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Design of a Semi-Submersible Tourism Ship for Bunaken Underwater Recreation in Manado, Indonesia

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Abstract

With a rapid increase in various number of marine tourism destinations, especially in The Bunaken National Park with the amount of tourists that has increased throughout the year rising by 23% for domestic tourists and 12% for international tourists between 2002 and 2018. Unfortunately, to enjoy the underwater scenery of The Bunaken National Park can access by diving and snorkeling which is not all tourist can do that. Furthermore, in order to support the marine tourism industry in Indonesia, a semi-submersible tourism ship was developed with a glass at the hull's bottom based on the standard spiral design and the safety standard established by the rules so the tourists can easily enjoy the underwater ecosystem. The concept design of bottom-glass ship with trimaran hull type is offered as a problem-solving in this paper. The final design of the main dimensions are length of overall (*LOA*): 23,1 meters, width (*B*): 8 meters, Draft (*T*): 2.22 meters but the maximum submerged up to 2,5 meters, speed of 10 knots, and passenger capacity of 44 persons.

1. Introduction

Indonesia is the largest archipelagic country with 17,499 islands and a total size of 7.81 million km2. The overall area consists of 2.55 million km2 of land and 5.8 million km2 of ocean, stretches from Sabang to Merauke. The Indonesia territorial consist of water with two-thirds of Indonesia's total size, the government have been focused on developing the tourist sector, particularly maritime tourism as a main tourism sector in Indonesia. The maritime tourism has the potential to benefit the government, the general public, and the commercial sector, and it is expected to contribute to the economic sector's development. The underwater beauty of Bunaken National Park is one of the tourist sites that has become a popular destination. Bunaken National Park is one of the natural wonders in Indonesia which has an area of 75,265 ha with a range of different environmental prospects, ranging from land potential, mangrove forests, to ocean potential. One of the renowned types of tourism in Bunaken National Park is underwater landscape tourism, where the seas in the Bunaken region are dominated by coral cliffs with a vertical steepness of 25-50 meters with a number of coral reef species of approximately 390 species and approximately as many as 3000 species of fish. In order to experience the beauty of the underwater scenery, Bunaken National Park has 20 dive sites with varying levels of sea water depth. According to the data obtained, tourism development in Bunaken National Park has increased each year. As shown in Figure 1, the average number of tourists visiting Bunaken National Park increased by 23% for domestic tourists and 12% for foreign tourists between 2002 and 2018. According to Government Regulation of the Republic of Indonesia No. 50 of 2011 about the Master Plan for National Tourism Development 2010-2025, the management of The Bunaken National Park must be carried out an integrated and synergistic method between the government and the public. As a result, during a visit to Bunaken on July 5, 2019, the President of the Republic of Indonesia provided a direction to the Minister of Transportation, to the developed maritime tourism facilities in the form of tourism vessel to experience the beauty of the underwater environment. In this context, the semi-submersible tourism vessels are an excellent option for implementation. Semi-submersible tourism vessels equipped with glass at the bottom of the hull, to provide tourists experience of the beauty underwater scenery without having to dive into the sea. This certainly benefits the tourists who do not have the skill to dive therefore everyone can still enjoy the beauty of underwater environment and using semi-submersible tourist ships can also bring extra benefit, such as the ability to preserve the underwater ecosystem.

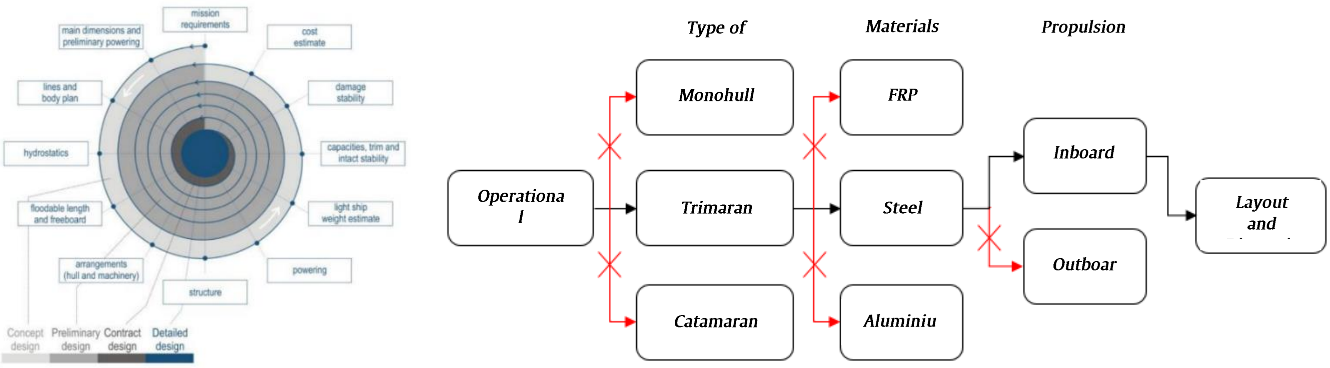
Many design studies on tourist boats have been conducted to support tourism industry and the local economy, such as those conducted by Utama et al. [1], which is an optimization of river tourism boat design for the Central Kalimantan area. Then there were various alternative designs, such as those done by Moganti et al. [2], which modified the ship's fin stabilizer to increase the ship's safety and comfort. However, all of these studies weren' t tourist ships for to observing the underwater beauty. A several studies of semi-submersible vessels equipped with glass on the ship has been conducted, such as the design carried out by Hidayat et al. [3], which conducted a study connected to the usage of flat plate designs for tourist boats in the Banyuwangi area. The ship is small in size and intended to carry a small number of people, thus improvements are required for use in the Bunaken area. Furthermore, some existing vessels related to semi-submersible vessels equipped with glass exist in Indonesia, which we shall explore further in the following sub-chapter because they have similarities with the design to be achieved. Hence, research conducted in the literature demonstrate that there are still few semi-submersible ships fitted with glass, implying that the development of design concepts for similar ships must be continued.

The present study analysis focuses on design of trimaran semi-submersible ship with equipped glass bottom using the spiral design concept in order to achieve the standards of efficiency and effectiveness. Furthermore, the finite element analysis had been perfomed to estimate the glass thickness required that applied in the ship and then empirical and numerical for resistance calculations was performed for comparisons. This paper aims to be used for guidance policymakers in Indonesia particularly the Directorate General of Sea Transportation of the Ministry of Transportation, as well as the public and local government where the ship would be operated

2. Methods

2.1. Spiral Design

In general, the spiral design concept, established in 1959 [4], is applied in ship design approach. The ship design will go through multiple cycles of changes and adjustments before it is ready to launch. The spiral design approach's design process phases are divided into various stages, including concept design, preliminary design, contract design, and detail design, as represented in Figure 1a. At each of these stages, the same iterative approach will be used, from determining the main dimension of the ships to estimating building expenses. The concept design represents the design of owner requirement which the parameters such as maximum speed is 12 knots and maximum capacity is 44 passengers. After obtaining the type and best design, a decision will be made regarding how this ship will be designed, including the type of hull, the material, and the propulsion system, which will eventually become a preliminary design that consist of general arrangement and the lines plan, general arrangement, hydrostatic, and etc.This design process is similar to the concept of a point-based design approach [5], as presented in Figure 1b.



a. Spiral Design b. Decision Tree

Figure 1. Ship Design Methodology

2.2. Semi-submersible Tourism Ship

In this study, a literature review of semi-submersible tourism ships has been conducted from related scientific papers to support the completion of this study. Semi-submersible tourism ships are the main object of this study, where the ships are equipped with glass at the bottom of the hull, therefore, the passenger doesn' t have to dive to enjoy the underwater scenery. The new design was developed based on the existing ship design, to be able to choose the suitable specification. It was discovered that several semi-submersible tourist ships had been built and are still in operation.

