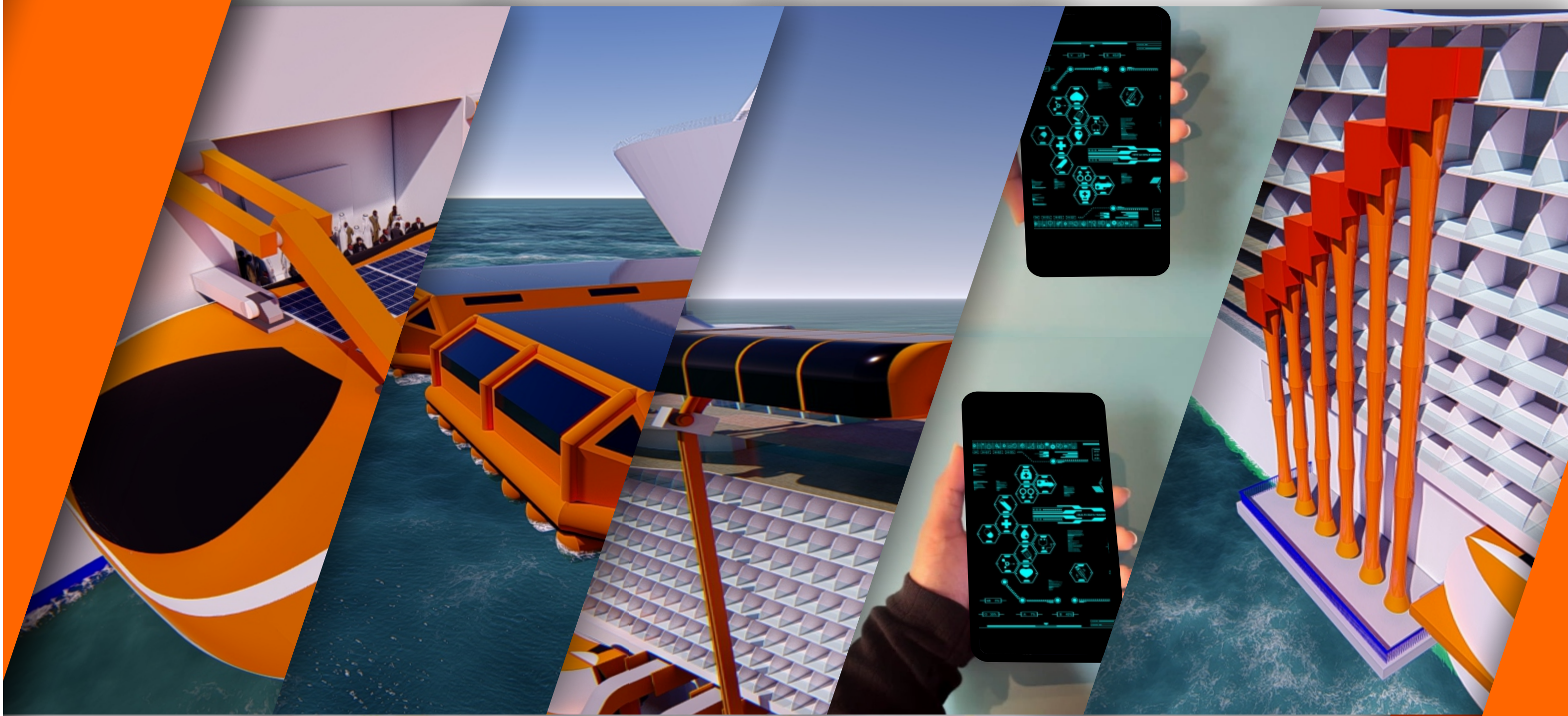
DEVELOPMENT OF AN INTEGRATED AND RESPONSIVE DESIGN FOR SAFETY SYSTEM AND EQUIPMENT IN THE NEW GENERATION OF CRUISE SHIPS



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SUMMARY OF LIFE SAVING APPLIANCES DESIGN

This future life-saving system is new way in evacuating passenger and the crew in cruise ship with new design of life boat, life raft, and evacuation system which are practical, time-effective, and reliable design to make sure safety cruise ship operation. There for these designs we entitled with "**Development of an Integrated and Responsive Design for Safety Systems and Equipment In The New Generation Cruise Ships**". These are the key features of the future of Life saving appliances:

1. Design Condition and Regulation Compliance

The life-saving appliances is adjusted according to the case ship technical specification and operation including the passenger and crew amount. To make the designed life savings system meets high standard of safety and reliability, the acknowledge and universal codes for life-saving appliances from IMO MSC and SOLAS 1974 were taken into consideration in making the design.

2. New and Innovative Lifeboat Design

The lifeboat can carry 533 people, is used with minimum space use, and is powered by a reliable and sustainable hybrid diesel-diesel electric propulsion. The lifeboats are placed in a space efficient and ergonomic. In addition, it is equipped with the necessities of food and freshwater to ensure survival in the lifeboat.

3. Inflatable all in one high-capacity Life raft Design

The Life raft has a capacity of 700 peoples and is equipped with a slide ramp for evacuation. Equipped with 4 engines as a life raft driver. In addition, there are tools that can support people's safety.

4. SKY LIFT (High-tech futuristic attraction and evacuation platform elevator).

A new and innovative way to evacuate people from higher deck by using a lift installed either side of the ship. The new and innovative not only for safe evacuation system, but also as high-class, futuristic and attractive value-added feature for future cruise ship. This the core of future lifesaving appliances that

5. Inflatable Evacuation Chute.

The quick and simple evacuation access from higher deck. The design is aligned with space-save and flexible installation concept. The design was inspired by the evacuation equipment of a high-rise buildings. And was provided for multiple decks that were far away by lifeboat or life raft.

6. AISEM (Autonomous Intelligent Safety and Evacuation Management)

An innovative and smart system to help the crew and passenger in manage life-saving condition, with the help of artificial intelligent integrate data between hazard Identification sensor and ship real-time condition, to reduce human sense of panic and uncontrolled evacuation, and also give real-time coordination with ship voyage condition and alarm network.

A. Life Saving System For Cruise Ship

1. Requirement

Safety is important to include in a major aspect of all ship operation and design. Because this is very important, IMO carries out the SOLAS convention as a legal level to regulate the improvement of the quality of safety in maritime. Safety matters based on IMO, pay attention to the safety of ships, passengers, crew and goods which includes design, operational procedures, lifesaving, equipment, firefighting systems, human issues, ship safety and navigation. Our issue focuses on the safety of cruise ships that must meet the requirements of existing Safety Regulations and the possibility of mitigating future accidents. Cruise ship safety will imply design, operation, arrangement, and development in life-saving systems. Life-saving requirements based on the IMO convention and its derivative codes set out in the IMO LSA code compliance MSC Resolution 48 (66) 2019, each of which is a code point associated with each of the Life Saving Tools specified in the appendix. The design that we will design to be placed on a cruise ship with predetermined conditions.

