The linear slide assembly will be arranged under the rail platform, positioned between the rails. The assembly consists of the guide support structure, four guides with four self-lubricated bearings and the rails. The two linear drives (rails) should be also fixed on the deck (or intermediate plate) with bolted connections, in order to be easily replaced for maintenance. Figures 2 and 4 explain extensively the slide assembly arrangement. The weight of the linear drives, since they are also 50 meters long as assumed earlier, is calculated as approximately 2 tons. The carriage of the assembly should be arranged with bolted connection on a respective arrangement under the platform. The assembly should withstand a load of 10 to 15 kN, considering the weight of the platform and the LSA. The carriage should speed up to 0.5 m/s as the speed of the platform (refer also to the next paragraph).

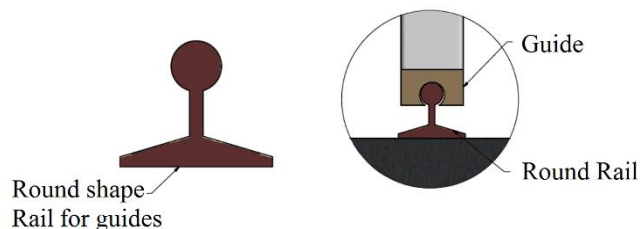


Figure 4. Rails for guides (slide assembly)

All bearings shall be of suitable heavy-duty adequate antifriction type. All the bearings shall have adequate load carrying capacity and shall be arranged so that they might be removed for their maintenance.

2.3 Operation characteristics

In cruise ships, the presence of a large number of passengers imposes safety requirements, despite the fact that a designated crew party shall oversee the platform movement. Therefore, the speed should not exceed 0.5 m/s. Such a speed will result in 100 seconds (max 2 minutes) time for the platform to move from one side to the other, assuming the 50 meters long rail installation. This specified timeframe may seem long enough but cannot be further reduced because of the aforementioned safety reasons.

2.4 Motor and electrical equipment

The cart will be electrically powered, while a battery pack should also be available for emergency situations. A complete description of specifications for the motor and the batteries is possible after being fully defining basic dimensions and load requirements.

The configuration of the power supply should be arranged through a power supply chain. According to the load carrying requirements and the weight of the cart, the power of the motor should be approximately 1 kW. The motor should be properly mounted on the frame in order to transmit the required torque to the axle, while it should be able to develop a counteracting torque for braking purposes. The motor should be placed beneath the top plate, to be close to the axle and near the edge, to be accessible for maintenance.

Batteries should be able to supply the required power to motor for at least 5 full routes, regardless of the standby autonomy. This is approximately a minimum of 10 minutes of use and at least 1 hour of standby autonomy. Batteries should be placed inside a properly sealed box in order to be protected from moisture and other environmental conditions.

2.5 Safety measures

All the equipment should meet the safety requirements based on safety regulations on ships and cruise vessels. Safety measurements should be applied in order to minimize the exposure of human to risk. Electronically and mechanically controlled brakes should be placed on the cart in case of battery failure. An emergency stop button should be placed on the control panels and on the rail cart. Limit switches should be placed at the end of the rails to prevent over-travel of the cart. Safety arrangements including protective covers for the moving parts, should be considered for the moving cart. Protective covers should be placed both on side and front of the rail platform.

3. INSTALLATION AND SYSTEM INTEGRATION

In general, the installation per se does not directly challenge any SOLAS regulations, it does not deviate from prescriptive requirements, and thus, there is no need to be assumed as an alternative design or arrangement. This was also confirmed by experts from classification societies in the context of SAFEPASS project. The rail installations have not a specified installation site for all vessels. They could be placed both on existing cruise ships, via retrofits, and newbuildings. It is evident that in existing vessels there are many restrictions for design alternations, whereas in a newbuildings, the design possibilities are endless.

