

# A Review on the Fishing Boat Outrigger Design and Construction Development in Indonesia

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## ABSTRACT

This study analyzes the designs, functions, and technological advancements of outrigger boats in Indonesia, emphasizing their critical role in enhancing the maritime stability and operational efficiency. Its objective is to examine how the innovations in the outrigger systems contribute to improving the vessel stability, safety, and sustainability, particularly in the fishing and transportation activities. The research methodology integrates observational data, dimensional measurements, material analysis, and an extensive literature review, focusing on the Indonesian fishing vessels. The key findings reveal that positioning the outrigger approximately 2 m from the vessel's side significantly reduces ship motions, such as heaving, rolling, and yawing, thereby preventing the capsizing and enhancing safety. The innovations presented in this work include a portable and movable outrigger system that optimizes the stability and space utilization. Also, the hydrodynamic improvements reduce the drag, while the integration of a power generation system harnesses the water flow to supply electrical energy for onboard lighting, which is advantageous for night fishing. A shift from the simple changes in structure to more advanced designs is observed. The latter improve the way the water flows around the vessel, using energy from the water movement, which is part of a larger trend towards more sustainable and efficient operations at sea. These advancements enhance the vessel performance and contribute to the environmental protection by reducing the reliance on external energy sources. It is concluded that optimizing the outrigger designs is essential for promoting safer, more efficient, and environmentally sustainable fishing practices in Indonesia, offering valuable insights for future maritime engineering developments.

*Keywords-outrigger boats; modification; design; stability; fishing; Indonesia*

## I. INTRODUCTION

The outrigger boats are commonly found in Indonesian waters. In Indonesia, the outrigger vessels are typically less than 7 Gross Tonnage (GT) and are, thus, categorized as boats [1, 2]. This is in accordance with the International Maritime Organization (IMO) [3], where the term boat is used for watercraft with a GT of less than 7 GT, while the term ship is used for watercraft with a GT of 7 GT. The outrigger boats serve as transport boats on rivers or around coastal waters for recreational activities and fishing [4, 5]. Outrigger boats also serve as maritime transportation tools used for tourism and inter-bay transportation, such as the outrigger boats in the waters of Cilacap, Central Java, with dimensions of 10.30 m in length and 1.20 m in width. The outrigger boat, which functions as a fishing boat and is classified as a traditional boat, is small in size, with a main Beam to Draft (B/D) ratio ranging from 1.36 m to 2.02 m. This B/D value indicates that the hull of the boat is unstable, necessitating an outrigger system for good stability performance.

The outrigger is a balancing device on the boat to prevent it from capsizing and to maintain stability when it is hit by waves. The former is not just a secondary part of the transportation tool but an essential component for coastal communities. The outrigger is an additional construction on a boat that functions as a stabilizing device [6, 7]. The outrigger is generally found on boats with a slender or sleek hull shape, such as the *jukung* boat [8]. However, there are also boats with a non-sleek hull shape equipped with the outrigger. The reason the boat owners use additional outriggers on boats with non-sleek hulls is to improve their stability. Authors in [9] demonstrated that the stability of fishing boats can be enhanced by adding outriggers. Additionally, the boats that use outriggers have a positive impact, in that their motion response to waves is reduced in terms of heave, roll, and pitch [10, 11]. Based on this phenomenon, the present study addresses the issue of how the outriggers commonly used on fishing boats in Indonesian waters are designed and constructed, and how modifications can be implemented without compromising their primary function of maintaining the boat stability. The objective of this study is to identify the design and construction of outriggers that are frequently employed on fishing boats in Indonesian waters. Additionally, the study attempts to modify the outrigger construction without compromising its functionality.

