



Preliminary Design of a Passenger Catamaran for the Tanglok – Gili Mandangin Route

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ABSTRACT

Passenger transportation between Tanglok Port and Gili Mandangin Island is currently dominated by traditional wooden boats that were not specifically designed to provide adequate passenger comfort, safety, or operational efficiency. This study aims to develop a preliminary design of a catamaran passenger vessel that meets local transportation demands, the operational characteristics of the route, and the technical requirements for high-speed craft. The research methodology consisted of field observations, interviews with local vessel operators, a comprehensive literature review, principal dimension determination using comparable vessel data and linear regression analysis, hull form development with Maxsurf Modeller, general arrangement design, and performance evaluation through speed, resistance, and propulsion power analyses. The proposed vessel is designed to accommodate 40 passengers with principal dimensions of 14.34 m length overall (LOA), 4.45 m breadth, 0.90 m draft, and 1.64 m depth, resulting in a displacement volume of 15.946 m³. The design service speed is 12 knots, satisfying the high-speed craft criteria stipulated in the Regulation of the Minister of Transportation of the Republic of Indonesia No. 12 of 2022. Resistance analysis using the Fung method predicted a total resistance of 28.3 kN at the service speed, corresponding to an effective power requirement of 538.56 HP. Considering propulsion efficiency and an appropriate power margin, the vessel is equipped with two 300 HP Yamaha F300 outboard engines. The proposed catamaran design provides a feasible and technically sound alternative for improving passenger transportation on the Sampang–Gili Mandangin route by enhancing safety, comfort, and operational performance.

INTRODUCTION

Gili Mandangin Island is one of the inhabited small islands located in Sampang Regency, Madura, Indonesia. Covering an area of approximately 1.65 km², the island is home to a population whose livelihoods are predominantly dependent on the fisheries and marine sectors. Situated approximately 9 nautical miles (about 14 km) from Sampang City, Gili Mandangin is relatively accessible via Tanglok Port, with a travel time of approximately 1.5 hours by motorized boat. Despite its limited land area, the island is inhabited by approximately 19,570 residents, making it one of the most densely populated small islands in the region. This demographic condition reflects an active socio-economic environment and highlights the importance of reliable maritime transportation to support community mobility and regional development (Prasetyo et al., 2023).

Passenger transportation between Gili Mandangin Island and Sampang Regency is currently served almost exclusively by traditional wooden boats. These vessels play a crucial role in transporting both passengers and essential goods; however, they were originally designed as cargo vessels and subsequently adapted for passenger services. Consequently, onboard facilities have not been specifically designed to accommodate passenger comfort or safety. Seating capacity is generally inadequate, forcing passengers to occupy limited deck space throughout the voyage. Furthermore, lifesaving appliances and occupational safety equipment, including life jackets and emergency equipment, remain insufficient. These conditions indicate that the existing ferry service does not fully satisfy modern safety, comfort, and operational standards, emphasizing the need for a purpose-built passenger vessel tailored to the transportation requirements of the Tanglok Port–Gili Mandangin route.

Field observations conducted on one of the vessel operators based at Tanglok Port revealed a consistently high demand for passenger transportation. The vessel carries no fewer than 30 passengers per day, including local residents, teachers, and healthcare personnel travelling between Sampang and Gili Mandangin. The voyage typically requires approximately 1.5 hours, depending on prevailing weather and sea conditions.





Figure 1. Passenger Deck Condition

In addition to passenger services, the same vessels are also used to transport various logistical supplies required by the island community. These cargoes primarily consist of daily necessities and construction materials, with a total payload reaching approximately 0.5 tonnes per trip. Operationally, passengers and cargo share the same wooden vessel, where passengers occupy the upper deck while goods are stowed beneath the deck. Moreover, the vessels are frequently utilized to transport motorcycles to Sampang City for maintenance and repair. Up to five motorcycles may be carried during a single voyage, often within the same space occupied by passengers. This mixed-use operational arrangement demonstrates that the existing vessels function as multipurpose carriers without adequate segregation between passengers and cargo, potentially compromising passenger safety, onboard comfort, and transportation efficiency.

Ship design must prioritize safety to ensure compliance with applicable regulations and operational reliability. Key design considerations include hull construction, structural integrity, propulsion systems, electrical installations, stability, and the arrangement of onboard spaces. In addition, lifesaving appliances, emergency equipment, and marine communication systems must be properly integrated into the vessel design to safeguard both passengers and crew. Compliance with these requirements is generally verified through statutory inspections and certification by the relevant maritime authorities. Furthermore, passenger vessels are commonly recommended to employ twin main engines to improve operational reliability, allowing the vessel to maintain propulsion capability in the event of a single-engine failure.

Based on these considerations, this study focuses on the preliminary design of a high-speed passenger vessel intended specifically for operation on the Tanglok Port–Gili Mandangin route. The proposed design aims to provide a safer and more comfortable mode of transportation while addressing the operational needs of the local community. The design process incorporates technical and operational considerations that reflect local environmental conditions and transportation demand. Furthermore, the proposed vessel complies with the requirements of the Regulation of the Minister of Transportation of the Republic of Indonesia No. 12 of 2022 concerning the Seaworthiness of Indonesian High-Speed Craft, ensuring that the design satisfies the prescribed safety and operational standards.

A catamaran hull configuration was selected in this study as an alternative to a conventional monohull due to its superior hydrodynamic characteristics, enhanced stability, and suitability for the relatively shallow waters along the Tanglok Port–Gili Mandangin route. Hydrodynamically, catamarans exhibit lower resistance at service speeds because of their slender hull forms, resulting in improved propulsion efficiency and reduced power requirements (Wulandari et al., 2025). In addition, the twin-hull configuration provides greater transverse stability than monohull vessels, significantly reducing rolling motion and thereby improving passenger comfort, particularly in coastal waters (Xhaferaj, 2025). From an operational perspective, catamarans also possess a shallower draft, enabling safer navigation in shallow waters influenced by tidal variations, such as those surrounding Tanglok Port. Another important advantage is the larger deck area, which facilitates a more efficient arrangement of passenger spaces and safety equipment in accordance with high-speed craft standards (Thomas et al., 2007). These technical and operational advantages make the catamaran configuration a more suitable solution for providing fast, safe, and comfortable passenger transportation on the Tanglok Port–Gili Mandangin route.

LITERATURE REVIEW

Maritime Transportation for Small-Island Communities

Maritime transportation serves as the backbone of connectivity for small-island communities, functioning as the primary means of passenger mobility, logistics distribution, and access to education, healthcare, and economic activities. As the world's largest archipelagic country, Indonesia is highly dependent on maritime transportation to connect its numerous islands scattered across the archipelago. However, the provision of maritime transport services in many small islands continues to face significant challenges, including limited vessel availability, inadequate port



infrastructure, and low service frequency and quality. (Naufal, 2024) reported that insufficient maritime transportation facilities and infrastructure are among the primary factors contributing to poor inter-island connectivity in Tambelan District. Similarly, (Arbiyati & Sulistiyono, 2024) found that although the development of port facilities in the Seribu Islands has improved community mobility, the passenger vessels operating on these routes still do not fully satisfy the requirements for safe and comfortable passenger transportation.