3.1 Necessary interventions for existing cruise ships

Based on the case study considered, there should be four rail platforms, namely two on port and two on starboard side, one towards the stern and one towards the bow. The default position of the platform can be anywhere along the rail installation. For the present case study and the

respective simulations, the default position for all platforms shall be in the middle of the rails, i.e., the middle of the MVZ, as assumed earlier (refer also to section 6). The installation of rails should be fixed on deck. An additional steel plate may be placed also on deck to partly hide the rails and to support movement. In general, a proper integration to the existing ship design is needed, regarding the following: (a) deck reinforcements, (b) electric supply, (c) movable furniture for allowing platform and passengers and crew movement, (d) appropriate modifications at the promenade, and (e) increased protection for storage (initial) area to prevent early incapacitation of LSA. In addition, since the proposed system is meant to be installed on cruise vessels, appropriate aesthetic interventions should be considered for the final solution to be elegant.

3.2 Newbuildings

In case of newbuildings, the rails could be recessed on the floor. Easily detachable material could be placed on top of the rails so people can walk over them. Side walls could be placed at the carts' initial position that will hide the installation when positioned in its default position.

4. SERVICE AND MAINTENANCE

In order to be safely operated in emergency conditions, both the rail platform, with the respective set of rails, and the novel LSA lifeboats should have a service and maintenance plan that will involve the following:

- The rail platform should be visually inspected according to the service and maintenance plan. All moving parts should be checked to prevent an unexpected failure.
- Rails should be inspected for defects and failures in order to prevent the risk of rail breakage and unwanted results, such as distortions due to loading of the underlying

deck, defects due to wear (increase of its surface), defects due to wear in the wheel/rail contact area and rail cracks.

- Bearings should be checked and replaced according to the manufacturer's instructions.
- Batteries should be checked, measured, and replaced according to the manufacturer's instructions.
- Wheels should be checked for distortions and fatigue.
- The electric motor should be checked for malfunctions based on its performance. Maintenance should be done according to the manufacturer's guidelines.

In general, based also on the feedback from equipment experts in the context of the project, the service and maintenance requirements are not particularly demanding and could be integrated into the general LSA equipment maintenance procedures with ease.

5. OPERATION AND HUMAN MODELING

The following considerations regarding integration with human modelling must be taken into account: (a) the LSA slides' entrances should be arranged evenly with deck, (b) designated points for the LSA deployment be defined, and (c) furniture placed near the rail installation must be easily removed. Additionally, a description of the operational phases-scenarios follows:

- 1st scenario – Normal cruise condition with no emergency: The novel LSA and their container remain stationed in the prefixed default location.
- 2nd scenario – Evacuation drill: LSA platform becomes operational and moves by the designated crew members as required from the evacuation drill scenario.
- 3rd scenario – Evacuation with no imminent incapacitation of the novel LSA: The LSA is deployed in its default location.

- 4th scenario – Evacuation with imminent incapacitation of the novel LSA: The LSA is moved accordingly (from crew or from bridge officers in association with crew) to avoid incapacitation, and it is then deployed.

6. DESIGN LIMITATIONS

Present section presents some design limitations that were identified, properly addressed and led to necessary adjustments of the suggested solution.

The first one refers to the occupied space from the rail platform and rail installation. In more detail, for the retrofit case, the used space is calculated as approximately 600 m² for all four installations. For the newbuilding case, the rails could be recessed, so the space is much less, i.e., 160 m² for the rail platforms only. In any of these cases, compared to the design of conventional lifeboats, the freed space is increasing, which was also confirmed from the group of experts. It was also noted that even in the retrofit case, a local redesign of the space configuration could lead to the reduction of the used space.

The second one refers to the problems for anticipating the large rotational loads which may be applied during the LSA's deployment or in case of extreme rolling behavior of the vessel. This is addressed by including in this first design approach the linear slide assembly and the hydraulic lock through support legs. However, a final design should incorporate all necessary load calculations and address weaknesses in the installation, if any.

Additionally, from the previous sections, the overall weight for all four installations is calculated as 26.4 tons. Despite that it is a significant number, during the solution assessment, all experts found it to be affordable, especially when considering the entire weight of the vessel.