The types of the data collected consist of dimensions, materials, design, and construction, as well as several studies on the modification efforts of the outrigger. The data were collected by reviewing various sources relevant to the outriggers, including theses, dissertations, reports, journals, and other publications, and through direct observation at one of the key locations for outrigger boats, Palabuhanratu Fishing Port. Data on the design, construction, and dimensions of the outrigger boats at Palabuhanratu Fishing Port were collected through direct observation and measurement. Data processing was done through data tabulation and description. Data tabulation was carried out to observe the diversity and uniformity of the design, construction, materials, and dimensions of the outrigger utilized on boats in Indonesia, and a description was performed to illustrate the outrigger design.

This study employs a comparative descriptive analysis to examine the various forms of outriggers used in different regions of Indonesia.

## II. USE OF OUTRIGGER BOATS IN THE PAST

Authors in [12] note that the ships or boats are the most complex artifacts produced by humans before the Industrial Revolution. The oldest implicit evidence of the use of sea vehicles comes from the Australasia region. The group of humans who began inhabiting the Sahul region around 50,000 years ago could only reach it after crossing various deep-sea straits between the islands of Nusa Tenggara, the Makassar Strait, and parts of the Banda Sea. They utilized simple boats or wooden rafts to travel across these waters. Sea vehicles are not just a means of transportation, but also an important part of the coastal communities' lives in Australasia since prehistoric times. Archaeological evidence shows that the sailing and trading between islands have been vital skills for these communities, confirming that the ability to sail and navigate the seas has been an essential human skill. Furthermore, the Southeast Asian region inhabited by Austronesian-speaking communities has been known for its maritime skills and shipbuilding expertise since around 500 BC [13, 14]. One of the characteristic sea vehicles of the Austronesian people is the outrigger canoe [15, 16], a maritime technological innovation that allows them to explore the vast oceans with high stability.

There is not much physical evidence about the use of the outrigger in Indonesia in ancient times. However, there is one relief at the Borobudur temple that provides sufficient evidence of the use of outrigger construction in the past. Authors in [17] stated that although no physical remnants of the outrigger ships or boats from the Majapahit era have been found to date, evidence of their use can be seen in the reliefs of the Borobudur temple. These ships played an important role in establishing the inter-island connections under the rule of the Majapahit Kingdom. Experts believe that the outrigger boat design depicted in the Borobudur reliefs reveals the high level of maritime skills at that time. The use of these ships by the Majapahit Kingdom demonstrates the importance of the inter-island trade and relations in strengthening the kingdom's political and economic power. The reliefs show how ships were used and became part of Nusantara society, even though no physical remnants have been found.

## III. DESIGN AND CONSTRUCTION OF OUTRIGGER BOATS IN INDONESIA

Outrigger designs generally consist of either a single-outrigger or a double-outrigger configuration. The single-outrigger design is generally used for small boats or traditional boats, while the double-outrigger design is more commonly utilized for larger boats with a greater cargo capacity [18]. The diversity of these outrigger designs allows boat users to choose among them according to their needs and the desired conditions of boat use. Both of these designs provide good boat stability. Outrigger boats in Indonesia have various regional names in Gorontalo, and almost all regions of Eastern Indonesia refer to them as *katinting* boats or *sema-sema* boats. The term *katinting* boat is derived from the engine used on the boat, called the *katinting* engine. The *katinting* boat is used as a means of

transportation by the fishermen during fishing and general sea transportation [19]. In the western region of Indonesia, particularly in the waters around Jakarta, it is commonly referred to as *jukung katir* boat, and in the central region of Indonesia, in Buleleng Regency, Bali, it is called *katir* boat [20]. In the Jakarta region, the outrigger boats are small and are specifically used for fishing with fishing rods. The single-outrigger boats are called *jukung pancingan*. The name is based on the design of the outrigger, which only uses a single outrigger installed lengthwise on one side of the boat. Single-outrigger and double-outrigger boats are called *perahu pancingan* and *perahu jepitan*, respectively [20]. One similarity in the outrigger boat design across Indonesia is the longitudinal placement of outriggers along both sides of the hull. In addition to the similarities, there are also differences in the shape of the bow's *linggi*, influenced by the varying marine environmental conditions and customs in each region, resulting in differences in the boat designs in each area [20]. The construction design and naming of the outrigger boats in Indonesia are shown in Table I.