2.2.1. Subsea Vessels

The subsea vessel is a semi submersible ship which operates in the southern seas of Bunaken Island, Indonesia, and is owned by Grand Luley Manado. This vessel has been in operation for 30 years and is made of aluminum, the interior of the ship can be seen in Figure 2. The ship main dimensions include length of overall (*LOA*): 15 meters, width (*B*): 2.5 meters, draft (*T*): 1.5 meters, service speed of 5 knots, and passenger capacity of 15 persons. This ship is quite comfortable in calm waters, but when the currents and waves are high, it causes nausea for the passengers (the ship has poor stability when the waves and undersea currents are high).

2.2.2. Underwater Explorer

The underwater explorer ship is a mono-hull type ship that operates in Argentina, which can be seen in Figure 3. The dimensions of the underwater explorer ship include length of overall (*LOA*):22.3 meters, width (*B*) of 5 meters, service speed of 8 knots, a main engine with 220BHP, and a passenger capacity of 83. Compared to the previously described glass-bottom vessel, this vessel is considerably larger and capable of operating in relatively deep waters.

Figure 2. Subsea Semi-submersible Tourism Ship

Figure 3. Semi-submersible Underwater Explorer

3. Results and Discussion

3.1. Objectives and Responsibilities

The purpose of semi-submersible tourism ship is to carry tourists around the Bunaken National Park area and show them the underwater scenery. Based on the ship's purpose, these are some functional design requirements: 1) Able to transport 44 passengers, 2) Able to reach a maximum speed of 12 knots and service speed of 10 knots, 3) Able to operate for 8 hours 15 minutes, 4) Able to provide high passenger comfort, and 5) Able to maintain high passenger efficiency (easy access, easy to use, high availability etc). Figure 4 illustrates the ship's operating area in the meantime.

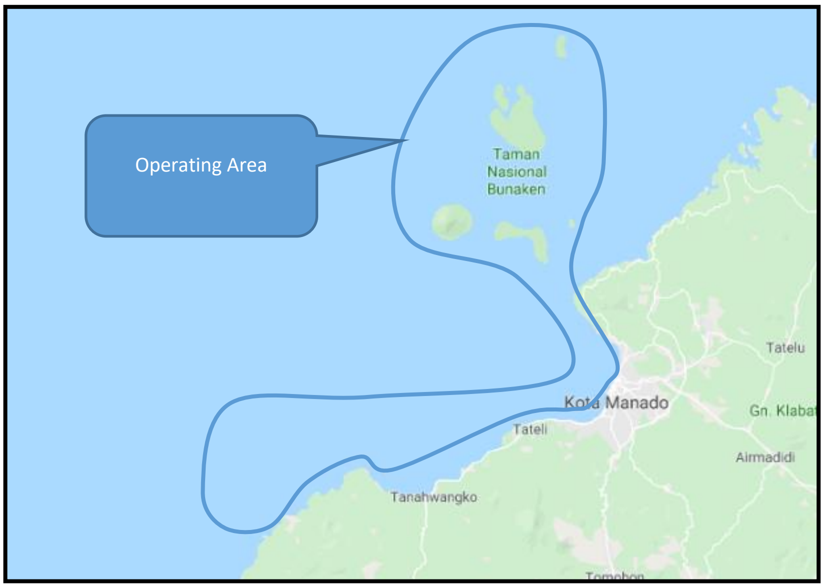
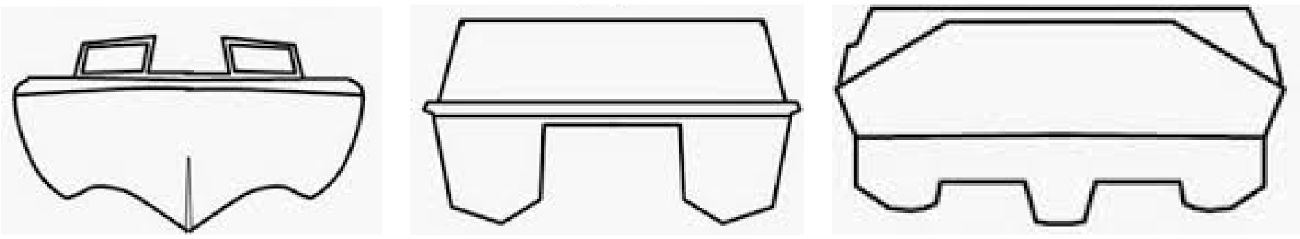


Figure 4. Ship Operation Area

3.2. Hull Types

The three types of hulls that are preferred options for bottom glass tourist ships are depicted in Figure 5. The advantages and disadvantages of the three types of hulls are as follows:

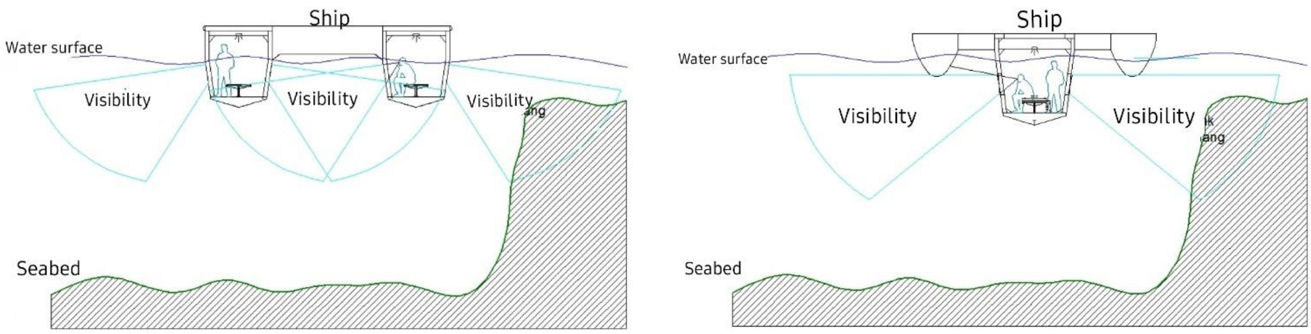


a. Monohull b. Catamaran c. Trimaran

Figure 5. Hull shapes

a. *Monohull*. The mono-hull type features a hull that lacks stability, is easily rolled by waves, especially from the side, and has a very small deck area [6].
b. *Catamaran*. The advantages of the catamaran hull over the monohull is that it has a sufficiently large deck area, can maintain speed in high waves, has a stable platform, and is more affordable than other hull types with the same performance [7].
c. *Trimaran*. Since the demi hull can maintain the ship even when attacked by waves, the trimaran design has excellent stability. Trimaran hulls are commonly used for passenger ships that sail the ocean due to their high stability. If it is properly designed, this hull has far less resistance, which allows the speed to be higher than mono-hull (conventional) [8].