Similar challenges have also been identified in other Indonesian archipelagic regions. (mafrisal et al., 2024) reported that traditional vessels remain the dominant mode of transportation in the Sangkarrang Islands, Makassar, despite limitations related to vessel condition, service quality, and operational efficiency. Comparable issues have also been observed internationally. (Vakili et al., 2023) emphasized that communities in *Small Island Developing States* (SIDS) rely heavily on maritime transportation as a lifeline to sustain regional connectivity and economic activities. Nevertheless, these regions continue to face challenges associated with aging vessel fleets, high operating costs, and inadequate transport services. Although previous studies have extensively addressed maritime connectivity, transportation policy, and port infrastructure, relatively limited attention has been devoted to the development of passenger vessel designs specifically tailored to the operational characteristics of individual routes and the transportation needs of small-island communities. Therefore, this study proposes a preliminary catamaran passenger vessel design as an engineering solution to enhance the safety, comfort, and operational efficiency of passenger transportation on the Tanglok Port–Gili Mandangin Island route.

Safety and Operational Limitations of Traditional Passenger Boats

Traditional vessels remain the primary mode of transportation in many Indonesian archipelagic regions due to their ability to serve remote islands that are not accessible by commercial ferry services. Nevertheless, numerous studies have identified significant limitations in terms of safety and operational performance. The implementation of the *Safety Management System* (SMS) in traditional shipping (*Pelra*) remains suboptimal because of technical, operational, and human resource constraints, resulting in incomplete compliance with existing maritime safety regulations (Wahid et al., 2024). In addition, the safety of passenger vessels is strongly influenced by the availability of lifesaving appliances, vessel arrangement, passenger capacity, and onboard operational practices (Rahadi et al., 2024). (Hasanudin et al., 2025) further reported that many traditional vessels do not determine passenger capacity based on stability analysis, thereby increasing safety risks, particularly when the vessels are also used to transport cargo.

These findings are consistent with the field observations conducted on the Tanglok Port–Gili Mandangin Island route. The vessels currently operating on this route are essentially traditional wooden cargo boats that have been adapted to transport both passengers and cargo simultaneously. Passengers, motorcycles, construction materials, and daily necessities are accommodated within the same open space without any clear separation between passenger and cargo areas. Furthermore, the vessels are not equipped with dedicated passenger seating, requiring passengers to remain seated on the deck throughout the voyage. Most of the observed vessels also lack adequate lifesaving appliances, including an insufficient number of life jackets corresponding to the passenger capacity. These conditions indicate that the existing vessels were not originally designed to provide passenger transportation services that satisfy fundamental requirements for safety, comfort, and onboard arrangement. Therefore, there is a need to develop a purpose-designed passenger vessel that accommodates the operational characteristics of the route, meets community transportation demands, and complies with applicable passenger safety standards. This study addresses these needs through the preliminary design of a catamaran passenger vessel.

Application of Catamaran Hull Forms for Passenger Vessels

Catamaran vessels have been widely developed as an alternative for passenger transportation because they offer several advantages over conventional monohull vessels, particularly in terms of stability, deck area, hydrodynamic performance, and passenger comfort. (Chrismianto et al., 2024) demonstrated that a catamaran tourist vessel provides a larger deck area while satisfying the stability requirements established by the International Maritime Organization (IMO), making it suitable for passenger transport operations. Similarly, (Santoso et al., 2024) reported that catamaran ferries exhibit superior stability characteristics and improved motion responses under various operational and environmental conditions, thereby enhancing passenger safety and comfort during voyages. In addition, (Khoirulloh et al., 2024) highlighted that the twin-hull configuration offers greater flexibility in onboard space arrangement, enabling higher passenger capacity without compromising vessel stability. Considering these advantages, catamarans represent a promising alternative for short-distance inter-island passenger services, particularly in archipelagic regions that require vessels with high stability, spacious passenger accommodation, and improved operational efficiency compared with traditional vessels.

Preliminary Ship Design Methods

The preliminary design stage is a critical phase in ship design, as it establishes the principal dimensions and general characteristics that determine the vessel's technical and operational performance. The overall ship design process is traditionally represented by the design spiral, which illustrates the sequential and iterative nature of ship design. Within this framework, various ship characteristics and design aspects are progressively evaluated and refined





based on the outcomes of preceding design stages, allowing the design to gradually converge toward a feasible solution that satisfies the established requirements, as illustrated in Figure 1 (Bottero & Gualeni, 2022). Although the design spiral provides a systematic framework for ship design, it does not prescribe a specific technique for determining the initial principal dimensions, which remain one of the most influential inputs during the conceptual design stage.



Figure 2. Ship Design Spiral

To estimate the principal dimensions, several methods have been proposed, including the parent ship method, statistical regression, and optimization-based approaches. The parent ship method estimates the dimensions of a new vessel by adapting the characteristics of existing vessels with similar operational requirements, making it particularly suitable when reliable reference vessels are available (Budianto, 2024). Statistical regression methods establish mathematical relationships between principal dimensions and operational parameters using historical ship databases, enabling rapid estimation during the conceptual design stage (Mauro & Salem, 2025). In contrast, optimization-based methods employ numerical algorithms to identify optimal design solutions by simultaneously considering multiple design objectives and constraints, such as resistance, stability, weight, or economic performance. Although optimization techniques can produce highly efficient designs, they generally require extensive datasets, sophisticated computational models, and clearly defined objective functions, making them more suitable for advanced design stages rather than preliminary conceptual design. Considering the availability of comparable passenger vessels operating under similar conditions and the objective of developing a practical conceptual design, this study adopts a combination of the parent ship method and linear regression analysis to estimate the principal dimensions of the proposed catamaran passenger vessel before proceeding to hull modeling and performance evaluation.

Resistance, Propulsion, and Operational Performance of Catamarans

Hydrodynamic performance evaluation is a crucial stage in preliminary ship design, as it determines the required propulsion power, engine selection, and overall operational efficiency of the vessel. For catamarans, the resistance characteristics are influenced not only by the principal dimensions and service speed but also by the twin-hull configuration (*demi-hull spacing*), which affects wave interference and the resulting total resistance. Previous studies have shown that resistance and power prediction are commonly performed during the conceptual design stage using empirical and numerical software, such as Maxsurf Resistance, allowing engine power requirements to be estimated before more sophisticated analyses, such as *Computational Fluid Dynamics* (CFD), are conducted. Chrismianto et al. (2024) employed Maxsurf Resistance to evaluate the hydrodynamic performance of a catamaran tourist vessel and demonstrated that the software provides reliable estimates of total resistance and propulsion power during the conceptual design stage. Similarly, (Tadros et al., 2023) emphasized that the optimization of high-speed catamaran vessels requires the simultaneous evaluation of resistance, propulsion power, and propulsion characteristics to achieve an efficient design without compromising operational performance. Furthermore, resistance prediction, propulsion performance, and engine power estimation constitute an integrated process in ship performance assessment, since the resistance generated at a given operating speed determines the effective power requirement, which subsequently influences the required propulsion and engine power (C. Zhang et al., 2023). Therefore, these parameters provide an important basis for evaluating whether the selected propulsion system can satisfy the intended service speed and operational requirements of the vessel. Accordingly, this study utilizes Maxsurf Resistance to predict the total resistance and propulsion power requirements of the proposed catamaran, which are subsequently used as the basis for main engine selection to ensure that the vessel can achieve the intended service speed efficiently.



