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Preliminary Design and Stability Assessment of a Solar-Assisted Glass-Bottom Tourist Catamaran for the Riau Islands Province

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ABSTRACT

This study presents the preliminary design and stability assessment of a solar-assisted glass-bottom tourist catamaran for shallow marine tourism in the Riau Islands. The novelty of the design lies in integrating three requirements: shallow-draft operation for reef areas, a glass-bottom observation space for non-diving tourists, and a solar-assisted auxiliary power system to reduce local environmental disturbance. The design was developed using a comparison-based preliminary approach, followed by lines plan, general arrangement, intact stability, and resistance analysis. The proposed vessel has principal dimensions of LOA 24 m, LWL 23.4 m, a beam 10 m, a depth 2.5 m, and a design draft of 1 m. At full load and even keel, the maximum righting arm is 2.603 m at 67.3 degrees. The estimated total resistance at 18 knots is 127.619 kN, requiring a propulsion power of 1584.759 kW. The preliminary photovoltaic assessment indicates an output of about 48.6 kWh/day, sufficient for auxiliary loads but not for main propulsion. The design's main contribution is a stable, shallow-draft tourist vessel with reduced auxiliary fossil fuel use for marine tourism in the Riau Islands.

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INTRODUCTION

Tourism plays an important role in regional income generation, employment creation, and the activation of coastal and island economies. In maritime provinces, tourism growth is closely linked to the quality of transport infrastructure because access, safety, and travel comfort strongly influence attractiveness of destinations (Nor Anisa, 2023) (Haryati, 2019) (Al Mustaqim, 2023) (Fadilla, 2024) (Rudy & Mayasari, 2019).

The Riau Islands Province has strong marine-tourism potential because 96% of its area is sea and the region contains many small islands, beaches, and underwater attractions. This geographical condition also means that inter-island connectivity and marine accessibility are essential components of tourism development. For this reason, tourist vessels are not only transportation assets but also part of the tourism product itself (Manik, et al., 2019). (Darma, 2019). (Nugraha, 2023).

However, most discussions on tourism development in the Riau Islands remain focused on policy, regional economy, or destination development, while technical studies on tourist vessel concepts for shallow coral-tourism areas are still limited. In particular, there is a need for a vessel concept that simultaneously addresses low draft for shallow waters, adequate stability for passenger safety, reduce environmental disturbances during sightseeing operations, and a realistic use of renewable energy. This gap becomes important because the Regional Medium-Term Development Plan (RPJMD) of the Riau Islands Province for 2021–2026 highlights the limited quality of supporting facilities and infrastructure at tourist destinations, including tourist boats.

Based on that gap, this study aims to develop a preliminary design of a tourist catamaran for underwater tourism in the Riau Islands Province and to evaluate its hydrostatic, stability, resistance, and auxiliary solar-energy performance. The novelty of the work lies in the integration of a shallow-draft catamaran hull, a glass-bottom observation feature, and a solar-assisted auxiliary electrical system in one design concept. The discussion of this study is cantered on preliminary design and stability assessment, while the energy efficiency claim is limited to the contribution of solar energy to auxiliary loads.

METHOD

This study used a comparison-based preliminary ship design approach. The tourist vessels with a similar operational role were used as the initial benchmark and then adjusted to the service requirements and physical constraints of the Riau Islands tourism area. The objective was not to produce a detailed production design, but to obtain a technically consistent concept and evaluate its hydrostatic, stability, resistance, and auxiliary solar energy performance.

The main site constraints considered in the design were shallow coral-tourism waters, relatively low current, and the need to minimize environmental disturbance during sightseeing operations. Based on reported underwater conditions around Beralas Pasir Island in Bintan Regency, where coral reefs were observed at depths of 4-5 m and current velocities ranged from 0 to 15 cm/s. (Rivaldi, et al., 2025), the vessel was limited to a design draft of 1 m. the service speed of 18 knots was selected to maintain practical inter-island accessibility.

Once the principal dimensions are defined, the study proceeds with the development of the lines plan, general arrangement, and three-dimensional design model.