The decision of the hull form is based on the design criteria to be made, in which the ship must have good stability and maneuverability so the hull type that fully satisfies the needs can be chosen later. The catamaran and trimaran hulls were chosen as the type of hull used due to its advantages in terms of ship stability and many other advantages that have previously been discussed. Technically, the main advantage of the trimaran hull type is its safety, as she has three hulls. If a one of the hull damages, the others can still be used as a reserve buoyancy.



a. Catamaran hull b. Trimaran hull

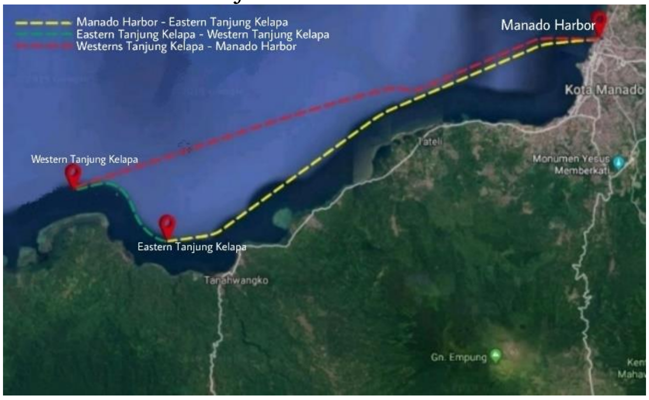
Figure 6. Visibility on Semi-submersible Tourism Ship design

The local geographic conditions are also considered while deciding on the type of hull. Geographical circumstances or the bottom morphology the Bunaken National Park waters shows that the seabed is covered with coral reefs and has the shape of a wall. As a result, the underwater landscape is only visible from one side of the hull, as seen in Figure 6**Error! Reference source not found.**. The tourism ship with a glass window position beside the ship will make it easier for tourists to see the corals more clearly and comfortably with the unsual bottom of the seas. When using a catamaran, tourists see only from one side of the ship, rendering this inefficient and potentially disrupting the ship's stability. The ship's hull will thus require a deeper draft due to the condition of the walled seabed in order to provide a wider viewing area. Because both hulls of a catamaran must be loaded if we want the deeper draft, the displacement will increases significantly. However, if we use a trimaran, we only need to add load in the middle of the hull to have a higher draft. The area of sight obtained is larger due to the design of the deeper main hull with trimaran hull design. Another advantage of utilizing the trimaran type hull is that the ship may approach closer to the coral wall for a better view because the demi-hull will not hit the wall because the draft of the ship is still sufficient, which the catamaran type hull cannot accomplish. With these two factors in mind, the trimaran type of hull was chosen for semi submersible tourism ships.

3.3. Trip Routes

Based on the recommendations from the Bunaken National Park Office, a semi submersible tourist ships have two operational routes to choose from. This path of operation encompasses both the North and South Bunaken National Parks. Figure 7 provides some recommendation of routes that were created based on survey data and advice from National Parks.

a. Route-1: Northern Bunaken National Park



b. Route-2: Southern Bunaken National Park

Figure 7. Choice of Cruise Route for Tourism

The first route, shown in Figure 7a, which begins at the Manado Public Port and ends at Manado Tua Island. Tourists can see various marine life using a semi submersible ship and do tracking here, then go to Bunaken Island through a spot in the northern seas of Bunaken Island. Tourists can see a variety of marine life at Bunaken Island's northern waters. The trip continues to Siladen Island, where tourists are allowed to snorkel and enjoy the underwater beauty of Siladen Island, or simply sit on the beach by the sand and a peaceful atmosphere. Siladen Island is the final tourism destination on this route. The southern part of Bunaken National Park, as given in Figure 7b, is the second route option. This route runs from Manado Port to Tanjung Kelapa seas, where tourists can cruise along the coral cliffs onboard a semi submersible vessel and snorkel to see the beauty of the Tanjung Kelapa coral gardens.

To maximize the tourist experience in enjoying the underwater scenery, the semi-submersible tourism ships requires a trimaran hull with a draft of around 2.2 meters. As a result, semi submersible tourism ships require a berth with suitable depth. According to the latest survey, ports with a depth of more than 2.2 meters can be found at the Port of Manado (port depth of 3.8 meters) and on the islands of the Bunaken National Park, where the seabed contours take the shape of coral cliffs, making the seas quite deep (165 meters). The two previously described routes are illustrations of routes developed using survey findings and advice from National Parks. However, in development and implementations, the management of the National Park Authority will determine the location of the ship' s operation based on many factors such as which locations are authorized to be visited, potential areas, and the best access to use.

3.4. Ship Speed

One of the most important components to ensure the performance of ship is speed. Based on the Figure 8, the ship route was divided by two routes, namely route 1 on the semi-submersible tour boat which is 25.6 nautical miles round-trip, and route-2 is 28 nautical miles round-trip. The journey of route-1 can be finished in approximately 8 hours with an average speed of 8 knots, Therefore the journey on route-2 can be finished in approximately 7 hours with an average speed of 10 knots. From Tanjung Kelapa to Manado Port takes 2 hours and 40 minutes via route-2.

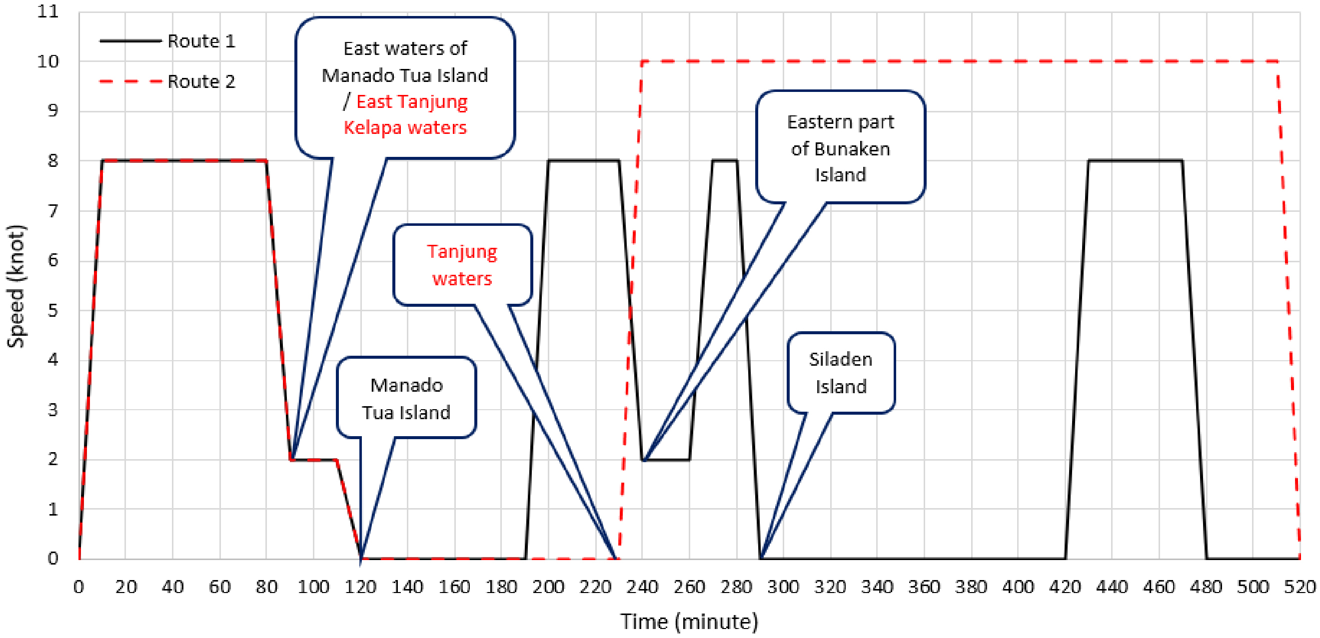


Figure 8. Comparison graph of ship speed and ship operating time on two different routes

3.5. Hull Form and Main Dimensions

The hull design chosen for the semi-submersible tourism ship is a trimaran hull with two stern drive propeller propulsion systems mounted in each demi hull, based on the specifications and justifications previously explained. The advantages of this type of hull will be described in detail below.