2. Life Saving System Overview.

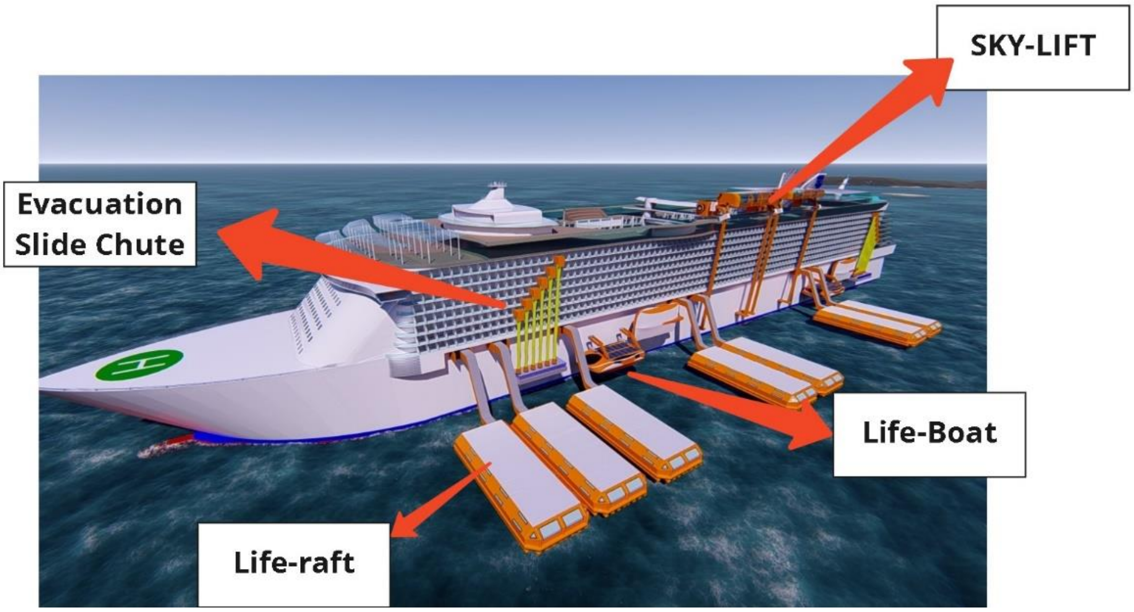


Figure 1. Layout Total Life Saving Application

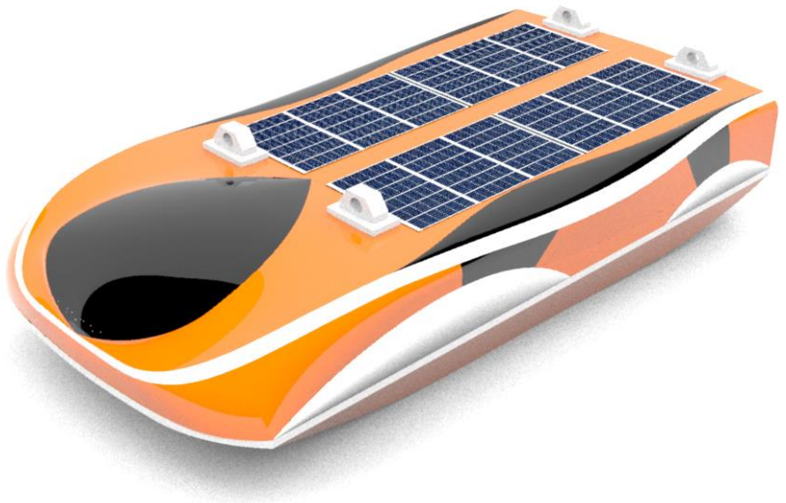
From the background and requirement for the safety and life-saving issue, we create the novel design with the reference ship with capacity 7000 person on-board, Tonnage 180000 GT and have life expectancy to 40 years. Our design of **Life Saving Appliances (LSA)** divided into 4 hardware and 1 software which are the hardware consist of **new lifeboat design**, **new life raft system**, **Sky Lift Evacuation System, Evacuation Chute.** And the software is **AISEM (Autonomous Intelligent Safety and Evacuation Management).** The look of the cruise ship with the LSA are shown in the figure 1.

B. New And Innovative Life-Boat Design

The life-boat design has sufficient specification and performance to fulfil the task and requirement of passenger and crews safely evacuation. The lifeboat is the new design of life saving appliances to answer the challenge from the mass passenger evacuation. The lifeboat can carry 533 persons, utilized with minimum space use, and powered with reliable and sustainable hybrid solar-diesel electric propulsion. With new concept of maximum capacity and high standard of equipment and outfitting, the lifeboat design will guarantee the ease of operation, reliable, maintainable, affordable installation and also eco-friendly technology in both existing or newbuild ship.

1. Shape and Dimension

Currently the largest Lifeboat is the CRV55 installed in the Oasis of the Seas (RINA) with a catamaran hull and has a capacity of 370 people. With a larger capacity, the evacuation of passengers will be faster. We suppose to know that LSA code 4.4.2.1 says that it is impossible for a lifeboat to have a capacity larger than 150 people. But with the agreement that Lifeboat has the same and even higher level of safety then it is allowed.



Length	20 m
Beam	10 m
Draft	1 m
Hight	3,9 m
Vs	10 knot
Capacity	533 p
Light Weight	62,8 ton

Figure 2. Lifeboat NWB01 and specification

We named this lifeboat design as **NWB01** and have the shape and dimensions below. We designed a lifeboat that is 2 times larger than the CRV55 so that the number of lifeboats can be reduced and in turn will reduce the crew handling in many lifeboat operations during evacuation. The design applies the monohull boat so that the lifeboat requirements are not too high because the ship requirements will affect the placement on the cruise ship that we are designing. The material used by this lifeboat was fiberglass because it had a lighter density but was still strong.

2. Layout and Feature

NWB01 has a very large evacuation capacity, there are 18 rows of seats on both sides and each row consists of 11 seats but at the front it only consists of 8 seats. While at the front as a navigation area which will be operated by the ship's crew.

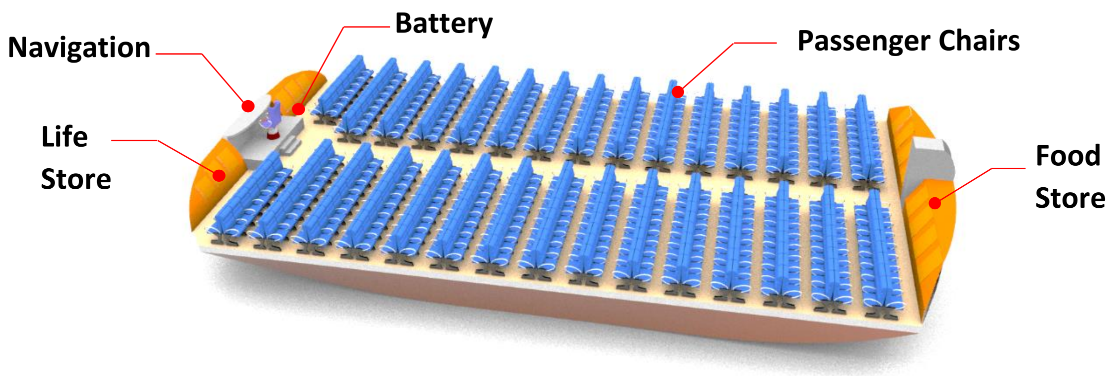


Figure 3. Interior Lifeboat NWB01

At the front there is a navigation area which is operated by the ship's crew. To ensure survival for passengers, they are given a life store to store safety needs such as flares and life jackets. While on the back it is useful for storing food to survive to supply the needs of all passengers.

3. Propulsion And Machinery System

The propulsion performance and power machinery will assure the NWB01 can survive and perform good evacuation in the sea passage. To make sure the machinery and power are sufficient for do high performance, the life boat is needed to do resistance simulation to determine the propulsion to be used in NWB01 using the Fung methods.

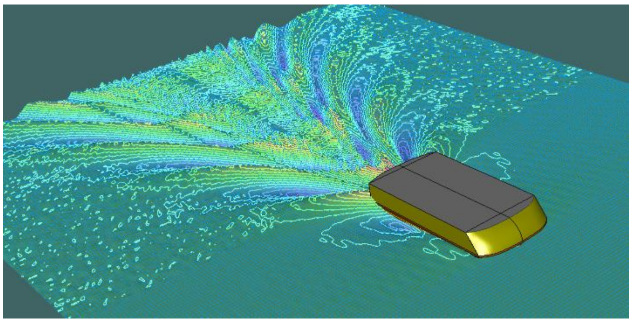


Figure 4. Resistance Lifeboat

From the calculation of the resistance, the minimum power requirement is obtained so that the machine to be used can be determined. Lifeboat is designed to be able to sail for 3 days so that fuel needs must be sufficient and the need for clean water must also be fulfilled.

Resistance	54,2 kN
BHP	557,48 kW
Engine	2 x 311 kW

Endurance	3 days
F.O Tank	12,6 ton
Water Tank	3,6 ton

Table 1. Power and tank Lifeboat

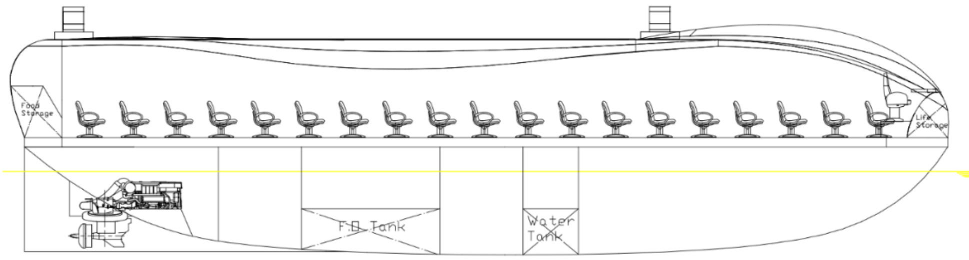


Figure 5. Machinery Lifeboat

The power source in the lifeboat is used to supply electrical equipment such as lighting, navigation lights, radar, GPS and reverse osmosis. The source of electricity used comes from solar panels that are placed on the top deck of Lifeboat. The summary of electrical supply machinery is shown the table below.

Total Power Electrical	12,52 kWh
AH Requiermnet	1210 AH
Baterry Capacity	14 x 90 Ah

Table 2. Power Battery Lifeboat

4. Sea Worthiness Test

a. Stability

Stability is the ship's ability to return to its original position after being subjected to external forces such as waves, wind or currents. The shape of the ship must have the ability to handle these resources or ensure the ship has good stability. *(Borg & Åkerblom, 2012).* Stability calculations are performed to determine the feasibility of a sailing ship. The stability of the lifeboat was calculated based on SOLAS II-1/8. Calculations are made in 3 conditions of load case.