Following the completion of the design phase, a series of technical analyses are conducted, including assessments of vessel stability, hydrostatic characteristics, and resistance performance for operational conditions within the tourism zones of the Riau Islands. These analyses

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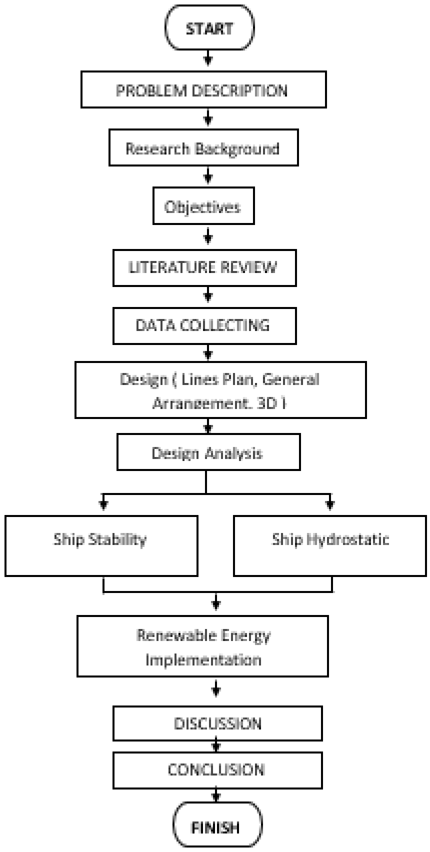
are carried out with an emphasis on energy-saving and eco-friendly design principles supported by the integration of renewable energy technologies.

The research concludes with a summary of findings and recommendations, serving as a foundation for refinement and further investigation in subsequent studies.



Picture 1. Research Flow Diagram

In the seakeeping analysis, wave heading conditions were applied during motion simulations. The operational speed analyzed corresponds to a service speed of 18 knots. These parameters are used to determine the vessel's principal dimensions, which serve as the foundation for developing the lines plan and general arrangement. These, in turn, will be further analyzed for stability and seakeeping performance, with the integration of renewable energy technologies in the design of an underwater tourism vessel suitable for operation within the tourism waters of the Riau Islands Province.

Data processing for the development of an energy-efficient and environmentally friendly tourist vessel is carried out in several stages. First, the lines plan and 3D model are developed using Maxsurf and AutoCAD software, based on the previously determined principal dimensions. This is followed by the preparation of the general arrangement plan, after which stability and seakeeping analyses are conducted, similar to the methodology employed by (Apriansyah, et al., 2023) in designing an energy-efficient fishing vessel integrating renewable energy technologies.

Subsequently, the renewable energy systems and equipment to be installed on the tourist vessel are designed using SketchUp software and visualized through three-dimensional representations.

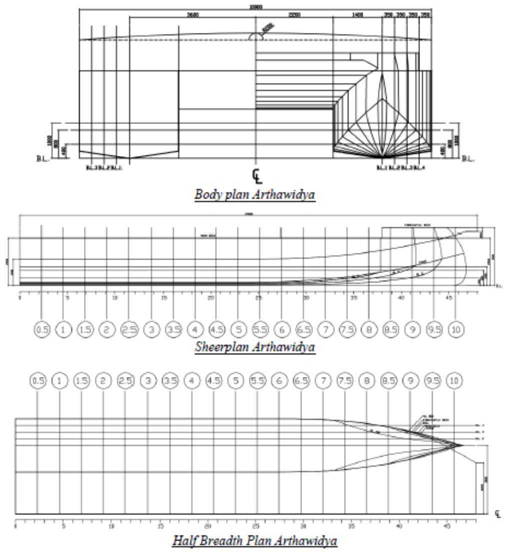
RESULTS AND DISCUSSION

The principal dimensions of this energy-efficient and environmentally friendly tourist vessel are designed with a length of 24 meters and a shallow design draft of 1 meter, making it suitable for underwater tourism activities in the Riau Islands region. The principal dimensions of the proposed energy-efficient and eco-friendly tourist vessel are presented in Table 1.

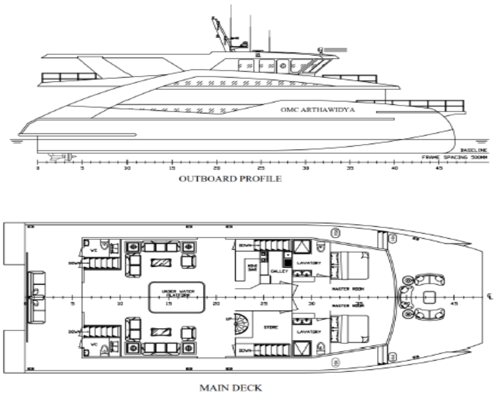
Table 1. Principle Dimensions of the Tourists Vessel

No	Descriptions	Dimensions
1	Length Over All (LOA)	24 m
2	Length Water Line (LWL)	23,4 m
3	Breadth (B)	10 m
4	Depth (H)	2,5 m
5	Draft (T)	1 m
6	Service Speed (VS)	18 Knots

From the table above, the principal dimensions of this energy-efficient tourist vessel indicate an operational speed of 18 knots, which is adequate for voyages to underwater tourism sites in the Riau Archipelago Province. The lines plan—comprising the body plan, sheer plan, and half-breadth plan—and the general arrangement that have been developed can be seen in Figures 2 and 3.



