# DESIGN OF AN EYE CLINIC SHIP WITH A HYBRID ELECTRIC ENERGY SOURCE FOR THE NUSA TENGGARA ISLANDS

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**Received:** March 14, 2023 | **Accepted:** March 14, 2023 | **Published:** March 17, 2023

**DOI:** 10.12962/j27745449.v3i2.622 | **Issue:** Volume 3 Number 2 2022 | **E-ISSN:** 2774-5449

**ABSTRACT**

The World Health Organization reports that cataracts are responsible for up to 77.7% of visually impaired individuals in Southeast Asia, with Indonesia having the largest population of such individuals. Cataracts can grow faster in areas exposed to much exposure to ultraviolet rays, such as the Nusa Tenggara Islands, which cover 3 provinces, namely Bali, West Nusa Tenggara (NTB), and East Nusa Tenggara (NTT). The availability of ophthalmologists in NTB and NTT is still lacking. One ophthalmologist serves 261,969 people in NTB and 871,510 people in NTT. This condition contrasts the target distribution of ophthalmologists according to the 2017-2030 Roadmap for Management of Visual Impairment in Indonesia. The development of the shipping industry has had a negative impact on world carbon dioxide (CO2) emissions. The use of a multi-energy hybrid system is believed to be able to effectively reduce energy consumption and emissions from ships. So, in this study, an innovation in the design of an Eye Clinic Vessel with a hybrid electric energy source was designed using the Spiral Design method. This paper aims to obtain operational patterns, payload, main dimensions, technical calculations, lines plan, general arrangements, safety plans, and 3D models. The ship will serve 14 areas with a ratio of ophthalmologists with a population of more than 1:250,000. Two ships will be built, which will be divided into 2 routes, namely the North Route and the South Route. Each area will be served for one week, so 1 round trip of the Eye Clinic Ship takes around 52 days. This ship has a payload in the form of a minimum deck area for clinical facilities of 228.2 m2 and can accommodate 25 patients with a length overall (Loa) of 38.27 m; Width (B) 10 m; Height (H) 3 m; Draft (T) 1.8 m; and Service Speed (Vs) 13 knots. The ship uses 86 units of solar panels with 120 batteries to store electrical energy. This solar panel can save fuel usage up to 54%.

**Keyword:** Ship, Hybrid, Health, Clinic

## Introduction

Impaired vision and blindness are serious problems that the world must face. The World Health Organization (WHO) notes that 2.2 billion of the 7.7 trillion world population have visual impairment and blindness. Indonesia has the blindest sufferers in Southeast Asia and is included in the 5 countries with the highest number of visually impaired people worldwide. Cataracts cause as much as 77.7% of total blindness cases. Cataracts are known to grow faster in people who live in areas with much exposure to ultraviolet rays from the sun, for example, such as coastal areas. Much exposure to ultraviolet light disrupts the metabolism of the eye from being clear to cloudy [1]. This condition certainly impacts the people of the Nusa Tenggara Islands, divided into 3 provinces, namely Bali Province, West Nusa Tenggara Province (NTB), and East Nusa Tenggara Province (NTT) where the prevalence of blindness for each of these provinces respectively, is 2.0%, 4.0%, and 2.0%. The cataract surgical coverage (CSC) rate for NTB and NTT is still quite low, with only 34.67% and 24.67%, respectively, in contrast to Bali, which has reached 66.33% [2].

To overcome this problem, Indonesia has designed a long-term plan listed in the Roadmap for Management of Visual Impairment in Indonesia for 2017-2030. The plan targets that in the 2020-2024 range, for each region, the ratio of ophthalmologists to the population reaches 1:250,000. The number of islands in Indonesia is a challenge related to providing transportation facilities and access to eye health services. Therefore, the existence of the Eye Clinic Ship is expected to be a new solution in providing eye health service facilities in Indonesia, especially in areas divided into islands such as the Nusa Tenggara Islands [3].