From the three load cases, stability calculations were carried out so that the following result.

Code	Criteria	Value	Units	Loadcase 1	Loadcase 2	Loadcase 3	Status
SOLAS, II-1/8	8.2.3.3: Maximum residual GZ (method 1)						Pass
	8.2.3.3: Passenger crowding heeling arm	0,040	m	2,719	2,650	3,013	Pass
	8.2.3.3: Launching heeling moment	0,040	m	2,719	2,650	3,013	Pass
	8.2.3.3: Wind heeling arm	0,040	m	2,705	2,634	2,982	Pass
SOLAS, II-1/8	8.2.4.a Maximum GZ (intermediate stages)	0,050	m	2,719	2,650	3,013	Pass
SOLAS, II-1/8	8.2.4.b Range of positive stability (intermediate stages)	7,0	deg	101,7	98,7	104,1	Pass
SOLAS, II-1/8	8.6.3: Margin line immersion - GZ based (EquilAngle ratio)	100	%	0,04	0,03	0,01	Pass

Table 3. Result Comparison LoadCase

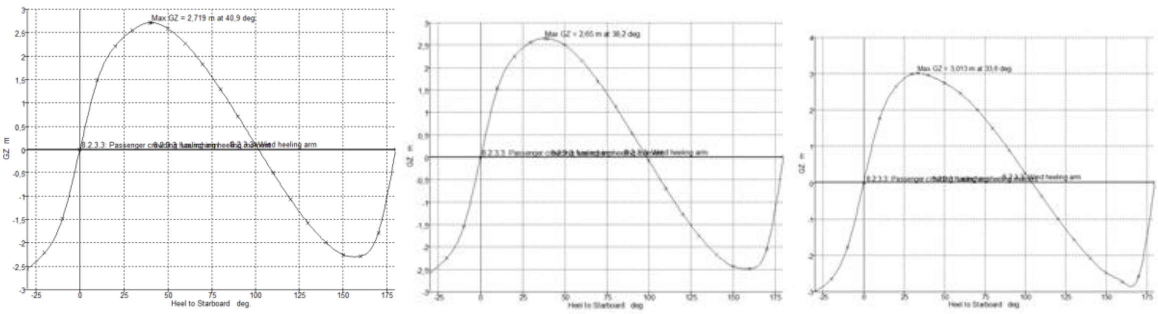


Figure 6. Loadcase 1(left), 2(centre), 3(right) GZ stability graph

The starboard lever curve is intended to show the ship's ability to withstand external tilt moments. The centre of gravity G can shift if there is a bright charge in it. The buoyancy is equal to the weight of the ship, but the direction of these forces is opposite. These two forces produce opposite moments, and the right-hand adjustment lever GZ is the lateral distance between the centre of gravity and the centre of buoyancy in the global coordinate system (Ruponen,2018).**Based on the calculation of stability, it is found that each condition has a safe value for seagoing based on the criteria SOLAS II-1/8 and the stability criteria for Lifeboat in IMO LSA Code.**

b. Seakeeping

This new design of lifeboat for cruise ship is aimed to achieve both high standard of survive and comfort when evacuation operation. In order to make sure Life-boat design operability will be survive in the harness condition of the parent ship sea area, the design is tested with motion and seakeeping simulation in the such sea condition (sea-state). In this paper, we done the test with numerical method based on ITTC seakeeping simulation with the help of software. The example below is one of the sea-state values in the average normal sea condition, which is Beaufort Sea-state 6 (Atzampos, G et al. 2019). The overall testing of sea-state motion are done from range sea-state 4 to sea-state 8 (most extreme condition).

Test on 10 knot Speed

Seastate	Wave heading			Wind Speed	Limit Check
	Head	Beam	Quarter		
4	0,557	0,205	0,087	16	Safe
5	0,926	0,342	0,144	21	Safe
6	1,295	0,478	0,202	27	Safe
7	1,665	0,615	0,26	33	Safe
8	2,036	0,751	0,318	40	Safe
9	3,701	1,366	0,578	47	Safe

Figure 7. Matrix Seakeeping Acceleration Motion Discomfort Result

The result proves that the design of this new concept is **fulfil the demand of sea survivability.** The ship metacentre in each motion (seakeeping) are not indicating the capsize measurement for seakeeping test on sea-state 4 (wave height 3 meter) to sea-state 8 (wave height 7 meter). In the normal ocean-going cruise sea condition (sea-state 6), the lifeboat give high self-righting and roll damping performance with 24,49 second period to stabilizing as shown in the figure. Not only the boat that will survive, the people in the boat also will survive in the matter of severe injury and discomfort as shown in the figure. The matrix shown the score of the discomfort level. Overall for testing Beaufort sea-state 4- Beaufort sea-state 8, the discomfort level are below the maximum discomfort passenger in evacuation scenario (J. M. Riola. 2006).

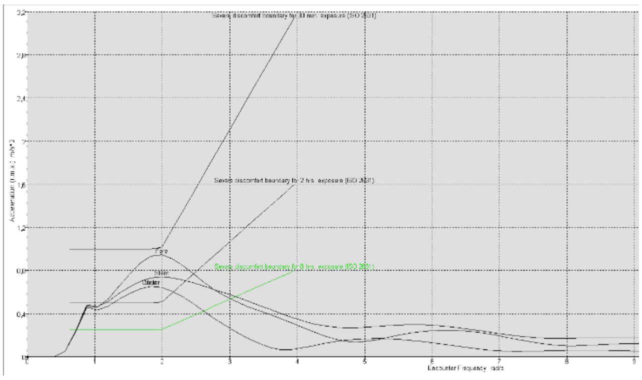


Figure 8. Sea state 6 MSI discomfort result example

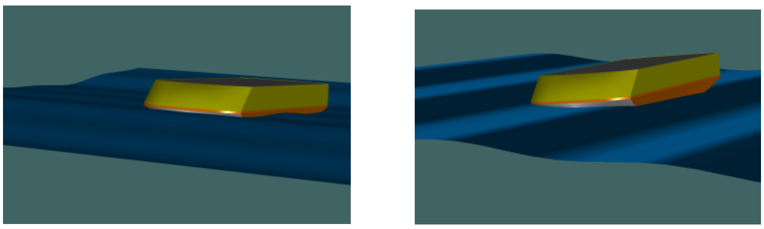
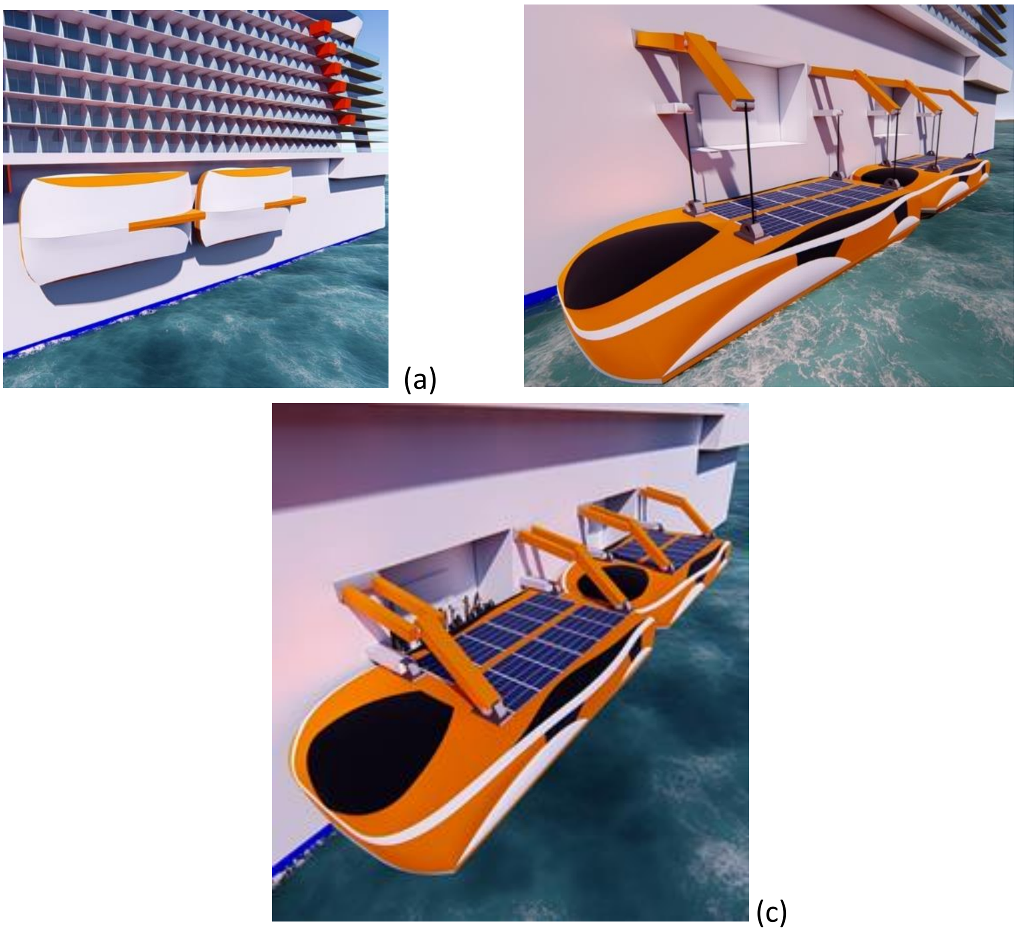


Figure 9. Seakeeping motion test on Life boat design

The view of life-boat seakeeping and motion seaworthiness testing meet the requirement of the standard which is based on the primary SOLAS chapter III and MSC 48(66) 2019, and also secondary standard on human survivability and comfort in the sea condition for example ISO 26311.