Table 1. Main Dimensions of Semi-submersible Tourism Ship

Parameter	Variable	Value	Unit
Length, Overall	L_{OA}	23.10	meter
Length, Perpendicular	L_{PP}	20.80	meter
Length, Waterline	L_{WL}	21.68	meter
Beam, Overall	B	8.00	meter
Beam, Main hull	B_0	2.80	meter
Beam, Demihull	B_1	1.60	meter
Beam, Main hull to Side hull	B_2	3.20	meter
Depth to Main Deck, at side	H	3.00	meter
Draft, Full Load	T	2.22	meter
Service Speed	V_S	10	knot
Maximum Speed	V_{max}	12	knot

1. **Extra space available.** Trimaran's three separate hulls can provide more space, usually up to twice the amount of room as a monohull of the same length. This condition allows us to design the space and adjust the passenger position on the ship more easily. Because of the passenger cruise design, the passenger deck and exterior deck can be on the same level [9].
2. **Sufficient stability**. This hull form provides adequate transverse and longitudinal stability to prevent the unwanted trim and heel angles during passenger loading and unloading. In fact, all trimaran' s hulls provide natural sea stability and do not require stabilizers.
3. **Safe.** This type of hull is incredibly durable and buoyant, making it nearly unsinkable. Although a trimaran can capsize in a major catastrophe, it is still safer to float on the rough water condition [9].
4. **Resistance and fuel consumption are relatively lower.** According to various studies, the trimaran hull has lower resistance than the monohull and catamaran hulls. This statement also applied for longer trips while using the same amount of fuel. A trimaran's overall fuel consumption is 30% less than monohull fuel consumption of the same length [8, 10].
5. **Excellent maneuverability**. Due to its three separate hulls and dual engines, these ships has good agility. With two distinct engines, a bow thruster is unnecessary. Trimaran has a shallow draft, allowing it to access locations that are unreachable by monohull. This is advantageous in cruising, as the water depth contour in the ship's operating area is quite varied [11].

6. **Adequate development costs.** By duplicating everything in the demi-hull, installation expenses can be made even cheaper. Spending extra on the security and comfort of passengers and their luggage does not appear to be a problem, given the other benefits listed in the previous lines. This is a great investment for the owner of the vessel [9].

Based on the data provided, the designer is confident that the symmetrical shape of the trimaran hull is the great decision for semi-submersible tourist ships. A minimum deck area was then determined to ensure the accommodation space was large enough to accommodate the entire passenger load. At the main hull, the required chamber space for glass-bottomed area for tourists measures 2.80 meters in width. Table 1 is the details of the ship's main dimensions.

3.6. Lines Plan

Lines plan is a view or projection of the hull that is cut transversely (front view), lengthwise (side view), and horizontally (top view). The lines plan is useful for obtaining the image shape of the hull, so that the designer can see the size of the space inside the hull. A lines plan that represents the planned hull model is constructed based on the main dimensions of the ship presented in Table 1. Figure 9 depicts a cross section of the ship or body plan. A bridge connects the main hull and side hull so that they become a single body. The bridge is 0.48 meters above the water's surface. The distance between the main and side hull centerlines is 3.2 meters, hence the ratio of the main and side hull distances to the ship's length (S/L) is 0.138. The S/L value is related to the wave making resistance generated by the hull, which affects the ship's total resistance [12].

The longitudinal cross-section of the ship′s main hull is a common design to ease the manufacturing process, even though it will result in water pressure when the ship is sailing gathered at the bow area of the ship, as seen in in Figure 10. . The stern of the main hull is then tilted upwards to minimize pressure at the ship's stern and adjust for pressure generated at the bow. Then the side hull is shaped in to form of a yacht or cruise ship, with the goal of reducing resistance caused by the hull shape and improving the design's aesthetics. The side hull's stern is designed by modeling the stern of ferryboats that use a propeller to provide a homogeneous flow of velocity into the propeller inlet, aiming to give a minor increase in thrust.

The volume of space owned by the ship, as depicted in Figure 11, can be viewed from the top view. The main hull has a vast volume of space with a parallel middle body that spans from station 4 to station 3 because the main hull is utilized as a chamber for tourist′s spot to view the underwater splendor through a glass panel. Furthermore, for the side hull, we modified the shape of the Wigley hull with a modest alteration to the bow and a modification to the stern to fit the propulsion equipment.