Picture 2. Lines Plan

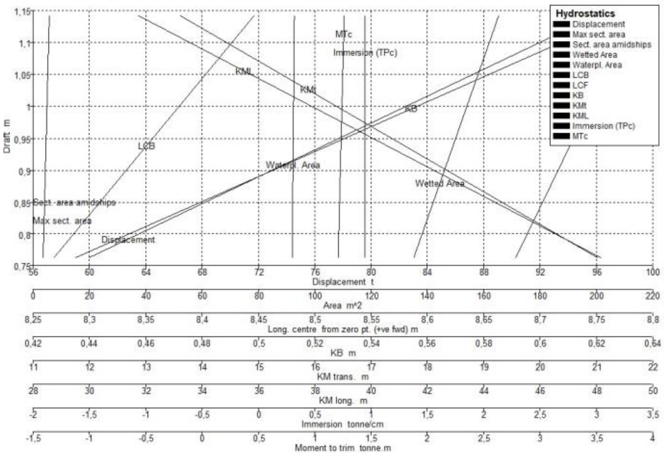


Picture 3. General Arrangement

Figure 4 shows the three-dimensional concept of the proposed tourist vessel. The tourism features include a glass-bottom observation facility for passengers who wish to observe coral reefs without diving, and a solar-panel arrangement on the roof/canopy area to supply part of the auxiliary electrical demand. In addition, the concept includes station-keeping support so that sightseeing operations can be performed with less disturbance to the seabed than conventional anchoring.

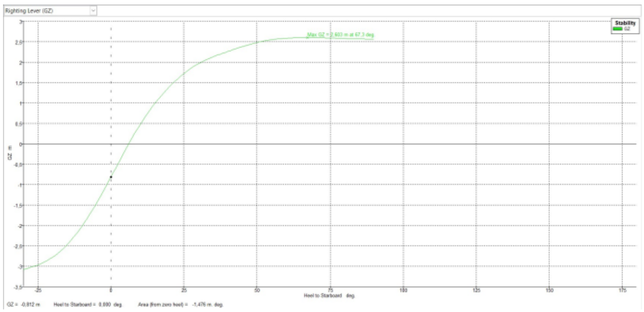
Picture 4. 3D Design Tourist Vessel

The hydrostatic-curve analysis of the energy-efficient tourist vessel, shown in Figure 5 below, indicates a displacement of 83 tons at a 1.0 m draft, with the keel of buoyancy at 0.56 m for that draft. This demonstrates that the vessel exhibits satisfactory keel-derived buoyancy values indicate that the selected principal dimensions provide sufficient buoyant volume at the intended shallow operating draft.



Picture 5. Hydrostatic Curve

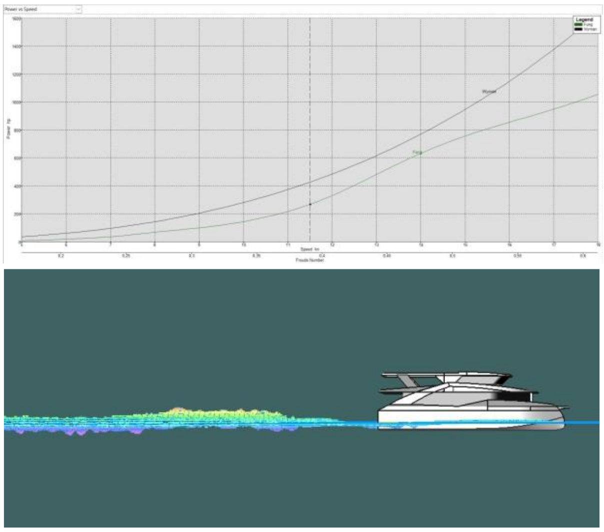
The stability analysis was conducted with reference to the energy-efficient tourist vessel in a full-load condition (maximum draft) with trim = 0° (even keel). Under full load, the maximum GZ is 2.603 m at 67.3°, as shown in Figure 6; this value still satisfies the IMO stability criteria for passenger vessels under 24 meters. For a preliminary tourist-vessel concept, this result indicates strong transverse stability and shows that the wide-beam catamaran configuration is the main contributor to the stability performance reported in this study.