5. Operation and Release Mechanism

The lifeboat will be placed on the side of the ship the same as the existing lifeboat. However, the NWB01 placement is unique because it is positioned in a 90 degree rolling position so that it does not take up space for a large lifeboat. There are two types of lifeboat release mechanisms when loading and unloading. The mechanism to be used is like davit, which is tied to a wire or dropped using a hook attached to 4 pieces. By removing the hook, the lifeboats can be freed to move away from the ship (Ramachandran, 2011) :



(a) (b) (c)

Figure 10. Footprint lifeboat (a), davits crane (b), release lifeboat (c)

When the passengers were about to enter the lifeboat, the side doors were opened wide enough so that a large number of passengers could enter at once. This was done to speed up evacuation times as the lifeboats mostly only provided a door for one person to pass.

Figure 11. Demonstration Open Door

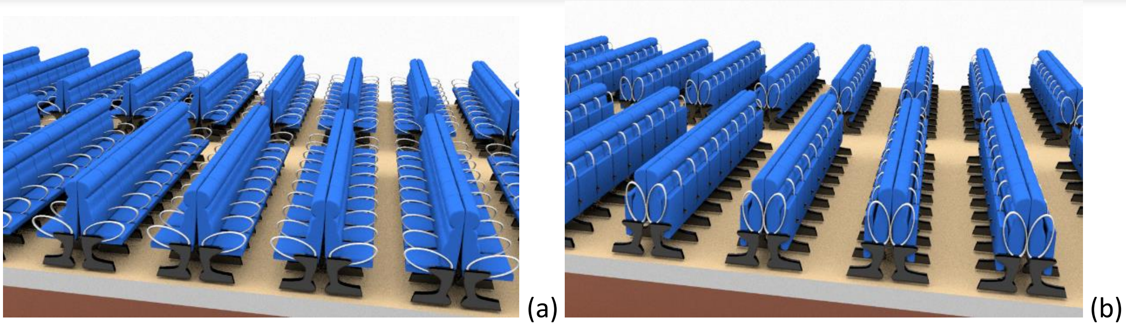


Figure 12. Open seat (a), fold seat(d)

By implementing a door that can be folded so that each area in the lifeboat can be maximally utilized and when the seats are folded, the area will be used as a passenger entry point so that if there are a total of 10 roads and range between seat is 0.8 m.

6. Survivability

a. Food and Medicine Stock

The lifeboat as required by the IMO MSC LSA CODE, supposed to have stock of food 10000 kJ and 1.5 liter fresh water at least for each person and 0,5 liter water from reverse osmosis. There for this design also include the amount of food and drink excessing the requirement.

The food and drink in the lifeboat design are 200unit self-contained military grade compact Meal, Ready-to-eat (MRE) for each 533 person which contain 2600Kcal per person, for supply 2 months at sea and the food can be last for 5 years. And the detail on the appendix.

b. Sea harness live support and search-and-rescue features

The lifeboat as required by the IMO MSC LSA CODE, suppose to equipped with SAR (Search and Rescue) equipment. Beyond that, the problem In the existing LSA is the minimum safety or secure feature. Therefore, this lifeboat design is equipped with sufficient sea harness live support and SAR feature.

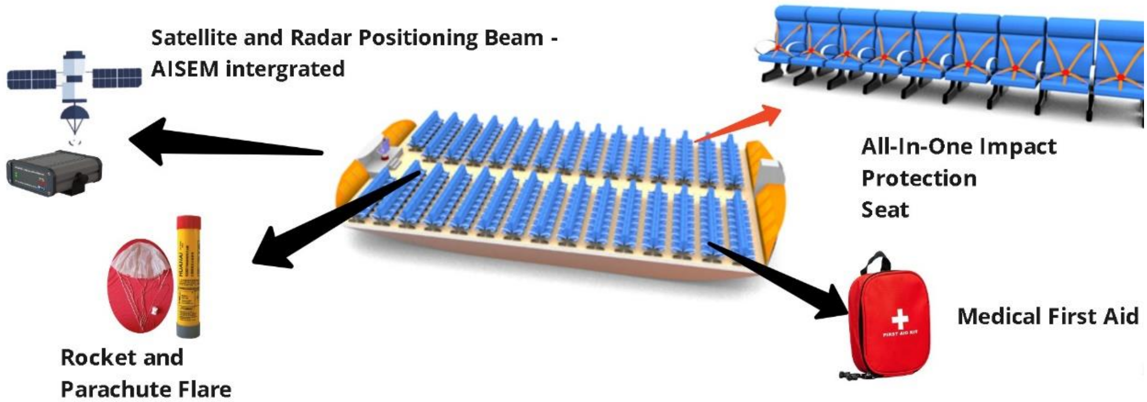


Figure 13. Fire and Safety Plan of NWB01

c. Compact Inflatable Life-raft Design

The compact Inflatable life-raft is a new technology in marine safety that we offer. We are designed life-raft, named "NW-LR1", with target 700 persons to ensure that all cruise ship passengers can be effectively rescue in safe place.

1. Shape and Dimension

"NW-LR1" life-raft has main principal dimension with length 33 m, Beam 1.4 m, and Height 3.45 m. The life-raft consists 5 main part, that are Bellow Longitudinal Float Surface, Upper Float Surface, Platform Surface, Inflatable transversal Frame, and Inflatable Longitudinal Frame.

Based at calculation for each main part, the total air volume that could be filled in the life-raft is 740 m3 with 2 psi dan total weight for this design is 12,6 ton.

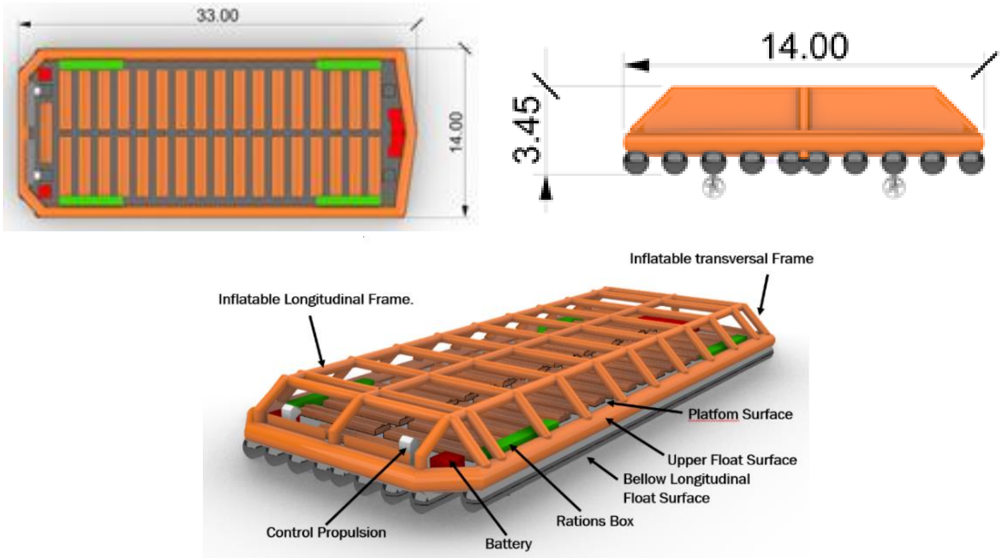


Figure 14. Dimension and Specification Life-raft "NW-LR1"

2. Features and Layout.

In life-raft layout and feature, "NW-LR1" life-raft has capability for carrying 700 persons. Due to fast time evacuation, the life-raft will be connected with Inflatable Evacuation Chute, which is attached in ship's deck, in after part of life-raft.