As an eye health facility, the Ophthalmic Ship will refer to existing regulatory standards so that ship operations can be more focused and the size can be more concise to reach areas that are difficult for large ships to pass through. This Eye Clinic Ship will serve when it is lean, so the ship will need a large enough electric power to supply various medical equipment. Thus, using a hybrid system between diesel generators and solar.

**Clinic**

A clinic is a health service facility that organizes and provides basic and/or specialist medical services, organized by more than one type of health worker and led by a medical worker. The operation of a clinic is regulated in PERMENKES Number 9 of 2014. In general, clinics are divided into Primary Clinics and Main Clinics. A primary clinic is a clinic that provides basic medical services, both general and special. The main clinic is a clinic that provides specialist medical services or basic and specialist medical services. Specialization, in this case, is specializing services in one particular field based on scientific disciplines, age groups, organs, or certain types of diseases. The Eye Clinic Ship will refer to the type of Main Clinic specializing in eye organs.

A clinic must at least consist of a registration room/waiting room, consultation room, administration room, medicine and consumables room, action room, breastfeeding room/corner, bathroom, and other rooms according to service needs. In addition, clinics must also be supported with complete infrastructure. Clinics need to have sanitation installations, electrical installations, fire prevention and control, ambulances (especially for clinics that carry out inpatient care), medical gas systems, air conditioning systems, lighting systems, and other infrastructure according to needs.

**Hybrid Power Generation System**

A hybrid power generation system (HPGS) can be defined as a power generation system that combines two or more generators that have different energy sources so that its application can generate advantages both technically and economically. HPGS usually consists of a combination of conventional generators (diesel or gas engines) and renewable energy.

The HPGS system components can be arranged in series hybrid system types, switched hybrid systems, and parallel hybrid systems. The use of a parallel hybrid system allows two power plants to supply the load simultaneously. This system uses a two-way inverter that can function as an inverter, charger, and regulator [4].

**Solar Panel**

Solar panels are devices that convert energy from sunlight into electrical energy in semiconductor devices, either directly using the photovoltaic effect or indirectly using centralized solar power. Solar panels consist of several silicon cells illuminated by the sun, which then produce photons that can generate an electric current. A collection of solar panels in one system is called an array [5]. The large number of modules arranged in series or parallel will determine the amount of output produced. The efficiency of the panel is calculated by dividing the cell power output (in watts) at maximum PowerPoint (Pm) by the input light (E) in W/m$^2$ and the surface area of the solar cell ($A_c$).

In general, a solar panel has an efficiency of only about 20-30%, which means that a solar panel can only convert about 20% of all the light energy received by the solar panel while the rest is reflected in the air. Solar panel installation can be done based on the function of the area where the solar panels will be installed. The number of solar panels that can be installed is obtained by comparing the area with the panel dimensions.

**Catamaran Ship**

A catamaran is a ship with two hulls or bodies connected by a deck or bridging platform in the middle. The bridging platform is free from the water surface so that the slamming and deck wetness of the ship can be reduced. Therefore, this ship is suitable for areas with shallow waters. This ship also has better stability than ships with monohull hulls. Another advantage of this type of ship is that under the same displacement conditions, this ship can produce 20% less resistance than monohull ships. In addition, this type of ship has a broader deck so that it can increase the size of the room inside [6].

## Methodology

**Problem Identification**

The initial step of working on this study is to determine the problem. The problem is that Indonesia is included in the top 5 countries with the most visually impaired people in the world, with a fairly high blind rate.

### Literature Study

A literature study was conducted to carry out this project. Researchers are learning about the existing problems and looking for information and references to solve the problem of designing this ship. These literature studies are related to understanding ship design, ship design technical factors, hull shape theories and concepts, technical calculations, stability calculations, freeboard, medical room technical guidelines, eye health services, hybrid power plants, and solar panels.

### Data Collection

In this project, the type of data used is secondary data obtained from various literature, papers, books, the internet, and databases. This data relates to eye diseases, blindness rates, the distribution of eye health facilities, and the population in each district/city.