The outrigger boat has a technical construction, consisting of a bow and stern that point upwards as one of its characteristics, a superstructure as a protector against the water entering the engine room, a closed deck as a protector against the water entering the boat, and an outrigger system [21]. There are several floating shapes in the design and construction of outrigger boats, namely rectangular, triangular, and circular. Each floating shape provides a different buoyancy force on the

outrigger. Authors in [22] mentioned that the rectangular floating shape provides a linear buoyancy force at a nominal depth when floated. Thus, the proposed floating shape for the outrigger is the rectangular one because it provides a uniform buoyancy force when the outrigger is operated at different water depths. The outrigger boat also has unique features compared to other boats or ships, such as a mast standing in the middle of the boat's deck to maintain the balance of the outrigger boat system, and a bow and stern that differ from other ships. The outrigger system consists of an outrigger boom, outrigger float, outrigger arm, and mast to enhance the stability of the outrigger boat [21].

#### IV. DIMENSIONS AND MATERIALS OF OUTRIGGER BOATS IN INDONESIA

According to [23], a stability analysis shows that the boats equipped with outriggers exhibit better stability compared to those without outriggers, in accordance with the stability standards issued by the IMO. Authors in [23] showed that the addition of the outrigger construction on the boat can provide perfect reserve buoyancy. The study was conducted on a boat with main dimensions of LOA 8 m, width 1 m, and height 0.8 m. The maximum height of the righting arm (GZ) for the outrigger boat occurs at a heel angle of 40°, with a value of 0.429 m-rad. This value is in accordance with the IMO standards, where the maximum GZ should occur at an angle of 30° with a righting arm of at least 0.2 m-rad.

TABLE I. CONSTRUCTION DESIGN AND NAMING OF OUTRIGGER BOATS IN INDONESIA

Outrigger design	Description	Boat usage	Location/region	Local name(s)	Design details
Single-outrigger	Generally used for small boats or traditional boats	Fishing with rods	Jakarta	<i>Jukung Pancingan</i>	Single outrigger attached lengthwise on one side of the hull
Double outrigger	More commonly used for larger boats with a greater cargo capacity, providing good stability, with the outrigger being installed lengthwise on both sides of the hull	General sea transportation, heavier sea conditions, carrying valuable cargo and use for fishing	Nearly all regions of Indonesia	More commonly used for larger boats with a greater cargo capacity, providing good stability, with the outrigger being installed lengthwise on both sides of the hull	General sea transportation, heavier sea conditions, carrying valuable cargo and use for fishing

TABLE II. DIMENSIONS AND MATERIALS OF OUTRIGGER BOATS IN VARIOUS REGIONS OF INDONESIA

Region	Outrigger length (m)	Outrigger material	Ship dimensions (m)			Reference
			L	B	D	
Cilacap, Cental Java	5.0	Teak wood ( <i>Tectona grandis</i> ) and resin	10.30	1.20	0.90	[24]
The Enemawira beach and Peta Port, North Sulawesi	8.0	Bayut ( <i>Gigantochloa apus</i> ) type of bamboo	5.10–10.10	0.64–9.00	0.38–0.56	[25]
Bitung, North Sulawesi	5.54–11.25	Local wood (variation)	9.60–17.18	0.80–1.95	0.64–1.74	[21]
Mandar, South Sulawesi	8.0–9.0	Local hardwood (various species)	7.0–11	0.6–0.8	0.5–1.0	[26]
Garut, West Java	5.0	Bamboo ( <i>Bambusa vulgaris</i> )	9.0–10	1.0–1.8	0.5–0.8	[27]
Banda Islands, Maluku	4.6	Local hardwood (various species)	9.80	0.8–1.10	0.85	[28]
Palabuhanratu, West Java	4.29–10.55	Teak wood ( <i>Tectona grandis</i> ) and resin	8.91–10.81	1.0–1.30	0.80–1.12	[29]