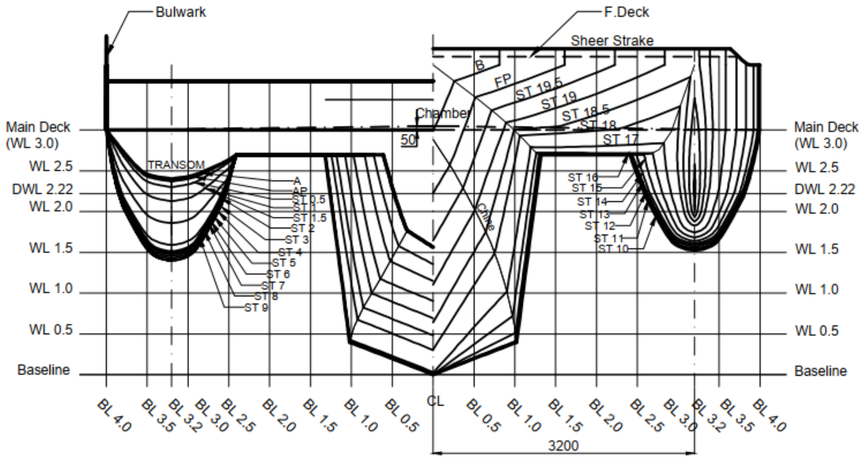


Figure 9. Body plan

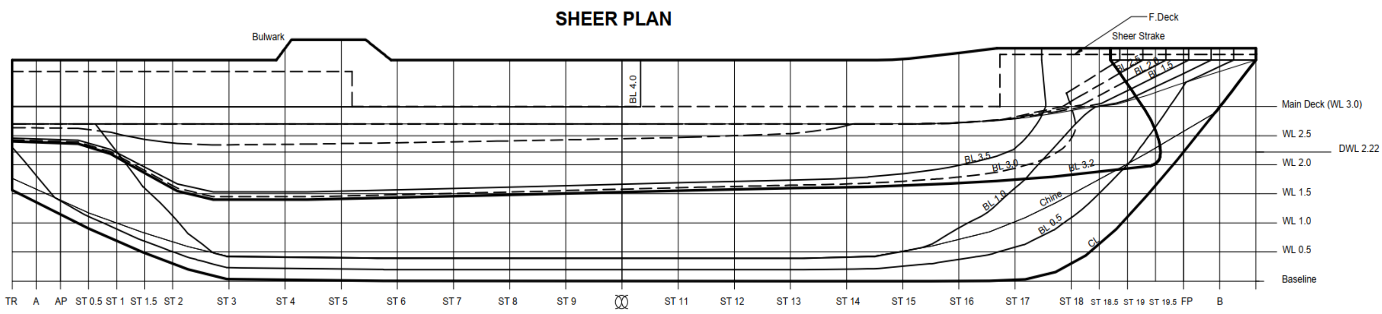


Figure 10. Sheer plan

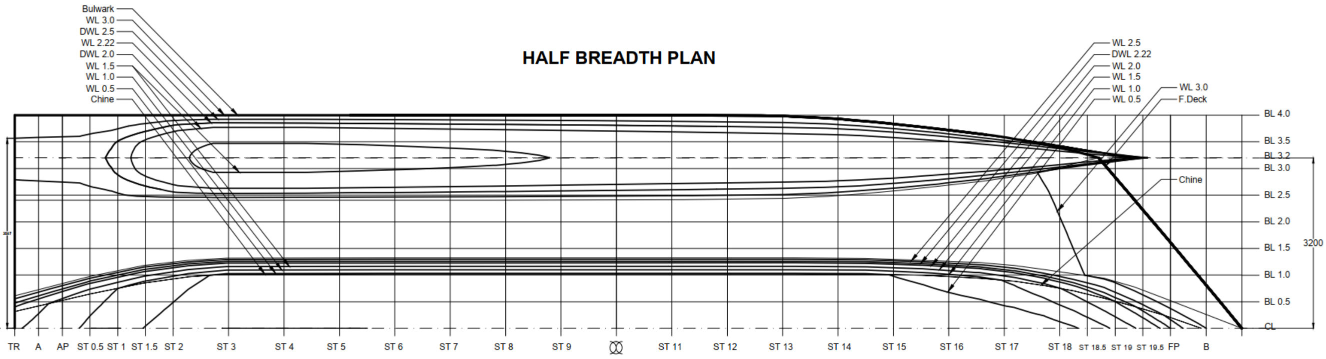


Figure 11. Half breadth plan

3.7. Resistance and Propulsion

Various calculation approaches, such as empirical and numerical calculations, are applied to estimate ship resistance. For empirical calculations, the Holtrop formula is applied, which is often used to predict the resistance for displacement ships [12]. For numerical calculations, the slender body [13], and Computational Fluid Dynamics (CFD) methods are utilized [8, 10, 14]. As shown in Figure 12, the results of the estimated ship resistance values will be presented graphically. From the results of the calculations, the trends, and characteristics of the Holtrop method calculations are nearly identical to those of the CFD calculations when compared to the Slender Body method. For this reason, the calculation utilizing the Holtrop formula and the CFD approach will serve as a reference when determining the ship's engine power requirements.

After calculating and analyzing the total ship resistance, the results will be converted into the minimal engine power requirement for the ship. In which the vessel must be able to reach 12 knots at 85% Maximum Continuous Rating (MCR). Several coefficient values are required to transform the resistance value, including the propeller efficiency value. Where in this design the Wageningen B-Screw Series propeller with an efficiency rating of 42.1% will be utilized. Then, other efficiency values will be determined using an empirical formula, as Parsons recommends for preliminary design [15]. The ship's engine power requirements at 85% MCR are shown in Table 2. The calculation indicates that the engine power requirement at a maximum speed of 12 knots in 85% MCR conditions is 832.42 HP for the Holtrop method and 751.18 HP for the CFD method. From this quantity, the engine power can be chosen with a minimum twin screw engine power specification of 2 × 450 horsepower.

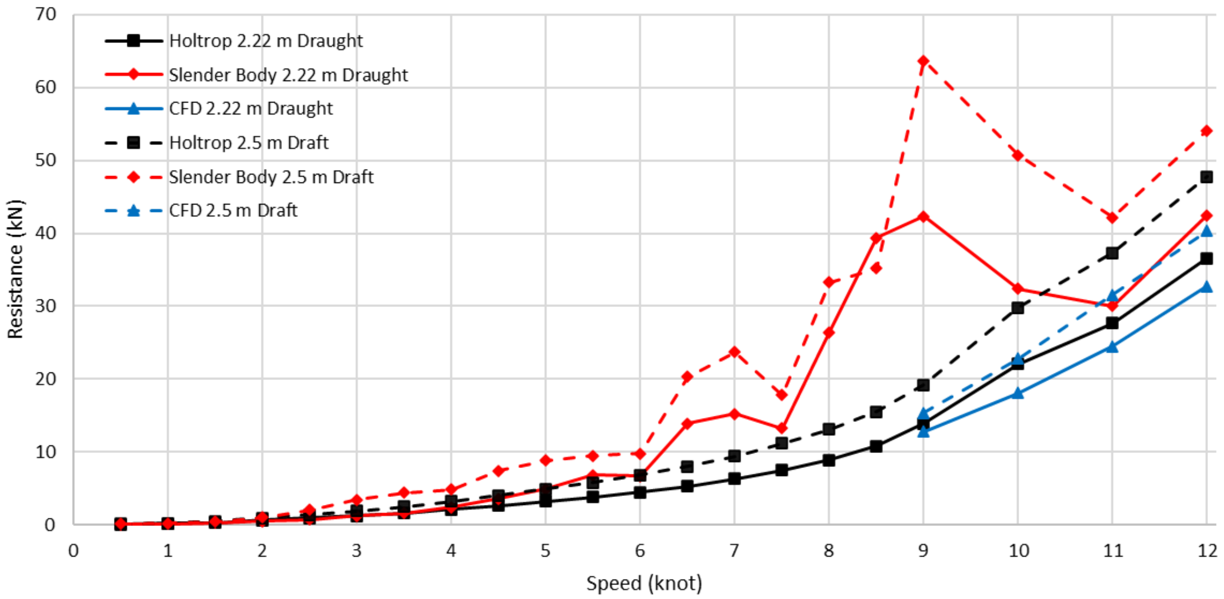


Figure 12. Resistance Curve

Table 2. Minimum Engine Power Requirement

Speed	Draft	Total Resistance (kN)			Power 85% MCR (HP)		
knot	m	Holtrop	Slender Body	CFD	Holtrop	Slender Body	CFD
9	2.22	13.90	42.30	12.78	237.10	721.55	218.07
10	2.22	22.10	32.40	18.12	418.87	614.08	343.41
11	2.22	27.70	30.00	24.51	577.50	625.45	510.89
12	2.22	36.60	42.50	32.76	832.42	966.61	745.18

3.8. Stability Analysis

The criteria for intact stability are based on the requirements of Badan Klasifikasi Indonesia (BKI) regulations for small vessels with a length of up to 24 meters, which provide a few criteria that must be met [16]. In this study, an intact stability calculation will be given for the ship's full load condition, which is a ship's departure condition with a full passenger capacity of 44 passengers and 100 percent consumables condition. Figure 13 shows a graph in which the value of the return arm (GZ) displayed as a function of the ship's angle of inclination [17]. The GZ value obtained from each ship's inclination angle can be used to look for the necessary stability criteria, the results of which can be seen in Table 3, where there are six stability criteria required by BKI for ships with a length of up to 24 meters. To ensure the safety of the ship, especially its stability, all stability requirements must be fulfilled; for this ship design, all stability criteria have been managed to meet.