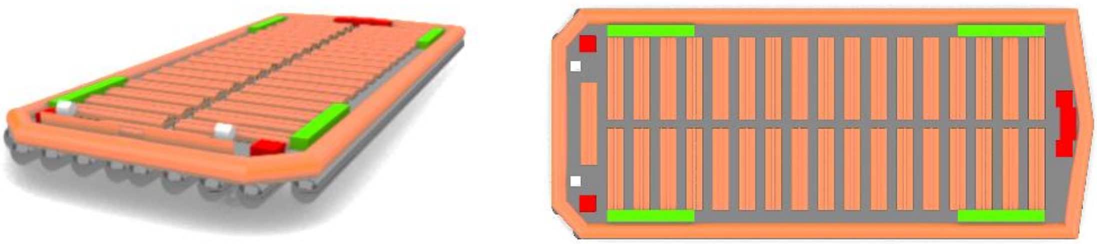


Figure 15. Life-raft "NW-LR1"

3. Seaworthiness

In seaworthiness performance, the life-raft is used material PVC for its skin. The electric self-propulsion motors with battery is also attached at life-raft to support life-raft stability and surge motion. The electric propulsion battery is designed to be active for 8 hours.

Figure 15. Propulsion of Life-raft "NW-LR1"

4. Operability and Release Method.

In this design, life-raft is used to Release with Auto-inflatable system and Hydrostatic Release Unit (HRU) system. Auto-inflatable system is an automatic mechanism in life-raft which is used automatically to expand life-raft body or part. Hydrostatic Release Unit (HRU) also use based on SOLAS 74. HRU will active under the pressure of water when it sinks below 4 m of water level. After the life raft is released there is a hose that connects the ship to the life raft so that passengers can jump into it.

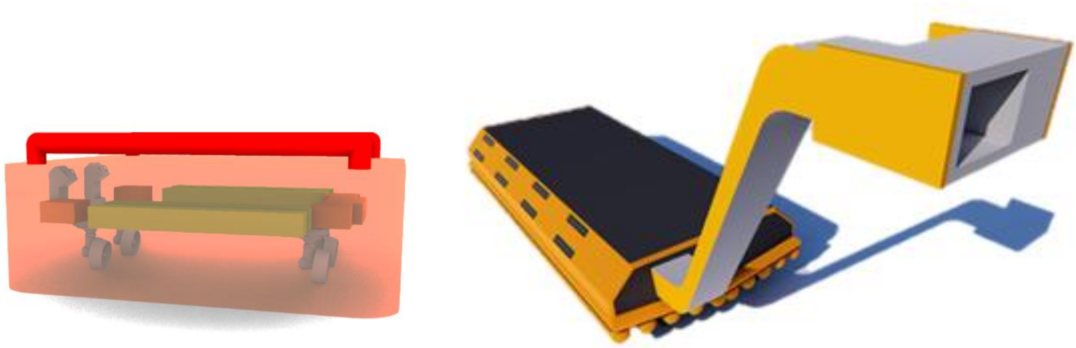


Figure 16. Release System "NW-LR1"

5. Survivability

In Survivability, based on IMO MSC LSA CODE about survival at Sea, the life-raft is designed with food's stock at least 10000 KJ and 1.5 l fresh water for each person (Life-raft Capacity number is 700 persons) in 30 days.

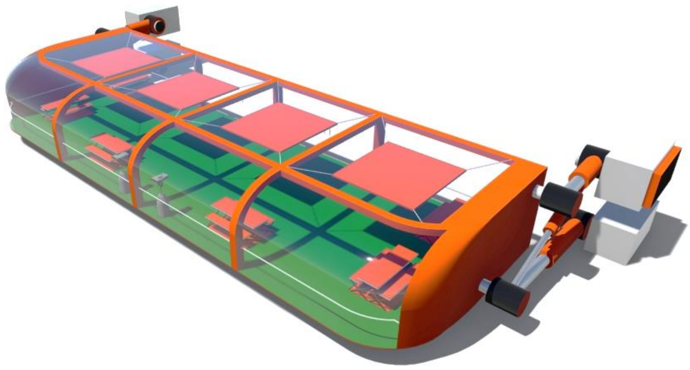
D. SKY LIFT (High-tech futuristic attraction and evacuation platform elevator)

The new and innovative not only for safe evacuation system, but also as high-class, futuristic and attractive value-added feature for future cruise ship Vertical platform elevator is the passenger movement and escape between the higher deck level to lower deck level using movable platform with securing bench to avoid escape disturb in ship listing condition. This technology can be functioned both for normal and emergency situations.

In the normal situation, this technology will give more hi-tech impression and entertaining value to the passenger. In the emergency situation, as the initial purpose in the design, this technology will give safe and faster escape way especially for infant people. With secured people seating and standing to avoid fall or accident during quick evacuation in any ship listing condition. Powered by independent hydraulic lifting gear for operation in emergency situation and air suspension for quick evacuation.

1. Dimension And Installation

The "sky lift" will be located at the top of the ship which can go down in an emergency as a lift and transport passengers from each deck to the lower deck. This equipment is given a rail that will be useful as a way up and down.



Length	24	m
Width	8	m
Height	3.2	m
Capacity	530	persons
Light Weight	60	tons
SWL	60	tons

Figure 17. SKY LIFT and specification

2. Evacuation and Emergency Feature

The Sky Lift can carry 530 people with a safe workload of up to 60 tons in an emergency. To reduce vibrations when doing a quick evacuation, this lift has 3 pairs of suspensions on both sides. chairs and tables in Sky Lift can be hidden during emergency conditions and replaced with handrails.

3. Normal Use and Tourist Attraction

In normal function, SKI LIFT can be used as an entertainment place or restaurant because it has a large area. Meanwhile, if an emergency comes, this function can be converted into an elevator to lower passengers on the upper deck.

E. Inflatable Evacuation Chute

Vertical Emergency Escape Chute is the emergency crew and passenger escape from the higher deck level to lower deck level in a instant way. This technology is a new innovation in cut the evacuation time for high rises superstructure ship.. This technology doesn't require power or either operator. Completed with self-adjuster vertical support and protected thick cover to give quick evacuation way in every ship emergency condition. The material and the design is to avoid and prevent fire spread.

1. Arrangement and Dimension

The chute has a inlet diameter of 600mm with varying lengths depending on the placement. Chute will be placed per deck with a total of 4 pieces on the front and back. The placement is only on the upper deck and if the deck is not too high then people can use the emergency stairs to get to the gathering point.

2. Operation Method

One way of vertical rescue is to use a chute. this method does not use electricity and has a simple way of working, just by sliding through the chute, people can get down to the muster point quickly. This chute has a support system for landing passengers during evacuation by opening the landing ramp platfor. To activate the chute is very easy, just drop the hose of the chute, the chute is ready to use.

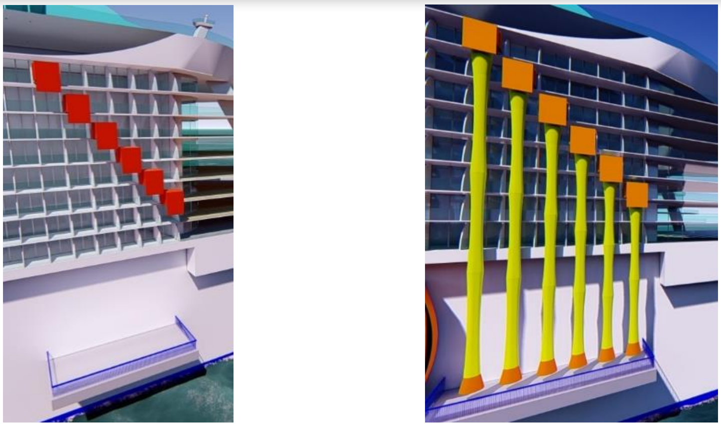


Figure 18. Release System for Chute

3. Safety and Protection

This hose chute has 3 layers, the first is the outer layer which is fire resistant, then the middle layer has a very flexible layer and the last layer is the core layer which is a support layer made with aramid fabric.

F. AISEM (Autonomous Intelligent Safety and Evacuation Management)

An innovative and smart system to help the crew and passenger in manage life-saving condition, with the help of artificial intelligent integrate data between hazard Identification sensor and ship real-time condition, to reduce human sense of panic and uncontrolled evacuation, and also give real-time coordination with ship voyage condition and alarm network.