Ship Safety and High-Speed Craft Regulation

The design of high-speed passenger vessels in Indonesia shall comply with the Regulation of the Minister of Transportation of the Republic of Indonesia No. PM 12 of 2022 on the Seaworthiness of Indonesian-Flagged High-Speed Craft. This regulation adopts the fundamental principles of the IMO International Code of Safety for High-Speed Craft (HSC Code) into the national regulatory framework and establishes the minimum seaworthiness requirements for high-speed craft operating in Indonesian waters. The regulation covers a wide range of safety aspects, including structural integrity, stability, fire protection, lifesaving appliances, navigation and communication systems, passenger accommodation, escape routes, and emergency evacuation procedures. Its primary objective is to ensure that high-speed passenger vessels provide an adequate level of safety for both passengers and crew throughout their operational service. Consequently, compliance with these safety requirements must be considered from the preliminary design stage, particularly in the development of the general arrangement, passenger capacity, accommodation layout, escape routes, and onboard safety equipment. Based on PM 12 of 2022, several safety requirements have a direct influence on the preliminary design of passenger vessels. Therefore, the provisions specified in the regulation are adopted as the primary design criteria for developing the general arrangement and passenger facilities of the proposed catamaran. A summary of the safety requirements considered in this study is presented in Table 1.

Table 1. Principal safety requirements adopted from PM 12 of 2022 for the preliminary design of the proposed passenger catamaran.

Safety Aspect	Requirement under PM 12/2022	Implementation in This Study
Passenger capacity	The number of passengers shall comply with the approved design capacity and stability requirements.	The vessel is designed to accommodate 40 passengers in accordance with the design criteria.
Passenger seating	Safe and adequate seating shall be provided for all passengers.	Individual passenger seats are provided throughout the passenger accommodation area.
Escape routes	Escape routes shall be clearly identified and remain unobstructed during operation.	A central aisle is provided to facilitate rapid evacuation to the exit doors.
Emergency exits	Adequate emergency exits shall be provided to enable safe evacuation.	Exit doors are arranged to provide direct access to the open deck.
Passenger corridors	Corridors shall provide sufficient width for passenger movement and emergency evacuation.	Corridor dimensions are determined in accordance with PM 12/2022 requirements.
Life jackets	Life jackets shall be available for every person on board.	Life jackets are provided for all passengers and crew, including additional reserve units.
Life buoys	The vessel shall be equipped with life buoys in accordance with the applicable regulations.	Life buoys are installed on both port and starboard sides of the vessel.
Fire protection	Appropriate fire detection and firefighting equipment shall be installed.	Portable fire extinguishers are provided in the passenger compartment and engine room.
Navigation and communication	Navigation lights and communication equipment shall comply with applicable regulations.	Navigation and communication systems are incorporated into the vessel specification.
Stability	The vessel shall satisfy the stability criteria specified for high-speed craft.	Stability performance is evaluated during the preliminary design stage.

METHOD

This study adopted a ship design approach to develop a preliminary design of a passenger ferry intended for operation on the Tanglok Port–Gili Mandangin Island route. The research methodology followed a systematic naval architectural design process consisting of problem identification, data collection, determination of principal dimensions, hull-form development, general arrangement design, and performance evaluation. Such a structured design framework is widely adopted in preliminary ship design to ensure that vessel performance, safety, and operational requirements are addressed during the conceptual design stage (Tadros et al., 2023).

The first stage involved identifying the existing transportation problems through field observations of ferry operations between Tanglok Port and Gili Mandangin Island. The assessment focused on evaluating vessel characteristics, passenger accommodation, cargo operations, onboard safety facilities, and operational constraints encountered during daily services. The findings revealed that the existing vessels were originally designed as wooden cargo boats and subsequently adapted for passenger transportation, resulting in limited passenger comfort and inadequate compliance with modern maritime safety standards.

Primary data were collected through field observations, interviews with vessel operators and port personnel, photographic documentation of existing vessels, and direct measurements of operational characteristics. Secondary data



were obtained from technical literature, government regulations, and previous studies related to passenger vessel design and high-speed craft. The collected data included passenger capacity, cargo capacity, voyage duration, sailing distance, operating speed, and waterway characteristics along the Tanglok Port–Gili Mandangin route. Based on field observations, the existing vessels accommodate approximately 30 passengers with an average sailing time of 1.5 hours over a route length of approximately 14.62 km.

The determination of the vessel's principal dimensions was carried out using the sister ship approach combined with linear regression analysis. A database of comparable passenger catamarans was compiled to establish statistical relationships between passenger capacity and principal dimensions. Regression equations were subsequently developed to estimate the length overall (LOA), breadth (B), draft (T), and depth (H) corresponding to the target capacity of 40 passengers. The parent ship method has been extensively employed in preliminary ship design because it enables designers to obtain principal dimensions that are technically feasible while maintaining consistency with proven vessel characteristics. Furthermore, regression-based approaches improve the efficiency of conceptual design by predicting principal dimensions from existing ship databases (S. Zhang, 2022; S. Zhang et al., 2021).

Following the determination of the principal dimensions, the hull geometry was developed using Maxsurf Modeller. The hull surface was generated based on the estimated principal dimensions and subsequently refined through fairing and smoothing processes to ensure hydrodynamic continuity and geometric consistency. Digital hull modelling software has become an essential tool in modern naval architecture because it enables rapid hull generation, hydrostatic analysis, and geometric validation during the preliminary design stage (Feng et al., 2021).

The general arrangement (GA) was then prepared to define the spatial layout of the vessel. The arrangement included passenger seating, machinery spaces, fuel tanks, battery compartments, storage areas, escape routes, and lifesaving equipment. Particular attention was given to passenger circulation, accessibility, operational functionality, and compliance with maritime safety requirements. The arrangement was developed in accordance with the Regulation of the Minister of Transportation of the Republic of Indonesia No. 12 of 2022 concerning the Seaworthiness of Indonesian High-Speed Craft.

The hydrodynamic performance of the proposed vessel was evaluated through resistance and propulsion analyses. Total resistance was estimated using the Fung resistance prediction method, while the effective power (EHP) was determined from the predicted resistance at the design service speed. Subsequently, propulsion efficiency coefficients and an appropriate power margin were incorporated to estimate the required installed engine power. Recent studies have demonstrated that resistance prediction and propulsion performance analyses remain fundamental components in preliminary ship design because they directly influence propulsion system selection, energy efficiency, and operational performance (Tadros et al., 2023; Wang et al., 2023).