### Determination of Operational Patterns

Based on the data obtained regarding the visual impairment condition in Indonesia, the operational pattern of the ship is determined according to the needs of the area.

### Determination of Required Deck Area

Determination of ship required deck area is done by analyzing the needs of health facilities based on the operational area of the ship. From determining the health facilities to be provided by the ship, the minimum room area needed for each facility is obtained regarding the relevant regulations.

### Determination of Initial Main Dimensions

Based on the required room area that has been obtained, an initial layout design can be carried out to determine the initial main dimensions of the ship. The initial main dimensions that have been obtained are checked and adjusted against the main size comparison limits.

### Technical Calculations

Based on the payload and the initial main dimensions of the ship that have been obtained, the following process is to process the data as input in the ship's technical calculations, which include the following: (1) Calculating the ship's coefficient; (2) Estimate the resistance of the ship; (3) Calculate the ship's propulsion efficiency; (4) Calculating the ship's electrical power requirements; (5) Calculating the need for solar panels; (6) Calculate the weight and center of gravity; (7) Calculating freeboards; and (8) Calculating stability.

## Regional Overview

### Regional General Overview

Nusa Tenggara Islands are a group of islands located east of Java Island, starting from Bali Island on the westernmost side to Timor Island on the easternmost side. This island is located at coordinates 9°00’S 120°00’E and has an area of 72,887 km2. Administratively, the Nusa Tenggara Islands consist of 3 provinces, namely Bali, West Nusa Tenggara (NTB), and East Nusa Tenggara (NTT).

Nusa Tenggara Islands are divided into several main islands so that the sea separates one area from another with a population of up to 13,675,089 people. The geographical shape of these islands makes sea transportation very reliable as a link between islands.

### Total Population of Bali Province

Bali province is divided into 8 regencies and 1 city, with the provincial capital being Denpasar City. The total population reaches 4,230,051 people.

### Total Population of NTB Province

NTB (Nusa Tenggara Barat) province is divided into 8 regencies and 2 cities, with the provincial capital being the city of Mataram. The province of NTB is divided into several islands, the largest being Sumbawa Island. The total population reaches 5,125,622 people.

### Total Population of NTT Province

The province of NTT (East Nusa Tenggara) has 21 regencies and 1 city, which is divided into several islands with the Sawu Sea in the middle. The total population reaches 5,541,394 people.

### Eye Health Statistics of the Nusa Tenggara Islands

The prevalence of blindness in people aged 50 years and over in Bali, NTB, and NTT reached 2%, 4%, and 2%, respectively. The province of NTB has a higher prevalence of blindness than the average for all of Indonesia, which is only 3%, with the main cause being cataracts.

### Nusa Tenggara Islands Eye Health Facility

The number of ophthalmologists in the Nusa Tenggara Islands, especially in the Provinces of NTB and NTT, needs to be more evenly distributed, in contrast to the Province of Bali.

The Province of Bali has 87 ophthalmologists in 28 hospitals which are spread evenly in all districts and cities.

The NTB province has 79 ophthalmologists in 20 hospitals, of which 9 are located in the city of Mataram, so there are still regencies or cities that only have one or do not have an ophthalmologist.

The province of NTT has 16 ophthalmologists who are only found in 10 hospitals, of which 6 are in Kupang City. There are still many districts or cities in NTT that only have one or do not have an ophthalmologist at all.

## Technical Analysis

**Determination of Operational Pattern**

The Eye Clinic Ship is planned to operate in the Nusa Tenggara Archipelago Region. It is known that eye health facilities in the Provinces of NTB and NTT are still lacking, so the operational area of the Ophthalmic Vessel will focus on these two provinces. The distribution of health facilities in NTB and NTT provinces is also uneven, with some hospitals still concentrated in one particular area. Based on the data, there are 27 districts or cities that only have one or even no ophthalmologist available.