1. Framework Overview and Operation

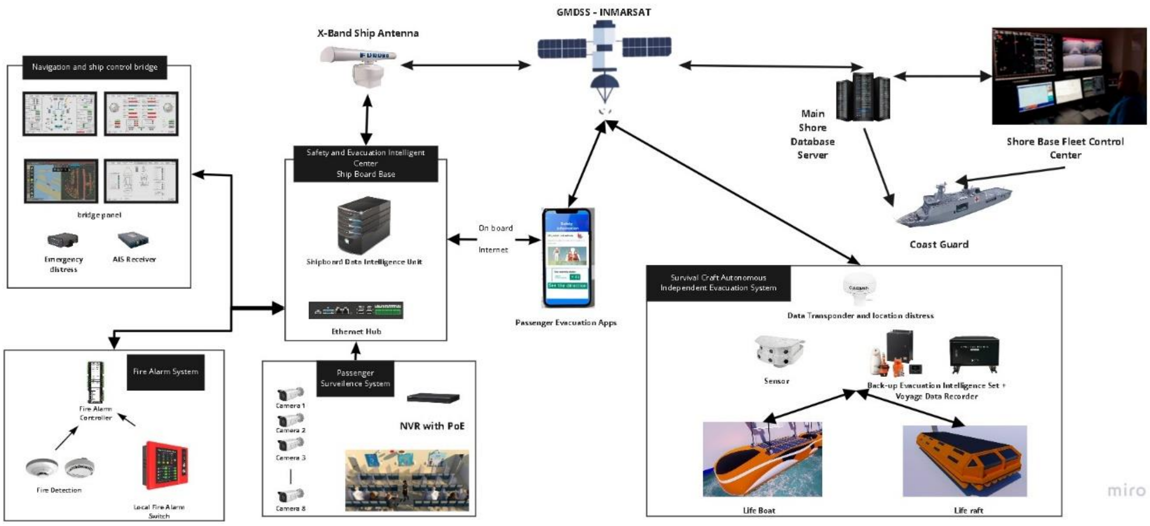


Figure 19. Framework Overview and Operation

This framework describes the description of the operation of the autonomous intelligent safety and evacuation management system. This autonomous system works if there is an abnormal reaction on the sensors and indicators on the ship, such as fire detectors, flood detectors, motion detectors.

The abnormality will be conveyed automatically to the navigation and ships control bridge as well as to the safety and evacuation intelligent centre in shipboard data base. Besides that, the safety and evacuation intelligent centre in shipboard data base also receives data from surveillance cameras that are scattered on the ship.

After receiving abnormal information from the sensor, the safety and evacuation intelligent centre will automatically forward the information to the x-band ships antenna and to the passenger evacuation apps. so that emergency information can be received by GMDSS - IMARSAT and passenger evacuation apps. After the emergency information is conveyed, the emergency preparation system will automatically activate to prepare the lifeboats, sky lifts, life raft and landing ramp platforms.

In addition, GMDSS - IMARSAT can also deliver emergency information to the main shore data base centre in the event of a ship hijacking, which is then conveyed to the maritime security authorities.

2. Survival Smart Life Jacket

All in one survival smart life jacket with artificial evacuation assistance, IOT life monitoring, Personal Positioning Beam, long lasting hight density food, anti-dehydrating water bag, airbag, and PC Material Thermal Keeper.

Figure 20. Smart Life Jacket

3. Safety bracelet and Evacuation Assistance in Passenger Apps

This system consists of 2 pieces of equipment, the first is a safety bracelet that is given to passengers when they enter a cruise ship. the safety bracelet serves to make it easier for officers in data collection to evacuate and also to make it easier for officers to track passengers when in an emergency. In addition, this bracelet can provide alarms in case of emergency so that passengers can respond to self-rescue.

The second is a mobile app-based system that can be downloaded and accessed with a passenger code. the system can function as a passenger guide when in an emergency. This app can display a map of the ship, provide emergency information and the location of the incident, the location of clinics and hospitals, emergency routes, buoys, hydrants, fire extinguishers, muster points and options that can be selected when in an emergency.

4. Shore Base Real-time Hazard and Safety Monitoring

This System functions is monitor the condition of the cruise ship from the shore base in real time condition, so that if an emergency occurs on the ship, the information on the situation can be informed quickly. it can help in the evacuation process.

G. Evacuation Procedure Analysis

1. Total Life Application at Ship

All LSAs installed on board must be able to evacuate passengers and crew of 7000 people. So, it is necessary to determine the amount of LSA from the design we made.

Name	Capacity	Number	Total
Life boat NWB01	533	4	2132
Liferaft NW-LR1	700	7	4900
Total number of people			7032

Table 4. Number of LSA

The arrangement of the number of LSAs as above has met the minimum requirements of passengers.

2. Determine the function each Life Application

Name	Priority
SKY-LIFT	Because the lift is used to evaluate every second and its limited capacity, this equipment is prioritized for parents who have difficulty using stairs, children, mothers, and people with disabilities
Chute	This equipment is used for adolescents and adults who are still in prime condition. This is due to the high enough altitude that passengers have to face so they have to have a strong physique and the courage to use the chute.
Emergency Stair	Apart from using a chute which requires time in line to be used, other passengers who are in good physical condition can use the emergency stairs
Life boat NWB01	Life boats are quicker to carry and more comfortable to use. so that it is prioritized for children, mothers, and people with disabilities. After that, if the capacity is still sufficient to be added, it can be added with others.
Liferaft NW-LR1	With a lower level of safety, the rest of the passengers and crew who do not use the boat can be directed to the liferaft.

Table 5. Function Life Application

Information about the use of the LSA is very important because it will help the crew in managing the panic that occurs on the ship. There are many passengers from various types of groups, including adults, women, children and the elderly, That are not given the same treatment as each other.

3. Evacuation Procedure

Evacuation will be carried out if the danger siren has been activated where passengers can also see through the **app** where the danger lies on the ship. The ship's crew will direct passengers to the master points of each deck. The Muster Point of each deck consists of the sky lift mustard points, the front and back emergency chutes. In addition, the crew will also direct other passengers to use emergency stairs to speed up the evacuation. After arriving in front of lifeboat, passengers are directed to enter in an orderly and orderly manner. The same is done when going to the life raft.

4. Evacuation Analysis

From the time calculation, we conclude that the faster scenario is **scenario 2 that** is using **new design** chute, sky lift and life raft for **18,185 minutes total evacuation time,** which is **12,68 Second Lower** than the maximum evacuation time in SOLAS Chapter III Regulation 21.1.4, 30 minutes. The detail calculation can be seen in the **appendix E**

Description	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
Max Walk Time	83,3	s	83,3	s	83,3	s	83,3	s
Max Chute/Stairs/Lift time	9000	s	208,3333	s	208,3333	s	1875	s
Max Lifeboat/Liferaft time	816,6667	s	799,5	s	1050	s	1050	s
Max Evacuation Time	9899,967	s	1091,133	s	1341,633	s	3008,3	s
Total Time	**165,00**	minutes	**18,18556**	minutes	**22,36056**	minutes	**50,13833**	minutes

Table 6. Evacuation Time

H. Life Expectancy and Maintenance Plan

The Overall Design of Life Saving Appliances System are aligned and engineered to at least as long as economically and same as the parent ship age. The list of each appliances lifetime and maintenance plan are explained on the table.

Life Saving Appliances	Lifespan	Maintenance Period	Description
Lifeboat (NWB01)	40 years	5 year, if follow the class renewal survey	The lifeboat structural lifetime is designed as long as the ship lifetime. But, there is require periodically inspection and maintenance to the supporting equipment such as food and Flare.
Life raft (NW-LR1)	25 years	30-60 month, depend on intermediate and class renewal survey	The material of the life raft using high durable and fire proof material that can guarantee mentioned lifespan.

Table 7. Maintenance plan

K. Conclusion

The LSA design we have proposed has advantages over the existing LSA. Lifeboat has a larger size up to 533 passengers and has a different quality and is more effective. While the life raft can hold 700 passengers plus 4 additional propulsion. There are equipment that speeds up the evacuation process, including the SKYLIFT and Chute. Sky lift is operated like an elevator to pick up passengers on each deck, while the chute is used as an escape route on the upper deck. The time needed to evacuate is also fast at less than an hour.

L. Reference

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APPENDIX A

REQUIREMENTS AND BACKGROUND OF LSA

The life-saving requirement based on the IMO convention and its derivative codes that are regulating in the IMO LSA code Resolution MSC 48(66) 2019 compliance. The sum of each codes for each appliance are shown in the table below.

General	Proper materials, not be damaged in stowage throughout the air temperature range -30°C to +65°C,
	be rot-proof, corrosion-resistant, and not be unduly affected by seawater, oil or fungal attack
	Colorized with international or vivid reddish orange, or a comparably highly visible colour on all parts where this will assist detection at sea, and retro-reflective material where it will assist in detection
	provided with electrical short circuit protection to prevent damage or injur
Personal Life saving appliances	**Lifebuoys**; Lifebuoy self-igniting lights; Lifebuoy self-activating smoke signals
	Lifejackets ; inflate automatically upon immersion, be provided with a device to permit inflation by a single manual motion and be capable of having each chamber inflated by mouth; have a luminous intensity of not less than 0.75 cd in all directions of the upper hemisphere.
	Immersion suits
	Anti-exposure suits; A person in fresh water wearing an anti-exposure suits complying with the requirements of this section shall be able to turn from a face-down to a face-up position in not more than 5 s and shall be stable face-up.
Survival Craft	**Life raft**; capable of withstanding exposure for 30 days afloat in all sea conditions.; Operation survival after dropped in 18 meter height minimum; enable it to be towed at a speed of 3 knots in calm water; be capable of withstanding a lateral impact against the ship’s side at an impact velocity of not less than 3.5 m/s; equipped with two buoyant paddles, e first-aid outfit, four rocket parachute flares, six hand flares, efficient radar reflector,