Finally, the proposed design was assessed by comparing its principal dimensions, passenger capacity, propulsion requirements, and operational characteristics with the existing transportation system. This evaluation aimed to determine whether the proposed catamaran provides measurable improvements in passenger safety, comfort, operational efficiency, and suitability for the environmental conditions of the Tanglok Port–Gili Mandangin route. The next stage of the study involved evaluating the vessel's performance, including resistance prediction, propulsion power estimation, fuel consumption assessment, and the preliminary design of the onboard electrical system. Ship resistance was analyzed using Maxsurf Resistance, which applies empirical resistance prediction methods to estimate the total resistance at the design service speed. The input parameters required for the analysis are described as follows.

Vessel Capacity

Based on field observations and interviews with local vessel operators, the operational characteristics of the existing passenger vessels were identified. Traditional wooden passenger boats generally carry cargo with a payload ranging from 250 to 500 kg in addition to passengers. Interviews with operators indicated that the average number of passengers per voyage is approximately 30 persons. However, to accommodate future transportation demand and improve service quality, the proposed catamaran was designed with a passenger capacity of 40 persons.

Route Characteristics

Route characteristics, including the sailing distance and voyage duration between Tanglok Port and Gili Mandangin Island, were collected to establish the operational requirements of the proposed vessel. Based on field observations and measurements using digital mapping tools, the sailing distance was determined to be approximately 14.82 km. The navigation route is illustrated in Figure 2.

Under normal operating conditions, the existing traditional vessels require approximately 1.5 hours to complete a single voyage between Tanglok Port and Gili Mandangin Island. The voyage duration is influenced by several factors, including vessel speed, weather conditions, sea state, and the hydrodynamic characteristics of the navigation channel (Aldhyani et al., 2022). These operational data served as the basis for determining the design service speed and evaluating the operational performance of the proposed vessel.



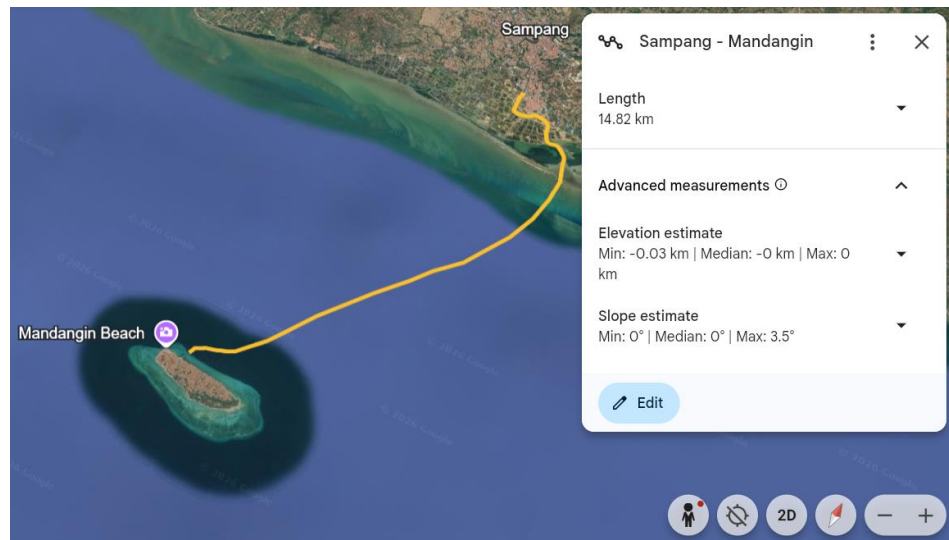


Figure 3. Sampang–Mandangin Shipping Route

Waterway Conditions

Hydrographic information was obtained through literature reviews and secondary data describing the environmental conditions surrounding Tanglok Port. These data were used primarily to determine an appropriate vessel draft and principal dimensions that would ensure safe navigation throughout the operating area. Available hydrographic data indicate that the water depth near Tanglok Port varies between 2.6 and 3.0 m during high tide (Indonesian Geospatial Information Agency, 2023), whereas the depth decreases to approximately 1.0 m during low tide. Similarly, the navigable channel width is strongly influenced by tidal conditions, measuring approximately 15 m during high tide and reducing to approximately 10 m at low tide. These environmental constraints were considered during the preliminary design process to ensure that the proposed vessel can operate safely under varying tidal conditions while maintaining adequate under-keel clearance and maneuverability.

Comparative vessel data

The determination of optimal principal dimensions represents one of the most important stages of preliminary ship design. Accordingly, an optimization process is required to establish vessel dimensions that satisfy both operational requirements and design constraints. Conventional ship design generally begins with one or more assumed principal dimensions, followed by repeated analyses and iterative optimization using the design spiral concept (Papanikolaou, 2021). Although widely adopted in naval architecture, the design spiral becomes increasingly time-consuming as the number of design variables and validation requirements increases.

To improve the efficiency of the preliminary design process, this study adopted the parent ship method (also known as the comparative ship method). This approach utilizes data from existing vessels with similar operational characteristics as design references for estimating the principal dimensions of the proposed vessel (Tadros et al., 2023). The parent ship database provides information on the principal particulars, including length overall (LOA), breadth (B), depth (H), and draft (T). These data were subsequently analyzed using linear regression analysis to establish statistical relationships between passenger capacity and the principal dimensions, enabling the determination of dimensions that are both technically feasible and operationally appropriate (Zhang et al., 2021; Wang et al., 2023). In this study, the principal dimensions of the proposed catamaran passenger vessel were determined using the parent ship method combined with linear regression analysis. The database of comparable vessels used in the analysis is presented in Table 2.

Table 2. Principal Dimensions and Characteristics of Comparable Catamaran Passenger Vessels

Ship Name	LOA (m)	B (m)	H (m)	T (m)	No. of Passanger	L/B	B/T
Jericho	6	2,26	0,9	0,45	8	2,65	5,02
Catamaran Glass Bottom	9,3	3,2	1	0,3	12	2,91	10,67
Grand Sea 12m High Speed Catamaran	12	3,7	0,91	0,55	20	3,24	6,73
Shuttle Cat	10	3,5	1,4	0,6	20	2,86	5,83
Panjahitan 473	13,24	4,63	1,54	0,98	24	2,86	4,72
Grand Sea 2	11,6	3,2	1,1	0,61	25	3,63	5,25
Grand Sea	12,8	3,4	1,22	0,61	26	3,76	5,57
GRP Catamaran	11,65	4,5	1,22	0,61	30	2,59	7,38



China GRP Ferry	12	2,88	1,22	0,61	30	4,17	4,72
Nusa Jaya Cruise 2	12,55	2,8	1,8	1	38	4,48	2,80
Incat Crowther 20m Ferry	20,5	6,5	2,2	2	50	3,15	3,25
TM203 Catamaran Ferry	20	6,4	2,5	1	90	3,13	6,40
Electric Catamaran Ferry	15,8	5,28	1,8	0,96	30	2,99	5,50

Source: (Boswel & Helmi, 2023; Grandsea, n.d.), internet

RESULT

Principal Dimensions

The determination of the principal dimensions is a critical stage in the preliminary ship design process, as these parameters directly influence the vessel's hydrodynamic performance, stability, and suitability for the intended operational conditions. In this study, the principal dimensions were determined using a linear regression approach based on a database of comparable catamaran passenger vessels with varying passenger capacities. The dataset comprised several catamarans with different passenger capacities, enabling the establishment of mathematical relationships between passenger capacity, considered as the independent variable, and the principal dimensions, namely length (L), breadth (B), depth (H), and draft (T). This approach provides a rapid and systematic estimation of the initial principal dimensions, which subsequently serve as the basis for hull form development and further design analyses.