Determining shipping destinations is obtained by calculating the ratio between ophthalmologists and the total population in each district or city, whether it exceeds 1:250,000, and considering location, so that 14 areas are used as shipping destinations, including: (1) Regencies West Sumbawa; (2) Dompu Regency; (3) West Manggarai Regency; (4) Southwest Sumba Regency; (5) East Sumba Regency; (6) Manggarai Regency; (7) Ngada Regency; (8) Nagekeo Regency; (9) Ende Regency; (10) Sikka Regency; (11) East Flores Regency; (12) Lembata Regency; (13) Sabu Raijua Regency; and (14) North Central Timor Regency.

**Figure 1**. The shipping route for the Eye Clinic Ship which is divided into the North Route and the South Route.

The shipping destinations are divided into 2 routes, namely the North Route and the South Route. In order to shorten the sailing time, 2 Ophthalmic Vessels are needed. Each ship will serve each of these destinations for 1 week. The North Route is a total distance of 800.4 nm and the South Route is a toatal distance of 890.3 nm. It is assumed that the maximum travel time for the crew and medical personnel to get enough rest is 16 hours, so the official speed based on the furthest route is 13 knots. An overview of the route can be seen in Figure 1.

**Required Deck Area Calculation**

The determination of the required deck area of the Eye Clinic Ship is based on the number of facilities that will be used as clinical facilities and infrastructure. Clinic facilities refer to the type of Main Clinic with specialist medical services specializing in eye health services. Eye health services provided to be able to deal with cataracts are secondary eye health services, which include examinations and/or specialist medical procedures in the field of eye health carried out by ophthalmologists and can collaborate with other health workers. Thus, the facilities built on the Eye Clinic Ship are: (1) Waiting Room; (2) Administration Room; (3) Service Room; (4) Operation Room; (5) Inpatient Room; (6) Nurse Post Room; (7) Laboratory Room; (8) Pharmacy Room; (9) Lactation Room; and (10) Accessible Bathrooms for the disabled. From these facilities, it was found that the required deck area for health facilities on the main deck was 228.2 m2, with details in Table 1.

**Table 1.** Minimum deck area for each eye clinic facility room

| **Facilities** | **Deck Area ($m^2$)** |
|---|---|
| The waiting room | 20 |
| Administration room | 6 |
| Service Room | 25 |
| Surgery room | 73 |
| Inpatient Room | 60,2 |
| Nurse Post Room | 8 |
| Laboratory | 12 |
| Lactation Room | 12 |
| Bathroom | 8 |

**Determination of Initial Main Dimension**

At this stage, each facility is arranged in such a way in one deck based on existing guidelines and regulations so that the initial main dimensions of the Ophthalmic Ship are obtained. The main size ratio is checked according to the existing ratio limits for catamarans, as can be seen in Table 2.

**Coefficient Calculation**

The shape of the hull refers to the Southampton Catamaran Series. From the L/B1 ratio value, a hull model that corresponds to this ratio can be made, which refers to model 6a with an L/B1 ratio of 15.1. Then, based on the body plan, the model is modeled and adjusted to the required size. The modeling results are used as parameters and determine the hull shape coefficient.

**Table 2.** Ratio comparison of the initial main sizes of the ships

| Size | Value | Ratio | Condition |
|---|---|---|---|
| $L/B_1$ | 15 | 10 < L/B1 < 15 | Fill up |
| B/H | 0,7 | 0,7 < B/H < 4,1 | Fill up |
| S/L | 0,19 | 0,19 < S/L < 0,51 | Fill up |
| $S/B_1$ | 0,9 | 0,9 < S/B1 < 4,1 | Fill up |
| $B_1/T$ | 0,9 | 0,9 < B1/T < 3,1 | Fill up |
| $B_1/B$ | 1,5 | 0,15 < B1/B < 0,3 | Fill up |

**Resistance Estimation and Propulsion Calculation**

After obtaining the main dimensions and shape coefficients of the hull, the resistance estimation is then carried out. The Ophthalmic Clinic ship uses a round bilge hull catamaran type, so the calculation of total resistance is carried out using the method from Insel & Molland [7][8]. In this method, obstacle interference components only occur in catamaran hull type ships, which can affect the total resistance value.