	food store not less than 10,000 kJ (2,400 kcal) for each person, 1.5 l of fresh water for each person, and thermal protective aids; The stability of the liferaft when in the inverted position shall be such that it can be righted in a seaway and in calm water by one person
	Lifeboat; The lifeboat should be constructed to have ample stability in a seaway and sufficient freeboard when loaded with their full complement of persons and equipment, and are capable of being safely launched under all conditions of trim of up to 10° and list of up to 20° either way; The vertical distance (interior height) should be 1.7m minimum; Every passenger ship lifeboat shall be so arranged that it can be boarded by its full complement of persons in not more than 10 min from the time the instruction to board is given. All lifeboats shall be stable and have a positive GM value when loaded with 50% or the number of persons the lifeboat is permitted to accommodate in their normal positions to one side of the centreline; The engine shall be provided with either a manual starting system, or a power starting system with two independent rechargeable energy sources; All lifeboats shall be provided with a rudder and tiller; . Lifeboats which are not self-righting when capsized shall have suitable handholds on the underside of the hull to enable persons to cling to the lifeboat; . Each free-fall lifeboat shall be so constructed as to ensure that the lifeboat is capable of rendering protection against harmful accelerations (3,5 m/s).
Launching and Embarkation Appliances	The passage of the **marine evacuation system** shall marine evacuation system shall provide for safe des provide for safe descent of persons of various ages, sizes cent of persons of various ages, sizes and physical capabilities wearing approved lifejackets from the embarkation station to the floating platform or survival craft
General emergency alarm system	**general emergency alarm system** shall be capable of sounding the general emergency alarm signal consisting of seven or more short blasts followed by one long blast on the ship's whistle or siren and additionally on an electrically operated bell or klaxon.

APPENDIX B

PARENT CRUISE SHIP INFORMATION

Length	340	**M (LOA)**
Tonnage	180000	GT
Capacity	5000	Passengers
	2000	Crew
Operation	Global	

APPENDIX C

Lifeboat

1. Light Weight Lifeboat

a. Frame

Frame	Area (m2)
st 1	2,918
st 2	3,307
st 3	3,38
st 4	3,43
st 5	3,469
st 6	3,497
st 7	3,517
st 8	3,53
st 9	3,536
st 10	3,538
st 11	3,539
st 12	3,54
st 12	3,54
st 13	3,541
st 14	3,542
st 15	3,542
st 16	3,543
st 17	3,543

Frame	Area (m2)
st 18	3,543
st 19	3,543
st 20	3,54
st 21	3,535
st 22	3,528
st 23	3,517
st 24	3,503
st 25	3,485
st 26	3,463
st 27	3,439
st 28	3,416
st 29	3,395
st 30	3,37
st 31	3,34
st 32	2,908
st 33	1,99
Total	115,967

Density of fiberglass	1230 kg/m3
thickness frame	0,05 m
Weight Construction	7131,9705 kg
	7,1319705 ton

b. Plat Needed

Plat 1	176,305	352,61
Plat 2	49,409	98,818
Plat 3	10,645	21,29
Plat 4	10,213	20,426
Plat 5	35,711	71,422
	Total	564,566 m2

Density of fiberglass	1230 kg/m3
thickness frame	0,045 m
Weight Construction	31248,728 kg
	31,248728 ton

c. Light Weight

Plat + Frame = 38,380699 ton

c. Electricity needs

equipment name	number	weight (kg/Unit)	Total(kg)
Panel Surya	68	12	816
Baterai	14	175	2450
Inverter	1	60	60
MPPT solar charger	5	40	200
Panel Bus	3	80	240
Main Switch Board	1	150	150
Jumlah			3916

equipment name	Total (Ton)
electrical equipment (Set)	3,916
Navigation and communication (Set)	1
Total	4,916

d. Seats

533 x	20 kg	=	10660	kg
			10,66	ton

e. Machinery Installation

1. Hull Resistance

Speed (knot)	Fung Resist. (kN)	Power (kW)	eff
10	54,2	557,46	50%

2. Main Engine

Merk/Tipe	Volvo Penta D6-IPS600		
Power	311	kW	622
Weight	920	kg	
Total	2	unit	
Total Engine	1,84	ton	

3. Aux, Engine

Merk/Tipe	Baterai	
Weight	12,5	kg
Total	11	unit
Total Battery	0,1375	ton

d Total Weight Aux. Engine

W mt = 1,9775 ton

Spare weight

Wres = 0,098875 ton

LWT = WST + WE&O + WM

LWT = 62,8783604 ton

2. Payload

Information	Total
Kru	1
Passenger	532
Total	533
Weight per person	100
Total (kg)	53300
Total (ton)	53,3

3. Consumable Tank

Fuel Requirements

Weight Fuel Oil Main Engine

WFO = BHPME .SFOC .Endurance . 10-6 (Ton)

Where BHPME = BHP Of Main Engine (kW)

SFOC = Specific Fuel Oil Consuption

Endurance = 3 Days (Maximum endurance)

So,	BHPME =	311	kW	
	FOC =	87830	g/h	
	WFO =	12,65	Ton	at 2 engine

Fresh Water Needs

Total Person	=	600	persons
Needs a drink	=	2	ltr/persons/days
Endurance	=	3	days
Total Freshwater Needs	=	3600	liter
	=	3,6	m3
Weight Freshwater	=	3,6	ton

4. Total Displacement

Payload	53,3 Ton
LWT	62,88 Ton
DWT	16,24758607 Ton
Total Weight	132,426 ton

5. Stability Lifeboat

Loadcase - Loadcase 1

Damage Case - Intact

Free to Trim

Specific gravity = 1,025; (Density = 1,025 tonne/m^3)

Fluid analysis method: Use corrected VCG

Item Name	**Quantity**	**Unit Mass tonne**	**Total Mass tonne**	**Unit Volume m^3**	**Total Volume m^3**	**Long. Arm m**	**Trans. Arm m**	**Vert. Arm m**	**Total FSM tonne.m**	**FSM Type**
Construction	1	38,100	38,100			9,538	0,000	1,300	0,000	User Specified
Persons	533	0,080	42,640			9,500	0,000	2,200	0,000	User Specified
F.O	100%	15,381	15,381	16,288	16,288	7,532	0,000	0,601	0,000	Maximum
Engine	2	1,000	2,000			5,000	0,000	0,800	0,000	User Specified
F.W	100%	4,391	4,391	4,391	4,391	11,399	0,000	0,541	0,000	Maximum
Electric	1	5,000	5,000			17,000	0,000	2,000	0,000	User Specified
Safety Equipment	1	1,000	1,000			2,000	0,000	2,000	0,000	User Specified
Seats	533	0,020	10,660			9,500	0,000	2,200	0,000	User Specified
Total Loadcase			119,172	20,679	20,679	9,504	0,000	1,611	0,000	
FS correction								0,000		
VCG fluid								1,611		

Loadcase - Loadcase 2

Damage Case - Intact

Free to Trim

Specific gravity = 1,025; (Density = 1,025 tonne/m^3)

Fluid analysis method: Use corrected VCG

Item Name	**Quantity**	**Unit Mass tonne**	**Total Mass tonne**	**Unit Volume m^3**	**Total Volume m^3**	**Long. Arm m**	**Trans. Arm m**	**Vert. Arm m**	**Total FSM tonne.m**	**FSM Type**

Construction	1	38,100	38,100			9,538	0,000	1,300	0,000	User Specified
Persons	0%	15,381	0,000	16,288	0,000	7,500	0,000	0,000	0,000	Maximum
F.O	0%	4,391	0,000	4,391	0,000	11,207	0,000	0,000	0,000	Maximum
Engine	533	0,080	42,640			9,500	0,000	2,200	0,000	User Specified
F.W	2	1,000	2,000			5,000	0,000	0,800	0,000	User Specified
Electric	1	5,000	5,000			17,000	0,000	2,000	0,000	User Specified
Safety Equipment	1	1,000	1,000			0,000	0,000	0,000	0,000	User Specified
Seats	533	0,020	10,660			9,500	0,000	2,200	0,000	User Specified
Total Loadcase			99,400	20,679	0,000	9,706	0,000	1,795	0,000	
FS correction								0,000		
VCG fluid								1,795		

Loadcase - Loadcase 3
Damage Case - Intact
Free to Trim
Specific gravity = 1,025; (Density = 1,025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	**Quantity**	**Unit Mass tonne**	**Total Mass tonne**	**Unit Volume m^3**	**Total Volume m^3**	**Long. Arm m**	**Trans. Arm m**	**Vert. Arm m**	**Total FSM tonne. m**	**FSM Type**
Konstruksi	1	38,100	38,100			9,538	0,000	1,300	0,000	User Specified
FO	0%	15,381	0,000	16,288	0,000	7,500	0,000	0,000	0,000	Maximum
FW	0%	4,391	0,000	4,391	0,000	11,207	0,000	0,000	0,000	Maximum
Orang	0	0,080	0,000			9,500	0,000	2,200	0,000	User Specified
Mesin	2	1,000	2,000			5,000	0,000	0,800	0,000	User Specified
listrik	1	5,000	5,000			17,000	0,000	2,000	0,000	User Specified
Peralatan keselamatan	1	1,000	1,000			0,000	0,000	0,000	0,000	User Specified
Kursi	533	0,020	10,660			9,500	0,000	2,200	0,000	User Specified