Picture 6. Stability Curve of the Tourist Vessel at Maximum Draft

This energy-efficient tourist vessel is designed for an operational speed of 18 knots. With a total resistance of 127.619 kN, the vessel requires a minimum engine power of 1584.759 kW, as illustrated in the graph shown in Figure 7.

The power value was validated using the effective-power approach. By converting 18 knots to 9.26 m/s, the effective power is calculated as PE = RT x V = 127.619 x 9.26 = 1.181,8 kW. With a propulsive efficiency (η_D) of 0.745, the estimated brake power becomes PB = 1,181.8 / 0.745 = 1.586,2 kW, which closely matches the software's reported value of 1.584,759 kW. This agreement validates the plausibility of the required propulsion power.



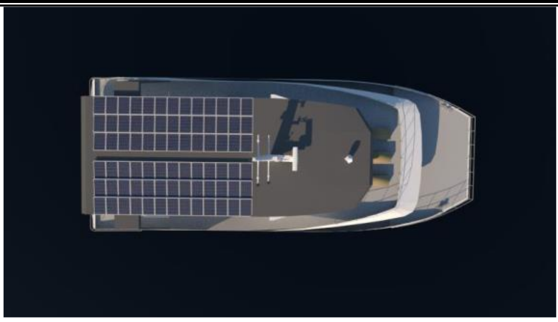
Picture 7. Ship Resistance Analysis

The design of this energy-efficient tourist vessel refers to the safety regulations of the Non-Convention Vessel Standard (NCVS) and SOLAS (Safety of Life at Sea). This underwater tourist vessel is equipped with two fire pumps, CO_2 and dry-powder fire extinguishers, a fire alarm system, and other supporting safety equipment. In terms of life-saving appliances, the vessel is fitted with two life rafts with a capacity of 10 persons per unit, 15 life jackets, and 10 life buoys. All equipment complies with SOLAS standards.

The vessel is also equipped with an innovative bottom-glass platform, an additional transparent chamber designed to accommodate passengers. This platform can be lowered below the water surface, allowing tourists to enjoy underwater scenery without the need for diving. To support this bottom-glass platform, the vessel incorporates the Spot Track System, which locks the vessel's position while at sea, enabling it to remain stationary without deploying an anchor—thus preventing environmental disturbance and preserving underwater ecosystems.

This environmentally friendly, energy-efficient tourist vessel utilizes a generator fully powered by solar energy, allowing for significant fuel savings during operation in marine tourism areas within the Riau Archipelago Province. Figure 8 illustrates the solar panels installed on the vessel. The contribution of solar energy should be interpreted carefully. Based on an assumed effective panel area of 72 m2, module efficiency of 20%, performance ratio of 0.75, and 4.5 peak-sun-hours/day, the photovoltaic system can provide approximately 48.6 kWh/day, equivalent to an average continuous power of about 2.0 kW.

Relative to the propulsion demand of 1584.759 kW, the instantaneous solar contribution is less than 1% at full speed. Therefore, the solar installation is technically appropriate for auxiliary loads such as lighting, navigation electronics, pumps, and tourism-support equipment, but it cannot be claimed as the main propulsion power source.



Picture 8. Solar Panel View

This energy-efficient tourist vessel is equipped with adequate interior facilities that provide comfort for passengers wishing to enjoy the underwater beauty of the Riau Archipelago, as illustrated in Figures 9.

Picture 9. Interior View

CONCLUSION

This study produced a preliminary design of a solar-assisted glass-bottom tourist catamaran for underwater tourism in the Riau Islands Province. The main technical result of the manuscript is the stability-oriented evaluation of a shallow-draft vessel concept intended for coral-tourism waters.

The proposed vessel has principal dimensions of LOA 24 m, LWL 23.4 m, a breadth 10 m, a depth 2.5 m, and a design draft 1.0 m. At full-load and even-keel condition, the maximum GZ reaches 2.603 m at 67.3 degrees, indicating strong transverse stability for the studied condition. At 18 knots, the vessel requires about 1.584,759 kW of installed propulsion power, and this value is supported by a manual power cross-check based on effective power and overall propulsive efficiency.

The renewable energy result must be interpreted as auxiliary energy support rather than full propulsion. Under the stated assumptions, the photovoltaic system can supply about 48.6 kWh/day, which is useful for auxiliary electrical loads but small compared with the propulsion demand. Therefore, the main contribution of the design is a stable shallow-draft tourist vessel concept with partial reduction of auxiliary fossil-energy use.

Future work should include seakeeping in representative wave conditions, structural assessment, detailed electrical load analysis, and economic feasibility before implementation.

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