Last but not least, common rules for the design of large passenger ships, instruct not to interact with the limits of the MVZ, in order to ensure the containment of a fire spread. Thus, the length of the rail installation in an enclosed space is not exceeding the length of an MVZ (i.e., 50 m). However, if the rail platform system is to be installed in an external space (i.e., balcony) a greater length could be assumed. This could have a greater impact in the reduction of the evacuation time, as it could introduce greater flexibility in the LSA relocation.

7. COST BUDGETING

Present section presents a preliminary cost budgeting in Table 1 for one installation. The prices are strongly depended on the materials that will be used, the standards of the manufacturing, the manufacturing country, the final load and power requirements and the control level. The prices were validated by experts, including LSA and equipment manufacturers, as well as engineers from shipyards, within the context of SafePASS project. During the validation, the overall cost of all four installations, nearly 300,000 €, was found affordable, in the context of the entire cost of a retrofit or newbuilding. The cost analysis does not contain elements from the environment of the installation (decoration, furniture, side walls). These cannot be specified and are not assumed as part of the container-platform-rails system.

Table 1. Budget analysis

COST DESCRIPTION	PRICE (€)
Study and design	5,000.00 €
Material and component costs	54,000.00 €
Manufacturing costs	6,500.00 €
Transport costs	2,000.00 €
Installation costs	6,000.00 €
Start-up and commissioning	3,000.00 €
Total Costs	76,500.00 €

8. SIMULATION MODEL

The efficiency of the proposed solution was examined by a ship evacuation model. Pathfinder by Thunderhead Engineering was the evacuation software that used, which is an agent-based mesoscopic (Guarin et al., 2014) evacuation analysis software. The model utilizes a sample large cruise ship, implementing decks 2 to 16 of the ship structure, and calculates the time needed for passengers and crew to assemble in the muster stations, and from the muster stations to the embarkation areas.

Table 2. Simulation Parameters

PARAMETER	IMPLEMENTATION
Population composition	MSC.1 / Circ. 1533
Walking speed	MSC.1 / Circ. 1533
Initial distribution of passengers and crew	MSC.1 / Circ. 1533
Response duration	MSC.1 / Circ. 1533
Vessel's capacity	3700 persons (2700 passengers, 1000 crew)
Embarkation deck	Deck 7
Dynamic position of the ship	Not considered
Fire propagation	Not considered
Human behavior factor	Not considered
Number of simulations run	50

In the context of the SafePASS project, simulations will be performed for multiple flooding and fire scenarios, environmental conditions, and passenger behaviors. At this analysis, the considered parameters are describing below. The IMO Guidelines, MSC.1 / Circ. 1533 (IMO, 2016) on evacuation analysis specifies values for the population of the passengers and the crew, based on two factors, gender and age, the initial distribution and the response duration, the walking speed on flat terrain and stairs, and a specific door flow rate. In this analysis, the provided values were used. The basic parameters of the simulations are presented in Table 2. Additionally, the following parameters were defined: (a) ship condition: fire, (b) Hs (m): 0, (c)

daytime: day, (d) at port: no. The fire was started in an A/C room at Deck 7, MVZ 4, and the adjacent rooms became inaccessible.

The developed baseline scenario testing the proposed solution was not incorporating the rails, but utilizing the existing LSAs, twenty LSAs with a capacity of 150 persons and two Marine Evacuation Systems (MES) of 474 persons each, were needed. The alternative scenario incorporating the rail solution includes four novel LSAs with a capacity of 1000 persons each. This scenario represents the 4th operational scenario presented earlier (refer to section 5), where the LSA is moving to a more optimal position. In Figure 5, the default (middle of the MVZ 5) and final positions of the novel LSA are shown. The length of the rail installation assumed equal to the length of the MVZ (refer to section 6), which represents a minimum length to test if there is a significant impact on the evacuation time.