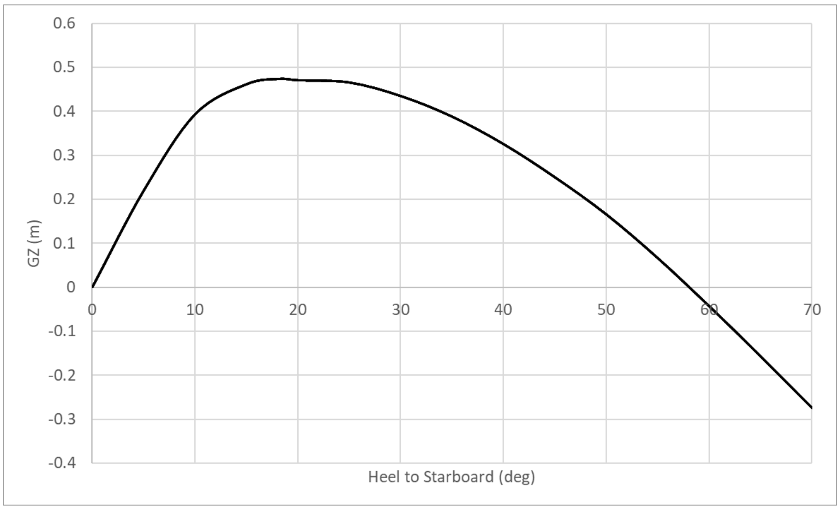


Figure 13. GZ Curve

Table 3. Checking stability criteria with BKI rules

Code : BKI (Rules For Small Vessel Up To 24 m					
Chapter	**Criteria**	**Value**	**Units**	**Actual**	**Status**
C.1.2.2.1	GM	0.35	m	2.7	Pass
C.1.2.2.1	Righting lever at 30 inclination	0.2	m	0.44	Pass
C.1.2.2.1	Area under lever arm curve up to 30 inclination	0.055	m.rad	0.2	Pass
C.1.2.2.1	Turning circle angle of heel 12	12	deg	1.7	Pass
C.1.2.1.1	$M = n(0.2B + 0.1), with\ \theta < 10^0$	362.898	kN.m	86.7	Pass
C.1.2.1.1	$M = 0.25D \times \frac{V^2}{L}(0.75H - 0.5T) + n(0.2B + 0.1), with\ \theta < 12^0$	393.293	kN.m	118.13	Pass

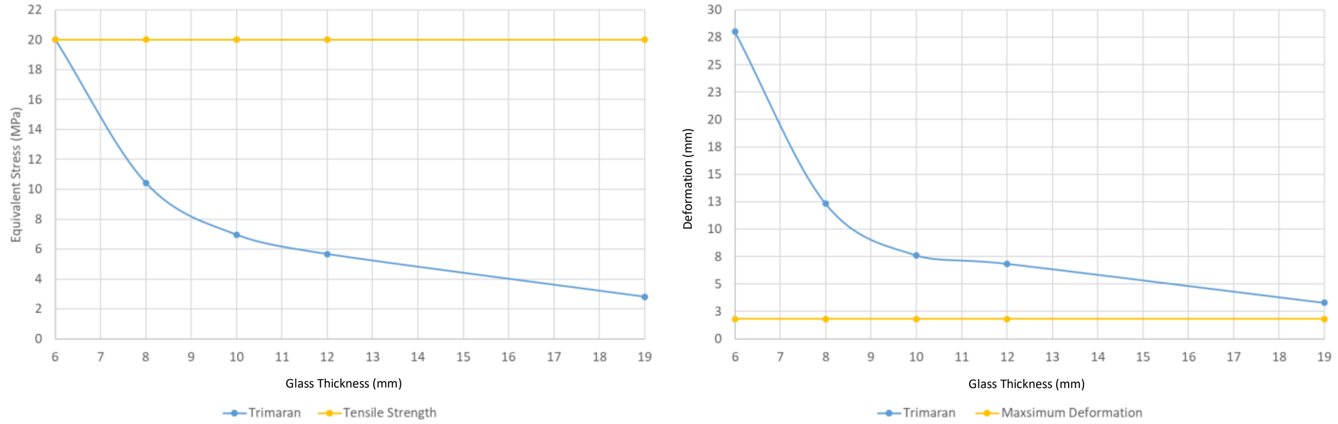
3.9. Semi-submersible Glass Windows Strength

In this study, Finite Element Analysis (FEA) conducted to estimate the glass thickness required for installation on the ship [17]. The material properties shown in Table 4. The simulation was conducted by varying the thickness of the glass from 6 millimeters to 19 millimeters and then analyzing the resulting stress and deformation. The parameters required for determining the thickness of the glass, then the stress that occurs in the glass should not exceed its tensile strength, and the maximum allowable deformation is 1.8 mm. To ensure the safety of the ship, the thickness of the glass will be multiplied by the safety factor at the end of the calculation. Figure 15 demonstrates that the resulting stress is quite small, although the deformation is relatively high. At 19 mm thick glass, the deformation is still greater than 1.8 mm; consequently, the applied glass is thicker than 19 mm. As previously stated, since the thickness of the glass is multiplied by the safety factor, approximately 38 mm of glass is used to ensure high safety.

Table 4. Mechanical Properties of Glass

Property	*Symbol*	*Unit*	*Value*
Young's Modulus	E	Gpa	70
Poisson's ratio	v	-	0.23

Thermal expansion coefficient	*α*	10-6K-1	9.1
Tensile strength	*ft*	Mpa	20 to 100
Compressive strength	*fc*	MPa	>800
Density	*ρ*	kg/m3	2500
Specific thermal capacity	*cp*	J'(kg K)	720
Thermal conductivity	*l*	W/(m K)	1