The principal dimensions of the reference vessels listed in Table 2 were processed using Microsoft Excel to generate regression curves and mathematical equations describing the relationships between passenger capacity and each principal dimension. The resulting regression curves are presented in Figure 4, while the corresponding regression equations and coefficients of determination (R^2) are summarized in Table 3. The high correlation coefficients obtained indicate that passenger capacity exhibits a strong relationship with the principal dimensions of the selected catamaran vessels, thereby providing a reliable basis for estimating the dimensions of the proposed 40-passenger catamaran.

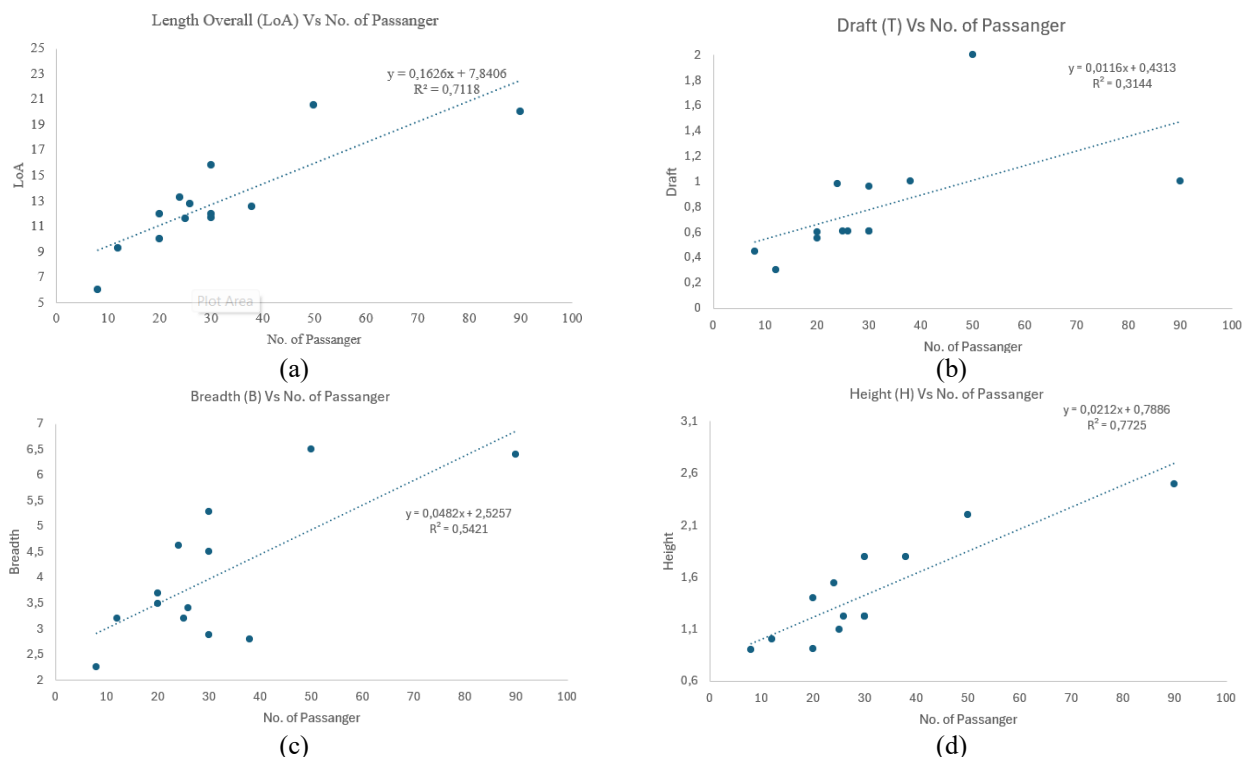


Figure 4. regression curves (a) LoA, (b) Draft (T), (c) Breadth (B), (d) Height (H) Vs Number of Passenger

Figure 4 presents the regression results used to estimate the principal dimensions of the proposed catamaran based on the number of passengers. In general, all regression plots indicate a relationship between passenger capacity and vessel dimensions, meaning that an increase in the number of passengers requires larger principal dimensions to provide sufficient accommodation space, buoyancy, stability, and operational safety. Figure 4(a) shows the relationship between length overall (LOA) and passenger capacity, where LOA increases as the number of passengers increases. This trend reflects the need for a longer hull to accommodate additional passenger seating, improve longitudinal space arrangement, and support displacement requirements. Figure 4(b) illustrates the relationship between draft (T) and passenger capacity. The increasing draft trend indicates that a vessel carrying more passengers requires greater submerged volume to provide sufficient buoyancy and maintain an adequate load-carrying capability. Figure 4(c) shows



the regression between breadth (B) and the number of passengers, where the increase in breadth contributes to a larger deck area and improved transverse stability, which are particularly important for catamaran passenger vessels. Meanwhile, Figure 4(d) presents the relationship between height (H) and passenger capacity, indicating that a greater depth is required to maintain adequate freeboard, structural volume, and internal arrangement as vessel capacity increases. Therefore, the regression curves provide a quantitative basis for determining the principal dimensions of the proposed 40-passenger catamaran, ensuring that the selected dimensions remain consistent with comparable existing vessels and are suitable for subsequent hull modelling, resistance analysis, and general arrangement design.

Table 3. Regression Equations

No	Parameter	Equation	Description
1	Length Overall (LoA)	$LoA = 0,1626(No. Pax) + 7,8406$	Relationship between ship length and number of passengers
2	Breadth (B)	$B = 0,0482(No. Pax) + 2,5257$	Relationship between ship breadth and number of passengers
3	Draft (T)	$T = 0,0116(No. Pax) + 0,4313$	Relationship between ship draft and number of passengers
4	Height (H)	$H = 0,0212(No. Pax) + 0,7886$	Relationship between ship height and number of passengers

Based on the regression equations presented in Table 3, the principal dimensions of the proposed catamaran passenger vessel were estimated for a design capacity of 40 passengers. The calculated principal dimensions are presented as follows:

$$LoA = 0.1626(40) + 7.8406 = 14.34 \text{ meter}$$

$$B = 0.0482(40) + 2.5257 = 4.45 \text{ meter}$$

$$T = 0.0116(40) + 0.4313 \text{ meter}$$

$$H = 0.0212(40) + 0.7886 \text{ meter}$$

The calculated principal dimensions obtained from the regression analysis are summarized in Table 4, which served as the basis for the subsequent hull form development, resistance prediction, and general arrangement design.