From the results of calculations that have been carried out at a speed of 13 kn, the total resistance is:

**RT = 34,941 kN**

The total resistance value is then used as a reference in propulsion calculations with a margin of 15%, so that the required brake horse power (BHP) is 890.43 kW.

**Hybrid System Calculation**

The eye clinic ship will be equipped with a hybrid system between a diesel generator and solar panels as a source of electrical energy. It is known that the roof area where solar panels can install is 248 $m^2$. From the layout result that has been made, the number of solar panels that can be installed is 86 units, with a total of 120 units of batteries to store energy. This system can save diesel generator fuel consumption by up to 54%.

**Weight – Displacement Check**

After knowing the ship's lightweight tonnage (LWT) and deadweight tonnage (DWT), these values are compared with the ship's displacement. The difference between the weight of the ship and the permissible displacement of the ship is 2-10%. Based on the results of the weight calculations that have been carried out, a difference of 5% is obtained with the details in Table 3.

**Waterline Length Inspection**

Waterline length calculation for ships is regulated in the 1966 International Convention on Load Line (ICLL) and PERMENHUB No. 39 of 2016. The calculation is intended to obtain the minimum freeboard height. For type B ships with a waterline length of 38 meters with other corrections, the minimum freeboard height is 0.725 m. The Eye Clinic ship has a raised hull as high as 1.2 meters, so it can be said that the free hull meets the requirements.

**Table 3.** Examination of ship displacement

| Component | Value | Unit |
|---|---|---|
| LWT | 50,462 | ton |
| DWT | 77,715 | ton |
| LWT + DWT | 128,357 | ton |
| Displacement | 135,100 | ton |
| Difference | 6,743 | ton |
| Margin | 5 | % |

**Table 4.** Load case for stability check

| Code | Crew (%) | Sewage (%) | Consumables (%) |
|---|---|---|---|
| A | 0 | 0 | 0 |
| B | 100 | 100 | 100 |
| C | 100 | 100 | 50 |
| D | 100 | 100 | 10 |
| E | 100 | 50 | 100 |
| F | 100 | 50 | 50 |
| G | 100 | 50 | 10 |

**Trim Check**

Ship trim limits are based on Safety of Life at Seas (SOLAS) Chapter II-1, Part B-1, Reg. 5.1 as a reference in performing calculations [9]. The maximum value of the trim is 0.5% LWL, which is 0.188 meters. Based on the calculation results obtained a value of 0.125 meters with the stern trim condition, it can be said that the trim condition meets the requirements.

**Stability Check**

Stability calculation is carried out by adjusting to various load case conditions, which can be seen in Table 4. Then for the Eye Clinic Ship, the stability criteria used are intact stability from IMO A.749 (18) and High-Speed Craft Code 2000 for a multihull. The results of the stability check can be seen in Table 5.

**Table 5.** Ship stability check based on IMO and HSC Code criteria.

| Criteria | Code | Load Case | | | | | | | Status |
|---|---|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F | G | |
| 3.1.2.1 Area 0 to 30 | IMO A.749 (18) | 78,69 | 55,6 | 84,38 | 65,04 | 79,32 | 82,16 | 63,77 | Pass |
| 3.1.2.1 Area 0 to 40 | | 106,02 | 75,46 | 108,91 | 88,81 | 106,70 | 106,29 | 87,02 | Pass |
| 3.1.2.1 Area 30 to 40 | | 27,33 | 19,85 | 24,53 | 23,78 | 27,38 | 24,13 | 23,26 | Pass |
| 3.1.2.2 Max GZ at ≥ 30 | | 2,972 | 2,15 | 2,71 | 2,55 | 2,98 | 2,68 | 2,50 | Pass |
| 3.1.2.4 Initial GMt | | 16,83 | 12,7 | 30,44 | 13,92 | 17,40 | 22,57 | 14,45 | Pass |
| 3.1.2.5 Angle of equilibrium | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Pass |
| 1.1 Area 0 to 30 | HSC Code 2000 | 43,67 | 28,81 | 43,86 | 44,48 | 28,82 | 44,03 | 44,78 | Pass |
| 1.2 Angle of Maximum GZ | | 19,10 | 18,20 | 20,90 | 20,00 | 18,20 | 20,90 | 20,00 | Pass |
| 1.5 Area between GZ and HA for Hpc + Hw | | 29,96 | 21,48 | 25,80 | 28,20 | 21,46 | 25,94 | 28,39 | Pass |
| 3.2.1 Angle of equilibrium for wind heeling | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Pass |