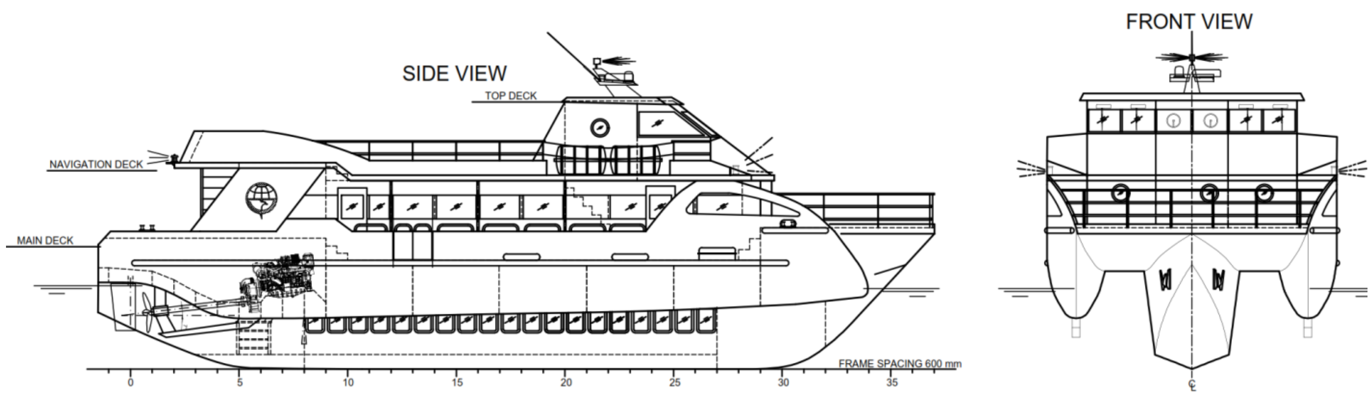


a. Equivalent Stress b. Maximum Deformation

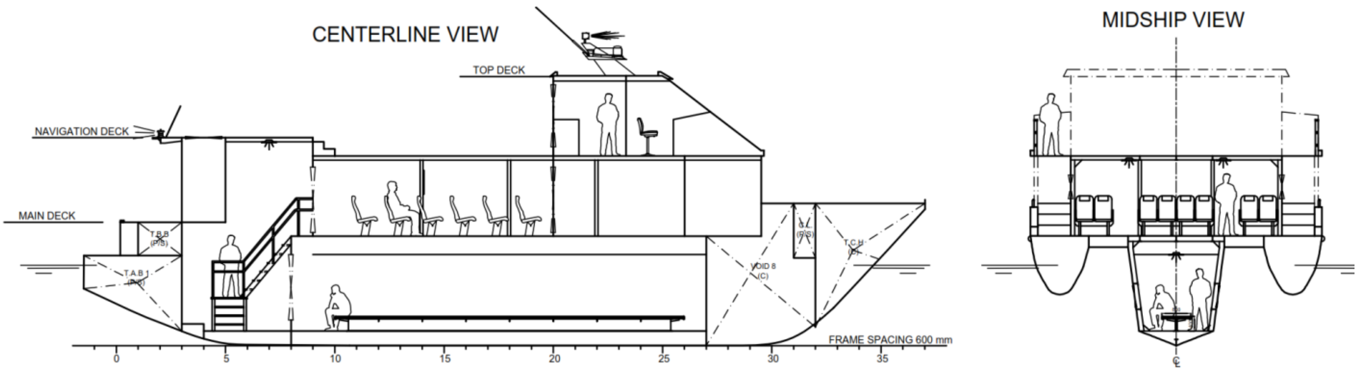
Figure 14. The stresses and deformations that occur in the glass

3.10. General Arrangements

The general plan or general arrangement is the planning of the required space in accordance with its functions and equipment. These rooms include the cargo room, the accommodation room, the engine room, the superstructure (upper building), and so forth. It also includes planning for the placement of the room's location and access. A decent arrangement considers the human factor who will reside on the ship when constructing the general plan for this semi-submersible tourism ship. A general arrangement must consider elements of elegance and convenience. The construction factor is also a concern in the design of the accommodation rooms. The size and capacity of the semi-submersible glass chamber room, which is positioned in the ship's main hull, are the most major considerations in this design. The glass chamber room must be spacious enough for passengers to enjoy underwater sights, such as deep and wide enough. The designer uses the glass chamber room as a preliminary step for setting up the initial overall layout. This is because the chamber room is the ship's main facility and takes up the most space. Other feature that contributes to passenger satisfaction is the provision of local amenities on both the main and upper decks. The initial setup of a glass-bottom tourism ship that complies with all specifications, rules, and regulations is depicted in Figure 15, which is a sectional side and front view of the vessel. This design will then be used as the primary data for further design stages.



a. Side and Front View

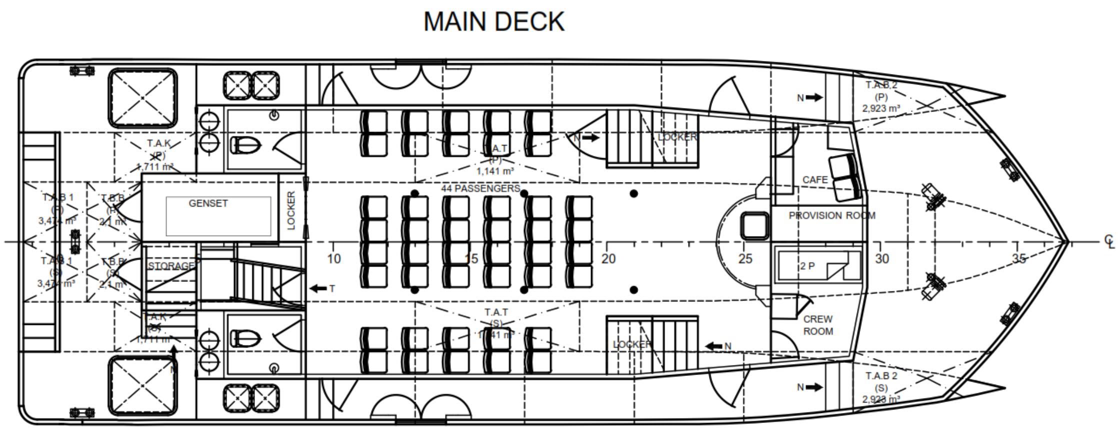


b. Side and Midship Section

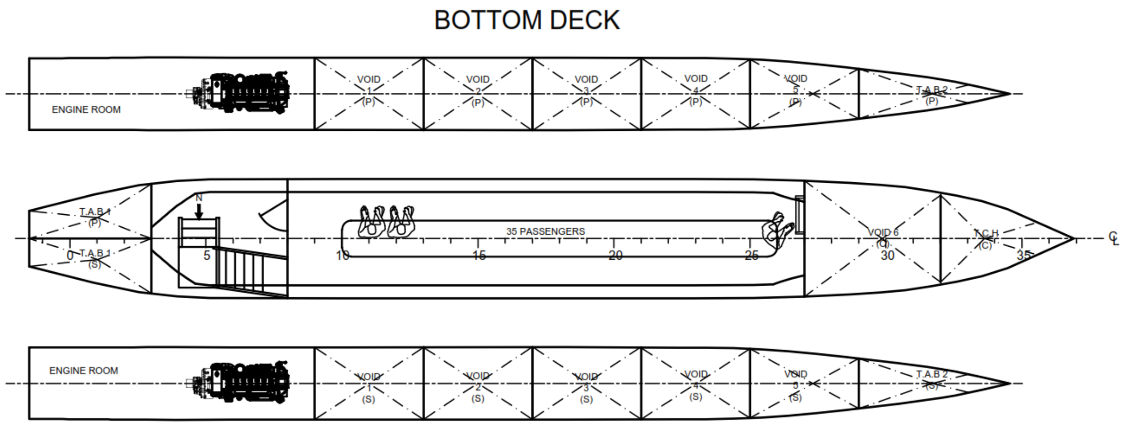
Figure 15. Side and Front View of The Semi-submersible Ship

Figure 16. A Three-dimensional Illustration of The Front and Side of a Semi-submersible Ship Design