Table 4. Principal Dimension

Parameter	Value
Length Overall (LoA)	14,34
Breadth (B)	4,45
Draft (T)	0,90
Height (H)	1,64

Lines Plan

Following the determination of the principal dimensions through the regression analysis, the next stage involved the development of the vessel's hull form. In this study, the hull was modeled using Maxsurf Modeller, with the modeling process initiated from a new design based on the estimated principal dimensions. The hull geometry was then refined to produce a fair and continuous surface suitable for hydrodynamic analysis and subsequent design stages. The finalized hull model was used to generate the Lines Plan, consisting of the Body Plan, Sheer Plan, and Half-Breadth Plan, which collectively describe the three-dimensional geometry of the proposed catamaran. The resulting hull form was subsequently developed into a three-dimensional (3D) model to facilitate visualization and to provide the geometric basis for the resistance prediction, propulsion analysis, and general arrangement design. The completed Lines Plan of the proposed catamaran is presented in Figure 5.

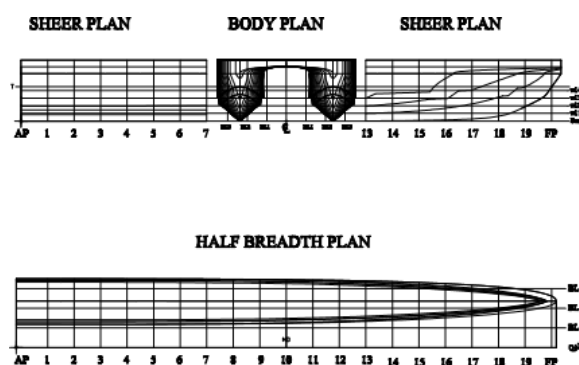


Figure 5. Lines Plan



Service Speed

According to the Regulation of the Minister of Transportation of the Republic of Indonesia No. PM 12 of 2022 on the Seaworthiness of Indonesian-Flagged High-Speed Craft, a vessel is classified as a high-speed craft (HSC) if its maximum speed is equal to or greater than the value determined by the following equation:

$$V_s = 3,7\nabla^{0,1667} (m/s) \quad (1)$$

$$V_s = 7,192\nabla^{0,1667} (knot) \quad (2)$$

Where ∇ represents the displacement volume (m^3) at the design waterline. Based on the developed hull form, the proposed catamaran has a displacement volume of $15.946 m^3$. Substituting this value into the equation yields a minimum required speed of $5.87 m/s$, which is equivalent to 11.41 knots, for the vessel to be classified as a high-speed craft under PM 12 of 2022. The proposed catamaran was designed with a service speed of 12 knots, which exceeds the minimum speed requirement specified by the regulation. Therefore, the proposed design satisfies the high-speed craft classification criteria stipulated in the Regulation of the Minister of Transportation of the Republic of Indonesia No. PM 12 of 2022. The detailed calculation is presented below.

Ship Resistance

Ship resistance is the resistive force acting on a vessel as it moves through water at a given speed. The total resistance consists of several components, including frictional resistance, wave-making resistance, and additional resistance arising from viscous effects and hull characteristics. An accurate prediction of ship resistance is essential during the preliminary design stage because it directly influences the propulsion power requirement, engine selection, and overall operational performance of the vessel.

Prior to selecting an appropriate resistance prediction method, the principal parameters governing the applicability of the available empirical methods were first evaluated. Based on the principal dimensions of the proposed catamaran, several hull-form parameters were calculated and subsequently used as the basis for determining the most suitable resistance prediction method in Maxsurf Resistance. This selection process is essential to ensure that the chosen prediction method is applicable to the hull geometry and operational characteristics of the proposed vessel, thereby providing reliable resistance estimates for the subsequent propulsion analysis. The calculated parameters used for selecting the resistance prediction method are presented as follows:

$$L/B = L_{wl}/B \quad (3)$$

$$B/T = B_{wl}/T \quad (4)$$

$$L/H = L_{wl}/H_{mld} \quad (5)$$

$$T/H = T/H_{mld} \quad (6)$$

$$Midship = 1/2 L_{wl} \quad (7)$$

$$Froude Number(Fn) = V_s/(g \times L_{wl})^{1/2} \quad (8)$$

Based on the parameters calculated from Equations (3)–(8), the appropriate resistance prediction method was subsequently selected. The selection was performed by comparing the calculated hull-form parameters and operational characteristics of the proposed vessel with the applicability ranges of the resistance prediction methods available in Maxsurf Resistance. The applicability criteria for each method are summarized in Table 5, which served as the basis for selecting the most suitable resistance prediction method for the proposed catamaran.

Table 5. applicability criteria for Ship Resistance Prediction method

Criteria	Method	Value Range	Value	Description
Froude Number (Fn)	Holtrop	0.00 - 0.80	0.694	Applicable
	Van Oortmerssen	0.00 - 0.50		Not Applicable
	Series 60	0.282 - 0.677		Not Applicable
	Compton	0.10 - 0.60		Not Applicable
	Fung	0.134 - 0.908		Applicable
L/B	Holtrop	3.9 - 15	3.84	Not Applicable
	Van Oortmerssen	3.00 - 6.20		Applicable
	Series 60	5.50 - 8.50		Not Applicable
	Compton	4.00 - 5.20		Not Applicable
	Fung	2.52 - 17.593		Applicable
B/T	Holtrop	2.10 - 4.00	4	Applicable
	Van Oortmerssen	1.90 - 4.00		Applicable
	Series 60	2.5 - 4.5		Applicable
	Compton			Applicable
	Fung	1.696 - 10.204		Applicable



Based on Table 5, the Fung Method was selected as the most appropriate resistance prediction method because all evaluated parameters, including the Froude number (Fn), length-to-breadth ratio (L/B), and breadth-to-draft ratio (B/T), fall within the recommended applicability range of the method. In contrast, the other empirical methods satisfy only part of the required criteria and are therefore considered less suitable for the proposed catamaran. Accordingly, the resistance analysis was performed using the Fung Method implemented in Maxsurf Resistance. The simulation was carried out over a speed range of 0 to 16 knots, and the predicted total resistance at each speed is presented in Table 6.