### Comfort Level Analysis

Analysis of comfort level is carried out by examining Motion Sickness Incidence (MSI) to ensure that the ship is comfortable and safe enough to carry out medical procedures. The analysis was carried out with a wave height of 1.5 meters with three variations of the wave direction following waves, beam waves, and head waves. The ship meets MSI's maximum limit for 8 hours of operation in following wave and head wave conditions but still needs to meet beam wave conditions. Therefore, to continue to carry out medical procedures, the ship must be positioned in such a way that the ship is in the following waves or head waves when it is leaning.

### Final Main Dimension

After calculating and checking the technical limits to meet the requirements and conditions, the final main dimensions of the Eye Clinic Vessel are obtained, as shown in Table 6.

**Table 6.** The main size of the final ship

| Size | Value | Unit |
|---|---|---|
| LOA | 38.27 | meter |
| LPP | 36 | meter |
| B | 10 | meter |
| B1 | 2.50 | meter |
| H | 3 | meter |
| T | 1.80 | meter |
| Vs | 13 | knot |

## Eye Clinic Ship Design

### Lines Plan

Drawing up a Line Plan to show a view or projected image of the ship's hull that is cut across (body plan), vertically lengthwise (sheer plan), and horizontally lengthwise (half breadth plan). The line plan of the Eye Clinic Vessel can be seen in Figure 2.

### General Plan

Making a General Plan is carried out to plan the space needed according to the functions and equipment of the ship. The General Plan of the Eye Clinic Vessel can be seen in Figure 3.

### Safety Plan

According to SOLAS, Eye Clinic Ships can be categorized as passenger ships because they carry more than 12 passengers. Therefore, a Safety Plan was created, considering the minimum standards based on the number of crew, medical personnel, and patients. The Safety Plan of the Eye Clinic Ship can be seen in Figure 4.

### 3D Model

After making a General Plan, then a 3D model design of the ship is made to visualize the shape of the ship. The 3D model of the Eye Clinic Vessel can be seen in Figure 5.