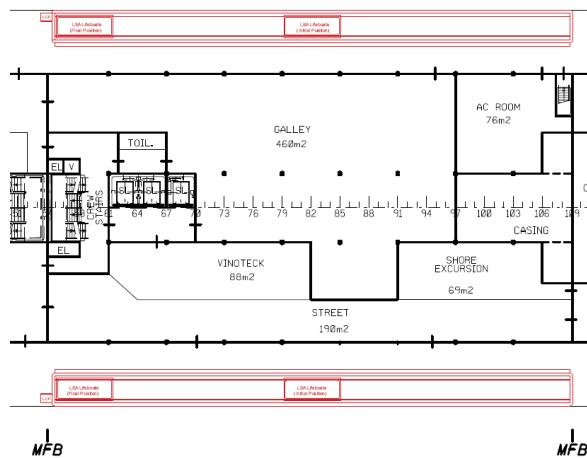


Figure 5. Initial and final position of the LSA

9. RESULTS

According to MSC.1 / Circ. 1533, the calculation of the total evacuation time is calculated by the sum of the Response duration (R), the Total travel duration (T), the Embarkation and Launching duration. The mathematical model for calculating the Total evacuation time is: $1,25 (R + T) + 2/3 (E + L) \leq n$, where $n =$

60 for ro-ro passenger ships and for passenger ships other than ro-ro passenger ships, if the ship has no more than three MVZ and $n = 80$ if the ship has more than three MVZ. Also, E+L duration should not exceed 30 minutes to comply with SOLAS Chapter III. Regulation 21.

The simulation results in terms of the time to reach LSAs for passengers and crew are shown in Figure 6 for both scenarios.

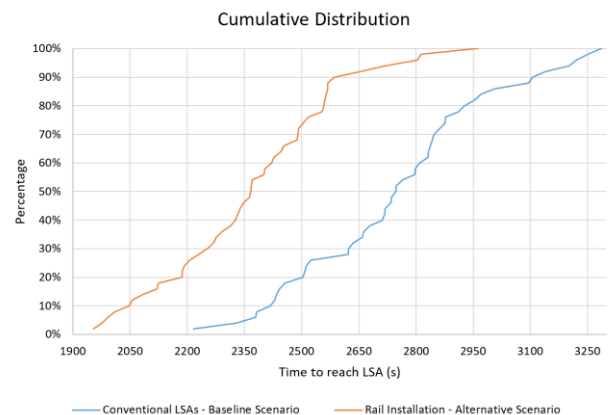


Figure 6. Cumulative plot for required time to reach LSA for baseline scenario (blue) and alternative scenario (orange)

For both scenarios the mustering time considered the same to examine the time needed from the muster stations to the LSAs. The presumed outcome was verified by the simulations, as the average time of 50 runs was equal to 2751,4 [s] for the conventional solution, while for the rail installation was 2371,0 [s], meaning the reduction was approximately 14%. A further reduction to the total evacuation time is expected by using the novel LSAs, where the embarkation and launching time will be significantly less than using conventional LSAs. Also, the resulting values are within IMO Guidelines. In the context of the project, a more detailed simulation analysis is performed, including ship's motion characteristics, unforeseen event effects and factors related to human behavior. For instance, reduction to speed due to fire effluents is not considered, as this paper refers only to a preliminary testing of the solution

and since it affects both scenarios. However, it will be included in later simulations, in the context of SAFEPASS project.

10. CONCLUSIONS

Present paper is introducing a novel solution for increasing availability and accessibility of novel LSA lifeboats in case of an emergency on large passenger vessels and reducing the required evacuation time. The component analysis and technical specifications may differ depending on the LSA design and the operational requirements, but in any case, should follow the basic design approach presented earlier, including all safety requirements. Maintenance is not considered to be demanding and may be incorporated into the general LSA equipment maintenance procedures. The integration of the solution is feasible not only in newbuilding cases as there are no space limitations, but also in retrofits since the required installation space is less than the existing one for the conventional LSAs. Weight and cost are also not considered as weaknesses of the solution, while they could be further minimized in a later detailed design by industry experts. The validation of the solution through evacuation simulations of a sample cruise ship presented earlier, illustrates that there is significant reduction of the required evacuation time by adopting such a system. Finally, the synergy of the rail platform with the additional proposed design solutions that are developed in the context of SAFEPASS will further reduce the overall evacuation time.

11. ACKNOWLEDGMENTS

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