Table 6. Resistance Simulation Result

Speed (kN)	Froude Number LWL	Froude Number Vol	Fung Resistance (kN)	Fung Power (hp)
0	0	0	--	--
1,2	0,053	0,124	--	--
2	0,088	0,206	--	--
2,8	0,124	0,288	--	--
3,6	0,159	0,371	0,9	2,249
4	0,177	0,412	1,1	3,083
4,8	0,212	0,494	1,7	5,525
5,6	0,247	0,577	2,5	9,719
6	0,265	0,618	2,9	12,023
7,2	0,318	0,742	4,9	24,296
8	0,353	0,824	6,6	36,285
9,2	0,406	0,948	9,7	61,726
10	0,441	1,03	13,6	93,603
11,2	0,494	1,154	22	170,219
12	0,53	1,236	28,3	234,563
13,2	0,583	1,36	36,9	336,042
14	0,618	1,442	41,5	400,777
15,2	0,671	1,566	46,6	488,459
15,6	0,689	1,607	47,8	514,937
16	0,706	1,648	48,9	540,114

Main Engine Power

The required main engine power was determined based on the total resistance of the vessel at the designated service speed. According to the resistance analysis, the proposed catamaran experiences a total resistance of 28.3 kN at a service speed of 12 knots. This resistance value was subsequently used to calculate the Effective Power (PE), which represents the power required to overcome the total hydrodynamic resistance of the vessel while maintaining the specified service speed. The effective power was calculated using the following equation:

$$PE = Rt \text{ (kN)} \times Vs \text{ (m/s)}$$

$$PE = 28,3 \text{ (kN)} \times 6,17 \text{ (m/s)}$$

$$PE = 174,61 \text{ kW}$$

The calculated Effective Power (PE) represents the power required to propel the vessel's hull at the designated service speed of 12 knots. However, the power delivered by the main engines cannot be entirely converted into useful thrust because of energy losses associated with the propeller, transmission system, and the interaction between the propeller and the hull. Consequently, the required engine power was determined by considering the overall propulsive efficiency (η_P), which accounts for the combined efficiencies of the propulsion components.

In this study, an overall propulsive efficiency (η_P) of 0.50 was adopted, representing a conservative value for small passenger vessels equipped with outboard propulsion systems (Rawson & Tupper, 2001). This value reflects the combined effects of propeller efficiency, hull efficiency, and transmission efficiency, and falls within the range commonly adopted for preliminary ship design. Accordingly, the required Brake Power (PB) was calculated using the following equation:

$$PB = PE / \eta_P$$

$$PB = 174,61 \text{ kW} / 0,5$$

$$PB = 349,22 \text{ kW} = 468,31 \text{ HP}$$

To account for operational conditions that are not fully represented in the calm-water resistance analysis, including the effects of waves, wind, variations in loading condition, hull surface roughness, engine performance degradation, and acceleration requirements, a 15% power margin was applied. Incorporating this design margin ensures





that the propulsion system is capable of maintaining the required service speed under realistic operating conditions and provides an adequate reserve for safe and reliable vessel operation.

The Maximum Continuous Rating Brake Power (BHP_{MCR}), representing the required engine power after applying the design margin, was calculated using the following equation:

$$BHP_{MCR} = PB \times \text{sea margin} (1 + 15\%)$$

$$BHP_{MCR} = 468,31 \text{ HP} \times \text{sea margin} (1 + 15\%)$$

$$BHP_{MCR} = 538,56 \text{ HP}$$

Since the vessel is designed to use two outboard engines, the total required propulsion power was divided equally between the two units, resulting in a minimum power requirement of approximately 269.28 HP per engine. Accordingly, two Yamaha F300 outboard engines, each rated at 300 HP, were selected. The combined installed power of 600 HP exceeds the calculated requirement and therefore provides sufficient power to achieve the intended service speed while maintaining an adequate operational reserve. The specifications of the selected main engine are presented in Table X.

Table 7. Main Engine Specification

Parameter	Specification
Engine model	Yamaha F300
Engine type	24-valve, DOHC-VCT, 60° V6
Rated power	300 HP
Operating speed	5,000–6,000 rpm
Engine displacement	4,200 cm ³
Lubrication system	Fuel-oil mixture
Fuel consumption	88.8 L/h at 5,500 rpm
Bore × stroke	96.0 mm × 96.0 mm

General Arrangement

The General Arrangement (GA) was developed by considering the operational requirements, passenger safety, and onboard comfort in accordance with the intended function of the vessel as a catamaran passenger craft. The arrangement of spaces on the main deck was designed to provide adequate passenger circulation, facilitate efficient embarkation and disembarkation, and ensure unobstructed evacuation routes in emergency situations. In addition, weight distribution was considered during the arrangement of compartments and onboard equipment to maintain proper trim, balance, and overall vessel stability. The layout was developed in accordance with the Regulation of the Minister of Transportation of the Republic of Indonesia No. PM 12 of 2022, particularly the provisions related to passenger accommodation, lifesaving appliances, and machinery systems.

The proposed General Arrangement consists of three principal views: Side View, Main Deck, and Draft Section, as presented in Figure 6. The Side View illustrates the wheelhouse located at the forward section of the vessel and the propulsion system comprising two outboard engines installed at the stern. The Main Deck arrangement accommodates 20 passenger seats arranged in two rows along a central aisle, with a dedicated life jacket storage area located at the aft section of the passenger compartment. The Draft Section illustrates the internal compartment arrangement beneath the main deck, consisting of an equipment space, ballast tanks, fuel tanks, and a battery compartment. These compartments are symmetrically arranged about the vessel's centerline to achieve balanced weight distribution, facilitate maintenance activities, and enhance the operational stability and safety of the proposed catamaran.

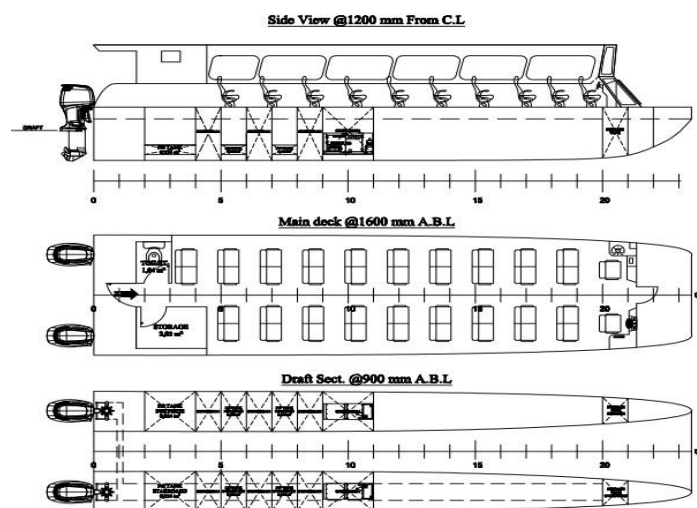


Figure 6. General Arrangement

Figure 6 illustrates the general arrangement of the proposed passenger catamaran, which was developed to ensure that the vessel layout supports safe, comfortable, and efficient operation on the Tanglok Port–Gili Mandangin route. The arrangement shows the spatial distribution of the main functional areas, including the wheelhouse, passenger accommodation, safety equipment storage, machinery arrangement, fuel tanks, ballast tanks, and battery compartment. The passenger area is arranged on the main deck with a central aisle to provide sufficient circulation space and to facilitate rapid evacuation during emergency conditions. The placement of the wheelhouse at the forward section provides adequate visibility for navigation, while the two outboard engines installed at the stern support propulsion reliability and maneuverability. The fuel tanks, ballast tanks, and battery compartment are positioned below the deck and arranged symmetrically to maintain balanced weight distribution and overall vessel stability. In addition, the provision of life jacket storage and clear access routes reflects the integration of safety requirements into the layout design. Therefore, the general arrangement demonstrates that the proposed catamaran is not only designed to accommodate 40 passengers but also to improve passenger comfort, operational practicality, and compliance with the safety principles required for high-speed passenger craft.