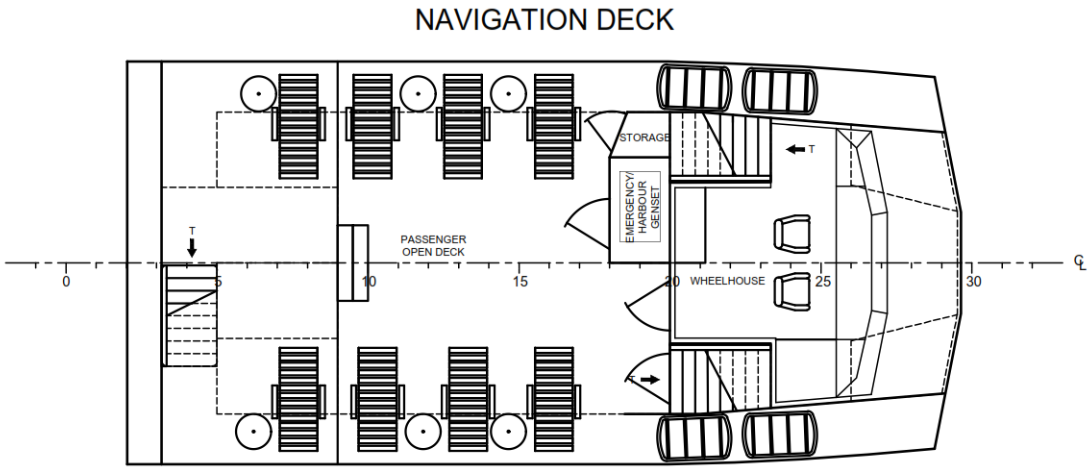
The ship's construction design is planned to use a transverse construction system with a distance between frames of 600 millimeters as shown in the ruler on the ship's baseline in Figure 15. Figure 15a, also shows that the glass used as a medium to appreciate the underwater sight is positioned at the main hull, approximately 1650 millimeters from the ship's baseline, with a glass dimension of 600 x 400 millimeters. With a height of 2.8 meters, the glass-bottomed chamber room allows tourists to enjoy the view from both sitting and standing positions. The main engine is located on both sides of the demi hull with a slope of 7 degrees and is equipped with a gear box and propeller shaft with a length of 2.4 meters. Figure 16 depicts a three-dimensional model of the glass-bottom ship design to provide a clearer depiction of the ship model from both the front and side viewpoints.



a. Main deck layout



b. Bottom deck layout

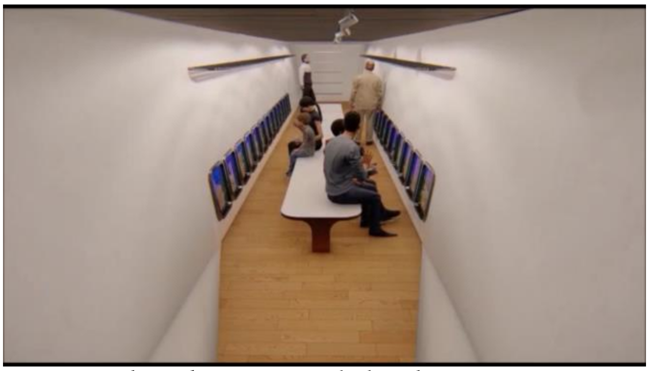


c. Navigation deck layout

Figure 17. The existing deck layout on a semi-submersible ship

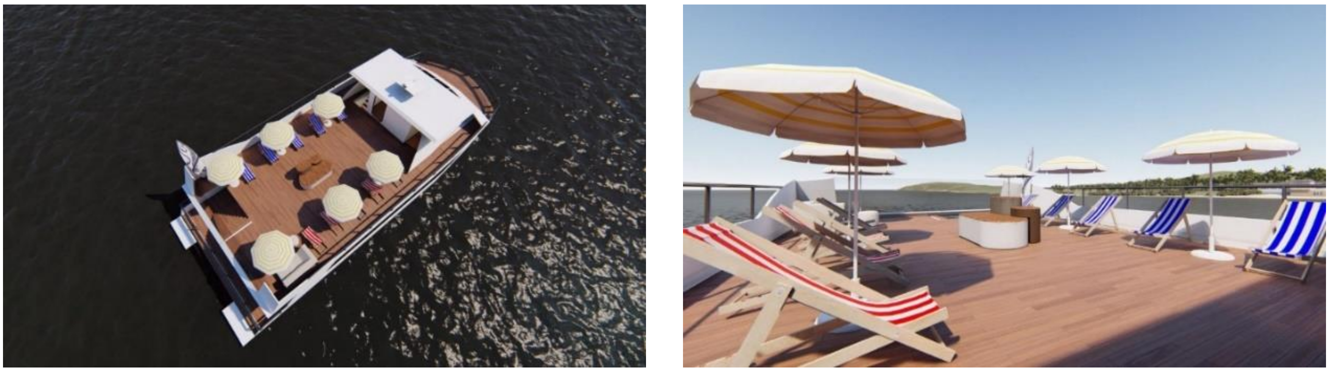
This ship is designed with three decks: the main deck, the bottom deck, and the navigation deck, as seen in Figure 17. The bottom deck is a deck on the main hull that serves as a lying area and a glass bottomed chamber for tourists. Figure 17b, depicts the void room and engine room on the side hull. Many of the ship's compartments are used as empty spaces or void, increasing the ship's buoyancy, and enhancing its safety. There are also several ballast tanks at the stern and bow of the ship, as well as the engine room, which spans from the ship's side hull to frame 8.

a. Passenger seat arrangement and entertainment facilities model



b. Glass Bottomed Chamber Room

Figure 18. Main Deck Accommodation Space and Glass Bottomed Chamber Room in three – dimensional



a. Open area and navigation deck

b. Wheelhouse

Figure 19. Navigation Deck Illustration in Three Dimensional

The main deck, as depicted in Figure 17a, is mostly the accommodation deck, with some onboard entertainment. The 44 passenger seats are divided into three columns, with the middle column containing six rows of four seats each. The remaining seats are then placed on the right and left sides of the center column of seats, which are separated by road access. This deck has two toilets, a cafe, a food store, and a crew room. The gasoline tank is also located on this deck, with a tank volume of 2.1 m3 containing two tanks at the stern region in frames 1 to frame 3. Aside from being used as a navigating room and steering room, the navigation deck also has an empty area where tourists can relax or enjoy the sea panorama around the ship, as illustrated in Figure 17c. A three-dimensional picture of the ship's main deck, glass bottomed chamber room and navigation space is illustrated In Figure 18 and Figure 19.

4. Conclusion

Operate in Bunaken National Park. The purpose of the semi-submersible is to convey tourists through the Bunaken national park area while observing the underwater beauty. Several conclusions is formed on the design based on the design process that has been accomplished, including:

1. The design of this ship features a trimaran hull since it has various advantages particularly connected to ship stability.
2. The main dimensions of the vessel are 23.1-meters long overall with a total width of 8-meters and a draft of 2.2-meters. The side hull is 1.6-meter wide, and the main hull is 2.8-meter wide with a centerline distance of 3.2 meters.
3. The ship has three decks, primarily the bottom deck as a semi-submersible glass bottomed chamber room which is fitted with 19 glasses on each left and right side of the main hull with a glass size of 600 x 400 millimeters which serves to see the underwater beauty.

4. The main deck is designated for guests with a passenger capacity of 44 passengers, then the navigation deck has an open space that may be used for tourist.

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