Total Loadcase			56,760	20,679	0,000	9,860	0,000	1,490	0,000	
FS correction								0,000		
VCG fluid								1,490		

APPENDIX C

Life raft

1. Life-Raft Material Weight

Total Weight of material Life-raft			
Density of Air	=	1.225	kg/m^3
Volume Life-raft	=	740.00	m3
Material Weight	=	Density x Volume	kg
	=	1.225 x 740	kg
	=	906.50	kg
	=	0.91	ton

2. Life-Raft Volume

Volume Liferaft		
Part	**Total**	**Total Volume (m3)**
Bellow Float Sufrace	10	259.05
Upper Float Surface	1	68.00
Platform	1	372.00
Inflatable transversal Frar	11	34.87
Inflatable Longitudinal	3	6.08
Total		740.00

3. Life-Raft Weight

Total Weight of Life-raft			
Equipment	Unit	Unit - Weight (ton)	Total (Ton)
Emergency Food Rations 10000 Kj - 0.5 gram	2100	0.0000005	0.00105
Propulsion 100 HP / 75 kW - 17	4	2	8.00
Battery 12V 2000AH	50	0.05	2.50
Propulsion Control	2	0.05	0.10
Material	1	0.91	0.91
Total			11.51
Space for another Equipment (Epirb, Whistle, Anchor, ect) 10%			12.66

APPENDIX D

Chute and Skylift

1. Life-Raft Material Weight

Total Weight of material Life-raft			
Density of Air	=	1.225	kg/m^3
Volume Life-raft	=	740.00	m3
Material Weight	=	Density x Volume	kg
	=	1.225 x 740	kg
	=	906.50	kg
	=	0.91	ton

2. Life-Raft Volume

Volume Liferaft		
Part	**Total**	**Total Volume (m3)**
Bellow Float Sufrace	10	259.05
Upper Float Surface	1	68.00
Platform	1	372.00
Inflatable transversal Frar	11	34.87
Inflatable Longitudinal	3	6.08
Total		740.00

APPENDIX E

Evacuation Analysis

1. Evacuation Time

One side Evacuation Analysis (Starboard side example) Scenario 1										
Number of deck	2x *SKY LIFT*		4 x *chute*		4 x *chute*		Stairs		Stairs	
	person	time (s)	person	time (s)	person	time (s)	person	time (s)	person	time (s)
Deck 1							500	1875	500	1875
Deck 2							500	1875	500	1875
Deck 3										
Deck 4-5										
Deck 6							300	9000	300	9000
Deck 7							300	12000	300	12000
Deck 8							300	15000	300	15000
Deck 9							300	18000	300	18000
Deck 10							300	21000	300	21000
Deck 11							250	17500	250	17500
Deck 12							250	17500	250	17500
Deck 14							250	17500	250	17500
Deck 15-16										
Deck 17							25	1750	25	1750
Deck 18							25	1750	25	

One side Evacuation Analysis (Starboard side example) Scenario 2										
Number of deck	2x *SKY LIFT*		4 x *chute*		4 x *chute*		Stairs		Stairs	
	person	time (s)	person	time (s)	person	time (s)	person	time (s)	person	time (s)
Deck 1							500	1875	500	1875
Deck 2							500	1875	500	1875
Deck 3										
Deck 4-5										
Deck 6	50	41,6667	275	206,25	275	206,25				
Deck 7	50	41,6667	275	206,25	275	206,25				
Deck 8	50	41,6667	275	206,25	275	206,25				
Deck 9	80	66,6667	275	206,25	275	206,25				
Deck 10	120	100	275	206,25	275	206,25				
Deck 11	200	166,667	150	112,5	150	112,5				
Deck 12	230	191,7	135	101,25	135	101,25				
Deck 14	250	208,3	125	93,75	125	93,75				
Deck 15-16										
Deck 17	50	41,7								
Deck 18	50	41,7								

One side Evacuation Analysis (Starboard side example) Scenario 3										
Number of deck	2x *SKY LIFT*		4 x *chute*		4 x *chute*		Stairs		Stairs	
	person	time (s)	person	time (s)	person	time (s)	person	time (s)	person	time (s)
Deck 1							500	1875	500	1875
Deck 2							500	1875	500	1875
Deck 3										
Deck 4-5										
Deck 6	50	41,6667	275	206,25	275	206,25				
Deck 7	50	41,6667	275	206,25	275	206,25				
Deck 8	50	41,6667	275	206,25	275	206,25				
Deck 9	80	66,6667	275	206,25	275	206,25				
Deck 10	120	100	275	206,25	275	206,25				
Deck 11	200	166,667	150	112,5	150	112,5				
Deck 12	230	191,7	135	101,25	135	101,25				
Deck 14	250	208,3	125	93,75	125	93,75				
Deck 15-16										
Deck 17	50	41,7								
Deck 18	50	41,7								

One side Evacuation Way (Starboard side example) Scenario 4										
Number of deck	lift		chute		chute		tangga		tangga	
	person	time (s)	person	time (s)	person	time (s)	person	time (s)	person	time (s)
Deck 1							500	1875	500	1875
Deck 2							500	1875	500	1875
Deck 3										
Deck 4-5										
Deck 6		0	265	795	265	795	35	1050	35	1050
Deck 7	50	41,6667	260	780	260	780	15	600	15	600
Deck 8	50	41,6667	250	750	250	750	15	750	15	750
Deck 9	80	66,6667	245	980	245	980	15	900	15	900
Deck 10	120	100	225	1125	225	1125	15	1050	15	1050
Deck 11	200	166,667	140	840	140	840				
Deck 12	230	191,7	135	945	135	945				
Deck 14	250	208,3	125	1000	125	1000				
Deck 15-16										
Deck 17	50	41,7								
Deck 18	50	41,7								

Survival Craft Embarkation + Deployment Time	Conventional lifeboat		New liferaft		New lifeboat	
	person	time (s)	person	time (s)	person	time (s)
	150	816,667	700	1050	533	799,5

Description	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
Max Walk Time	83,3	s	83,3	s	83,3	s	83,3	s
Max Chute/Stairs/Lift time	9000	s	208,3333	s	208,3333	s	1875	s
Max Lifeboat/Liferaft time	816,6667	s	799,5	s	1050	s	1050	s
Max Evacuation Time	9899,967	s	1091,133	s	1341,633	s	3008,3	s
Total Time	**165,00**	minutes	**18,18556**	minutes	**22,36056**	minutes	**50,13833**	minutes

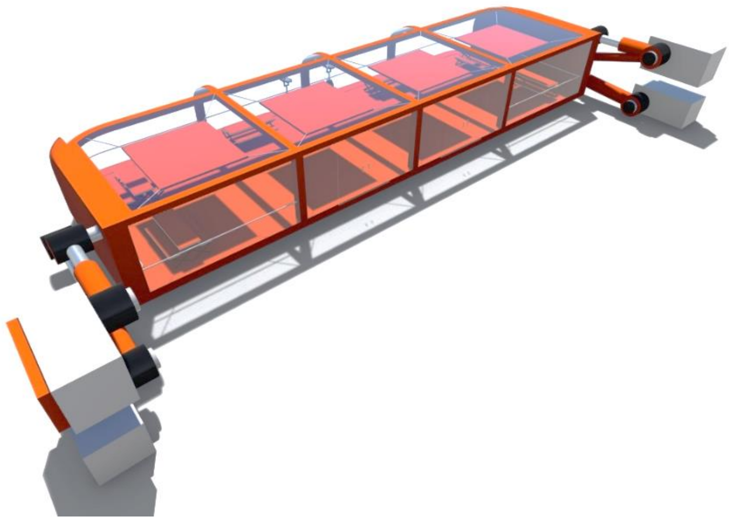
Scenario 1	Conventional (Existing)	Room > Stairs > Existing Lifeboat
Scenario 2	New Design 1	Room > Chute & Skylift > New Design Lifeboat
Scenario 3	New Design 1	Room > Chute & Skylift > New Design Liferaft
Scenario 4	All Possible	Room > Chute & Skylift & stairs > New Design Liferaft

From the time calculation, we conclude that the faster scenario is scenario 2 that is using chute, sky lift and life raft for **18,185 minutes total evacuation time**, which is **12,68 Second Lower** than the maximum evacuation time in SOLAS Chapter III Regulation 21.1.4, **30 minutes**

APPENDIX F

Sky Lift

1. Lift Design



APPENDIX G

Evacuation Chute

1. Chute Design