DISCUSSION

Assessment of the Proposed Principal Dimensions

The principal dimensions obtained through the combined parent ship method and linear regression analysis provide a practical approach for developing a preliminary design that satisfies the operational requirements of the Tanglok Port–Gili Mandangin Island route. Compared with the conventional spiral design approach, the regression-based method enables a rapid estimation of the principal dimensions while maintaining consistency with the characteristics of existing passenger catamarans. The resulting dimensions (LOA = 14.34 m, B = 4.45 m, H = 1.64 m, and T = 0.90 m) remain within the range of the reference vessels, indicating that the proposed design is representative of current catamaran passenger vessel practice.

The selected draft of 0.90 m is particularly appropriate for the operational environment of Tanglok Port, where water depth is influenced by tidal conditions. A relatively shallow draft reduces the risk of grounding while maintaining sufficient displacement to accommodate 40 passengers and the required onboard equipment. This finding supports previous studies suggesting that preliminary design based on statistical approaches can provide reliable principal dimensions before more detailed optimization is performed (Papanikolaou, 2021). Therefore, the proposed dimensions provide an appropriate balance between passenger capacity, operational requirements, and navigational constraints.

Hydrodynamic Performance and Propulsion System

The hydrodynamic analysis indicates that the proposed catamaran is capable of achieving the intended service speed of 12 knots while maintaining a reasonable resistance level. The selection of the Fung Method for resistance prediction was justified because all evaluated hull-form parameters fell within the applicability range of the method. Consequently, the estimated total resistance of 28.3 kN is considered representative for the proposed hull configuration during the preliminary design stage.

The predicted propulsion power further demonstrates the consistency between hull resistance and engine selection. After considering the overall propulsive efficiency and a 15% design margin, the required installed power was satisfied by two 300 HP Yamaha F300 outboard engines. Providing installed power slightly higher than the calculated



requirement is common engineering practice because the vessel may encounter additional resistance caused by waves, wind, hull fouling, and loading variations during operation. Similar design considerations have been reported for high-speed catamaran vessels, where adequate propulsion margins are necessary to maintain service speed and operational reliability (Tadros et al., 2023; Papanikolaou, 2021). Therefore, the selected propulsion system is expected to provide sufficient performance while maintaining operational flexibility.

Safety Improvement and Compliance with PM 12 of 2022

One of the primary contributions of the proposed design is the improvement of passenger safety and onboard arrangement compared with the existing transportation system operating on the Tanglok Port–Gili Mandangin route. Field observations revealed that the current vessels are essentially traditional wooden cargo boats that simultaneously transport passengers, motorcycles, construction materials, and general cargo within the same space. Such arrangements reduce passenger comfort and increase operational risks because dedicated seating, escape routes, and sufficient lifesaving appliances are generally unavailable.

The proposed general arrangement addresses these limitations by providing dedicated passenger accommodation, a central aisle for passenger circulation and emergency evacuation, separate compartments for fuel tanks, batteries, ballast tanks, and equipment, as well as designated storage for lifesaving appliances. These arrangements are consistent with the provisions of PM 12 of 2022, particularly those related to passenger accommodation, machinery arrangement, and onboard safety equipment. Consequently, the proposed design not only improves passenger comfort but also enhances operational safety by separating passenger spaces from machinery and service compartments while ensuring a more balanced weight distribution.

Engineering Implications

The proposed catamaran design demonstrates that a route-specific passenger vessel can be developed by integrating operational requirements, local waterway characteristics, and applicable safety regulations within a preliminary design framework. Unlike many previous studies that primarily focus on hydrodynamic optimization or general passenger vessel design, this study considers the actual operational conditions of a small-island transportation route, including shallow water depth, passenger demand, and regulatory compliance. As a result, the proposed design provides a practical engineering solution that is directly applicable to the Tanglok Port–Gili Mandangin service.

Beyond its application to the study area, the proposed design methodology may also be adapted for other short-distance inter-island routes in Indonesia with similar operational characteristics. The combination of the parent ship method, linear regression analysis, Maxsurf-based hull modeling, and resistance prediction using the Fung Method offers a systematic and efficient workflow for developing preliminary passenger vessel designs. Nevertheless, this study remains limited to the preliminary design stage. Future research should incorporate stability assessment, seakeeping analysis, structural design, computational fluid dynamics (CFD), and techno-economic evaluation to further validate the operational feasibility and overall performance of the proposed catamaran.

CONCLUSION

The preliminary design of a catamaran passenger vessel for the Tanglok Port–Gili Mandangin Island route has been successfully developed by considering local transportation requirements, the characteristics of the operating waters, and passenger safety and comfort. The principal dimensions were determined using a linear regression approach based on comparable vessel data, resulting in a design capable of accommodating 40 passengers with a length overall (LOA) of 14.34 m, a breadth (B) of 4.45 m, a draft (T) of 0.90 m, and a depth (H) of 1.64 m. These dimensions are considered appropriate for operation in relatively shallow waters while providing significantly improved passenger space and onboard comfort compared with the traditional wooden vessels currently serving the route.

The proposed vessel has a displacement volume of 15.946 m³ and is designed to operate at a service speed of 12 knots. This operating speed satisfies the high-speed craft requirements specified in the Regulation of the Minister of Transportation of the Republic of Indonesia No. 12 of 2022, which stipulates a minimum speed requirement of 11.41 knots. Resistance analysis using the Fung method predicted a total resistance of 28.3 kN at the service speed. The corresponding effective power requirement was estimated at 468,31 HP. Considering for propulsion efficiency and a 15% power margin, the required installed power increased to approximately 538.56 HP, making the selection of two Yamaha F300 outboard engines, each rated at 300 HP, sufficient to meet the vessel's operational requirements.

Overall, the proposed catamaran design represents a practical and technically feasible alternative for improving passenger transportation on the Sampang–Gili Mandangin route by offering enhanced safety, passenger comfort, and operational performance. The general arrangement has been developed with careful consideration of passenger accommodation, equipment spaces, fuel tanks, battery compartments, and the organized storage of safety equipment. Therefore, this preliminary design provides a solid foundation for future development, including detailed analyses of stability, structural design, safety systems, economic feasibility, and design validation to ensure full compliance with applicable technical and operational standards.





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