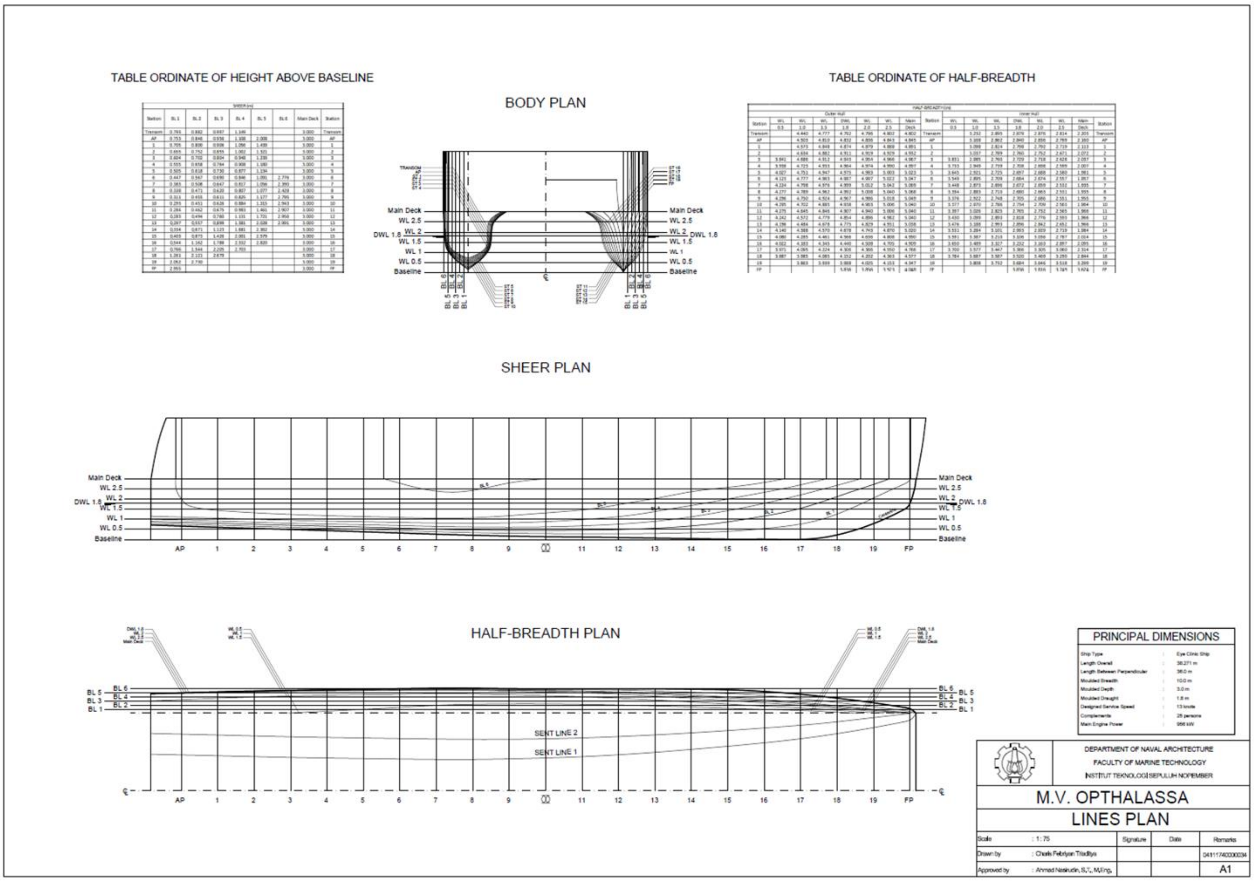


**Figure 2.** Eye Clinic Ship Line Plan Design

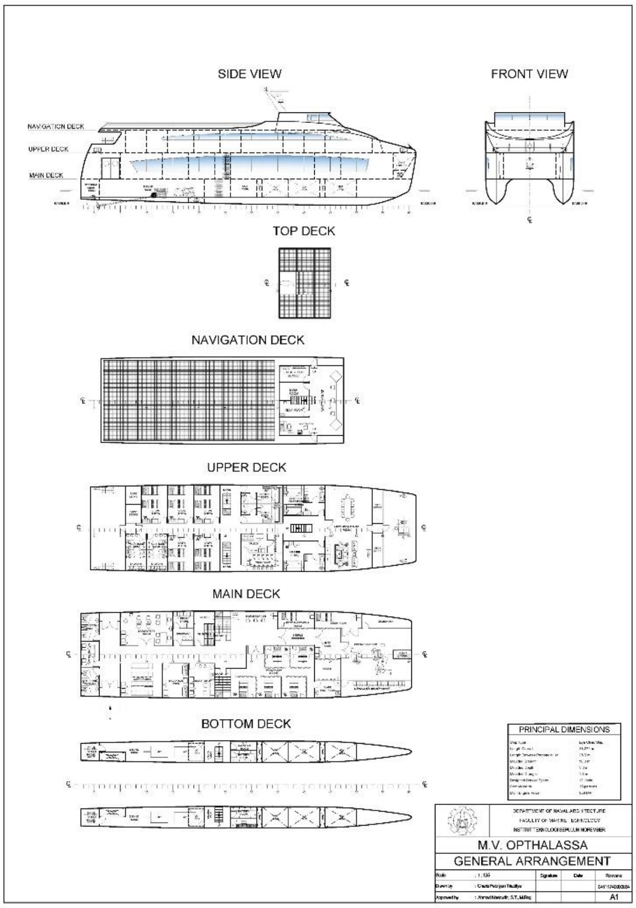


**Figure 3.** General Plan Design for Eye Clinic Ship

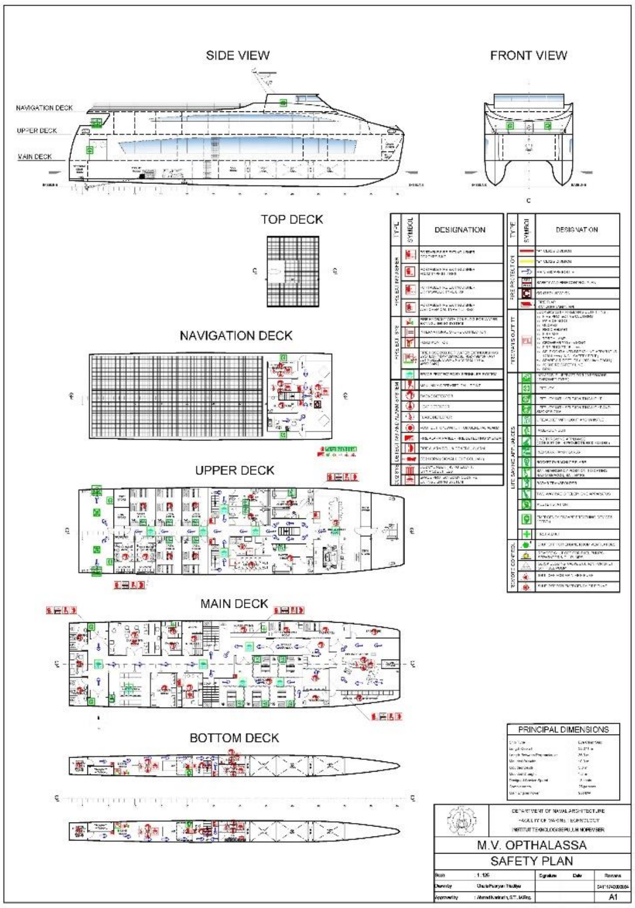


**Figure 4.** Design of Eye Clinic Vessel Safety Plan


**Figure 5.** Design of 3D Model of Eye Clinic Ship

## Conclusion

After calculations and analysis, the conclusions of this study are as follows: (1) The operational pattern of the Eye Clinic Ship has 14 destinations which will be served for 1 week at each destination and are divided into 2 routes so that 1 round trip of the Eye Clinic Ship is 52 days; (2) Obtained ship payload in the form of a minimum deck area of 228.2 m2 with the clinical facilities waiting room, administration room, action room, service room, operating room, inpatient room, nurse post room, laboratory room, lactation room, and bathroom accessible for the disabled; (3) The main dimensions of the ship are obtained, namely LOA = 38.27 m, LPP = 36 m, B = 10 m B1 = 2.5 m, H = 3 m, T = 1.8 m, and Vs = 13 kn; (4) The technical calculations carried out have complied with: (a) The weight calculations carried out produce a weight margin of 5% so that the weight calculation is accepted; (b) The height of the 1.2 meter freeboard hull meets the minimum value of 0.725 m in accordance with SOLAS and PERMENHUB, so that the freeboard condition is acceptable; (c) Calculation of the maximum ship trim condition of 0.188 m and obtained the ship's actual trim condition of 0.125 m with stern trim so that the ship's trim condition is acceptable; (c) The calculation of ship stability with 7 load cases and referring to IMO A.749 (18) and HSC Code 2000 criteria has fulfilled all requirements; (5) Drawings of Line Plans, General Plans, Safety Plans, and 3D Models are obtained.

## Acknowledgements

The author would like to thank the Central Bureau of Statistics for the Provinces of Bali, NTB Province and NTT Province, Health Human Resources Development and Empowerment Agency, and the Ministry of Health which has provided data source assistance to be used in study.

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