The hull of the boat, as well as all the beams and struts, are made of wood. Outrigger floats on both sides of the boat are made from 3-inch-diameter Polyvinyl Chloride (PVC) pipes. Two lateral outriggers that extend across the hull of the boat are made of wood and are secured to the hull using nylon ropes. The structure connecting the outriggers and the outrigger poles is constructed with a 10 mm diameter iron bar commonly used in concrete construction, which is fastened to the poles, and outriggers with nylon ropes. The dimensions and materials of the outrigger boat in several regions in Indonesia are depicted in Table II. The length of the outrigger should not exceed the length of the boat's activity area. Otherwise, the presence of the outrigger construction can disrupt the crew's activities on the boat, specifically for boats conducting activities, such as loading and unloading, at the bow. This observation complies with [30], according to which, if the placement of the outrigger on the boat tends to be more towards the front, it will be rejected by fishermen because it can disrupt the loading and unloading activities. An outrigger is in a state of perfect balance when the length of the outrigger does not exceed  $\frac{1}{2}$  of the boat's LOA. Authors in [31] claimed that one of the reasons for placing the outrigger at the stern of the fishing boats in the Southern Sea is to provide a perfect boat balance.

The distance between the keel and the hull of the boat greatly affects the wave resistance formation on the boat. There are eight primary methods for calculating the ship resistance [32]. The Van Ootmerssen and Holtrop methods are the most appropriate for the characteristics of the outrigger boats in Indonesia, which typically operate at low to medium speeds and employ a displacement hull type. Both methods are used for the analysis of the resistance in small boats with a displacement hull type, such as the outrigger boat. The distance between the outrigger and the boat's hull has been the subject of numerous studies. Authors in [32] investigated the stability performance of fishing boats in response to variations in the outrigger. As the results of the calculations are relatively identical, the distance of the outriggers does not have a substantial impact on the total resistance. Conversely, the variation in the outrigger distance has a substantial impact on the formation of the wave resistance on this fishing boat, which has dimensions of 10.23 m in length, 2.00 m in width, and a draft of 0.44 m. Consequently, the boat's resistance can stabilize at a Froude number exceeding 1.5 [32].

The traditional outrigger construction in Indonesia has historically relied on wood, which remains the main material used in most boats today. One example is in the Sangihe Islands Regency, where the materials used in the construction of the outrigger boats for the keel, support posts, and ship's ivory are usually made from Ketapang (*Terminalia catappa*) and Nyamplung (*Calophyllum inophyllum*) wood; the hull is made from marine plywood; the outrigger system is made from short-segment bamboo of the Bayut (*Gigantochloa apus*) or Tabadi (*Bambusa vulgaris*) type. In the Pusu type outrigger boat, though, the outrigger system is made from wood and bamboo, and the floats are made from bamboo with a diameter of 5-6 cm [33]. However, over time and owing to the technological advancements, traditional boat designers use materials other than wood as the basis for making the outrigger.

Based on their construction materials, there are 2 types of outrigger boats in the Pangandaran area, namely those made of resin (fiberglass) and those made of wood [31]. Authors in [34] stated that the outrigger is made from Ori (*Gigantochloa apus*) or Pethung (*Dendrocalamus asper*) bamboo, which is used by the fishermen and boat builders. The material selection is based on their strength, durability, and longevity. Authors in [35] claimed that Pethung bamboo has reliable properties for the construction of boats, including its strong, flexible, straight, flat, hard, easily split, and easily shaped stems.

PVC pipes are also utilized as a basic substitute for wood in the outrigger construction. Authors in [36] showed that traditional outrigger boats used by the fishermen in Gorontalo City employ 3 cm-diameter PVC pipes as stabilizing outriggers on the fishing boats. The availability of timber-producing forests is increasingly diminishing. This has resulted in serious problems for the construction and repair needs of the wooden boats [37]. Thus, resin (fiberglass) and PVC pipes are utilized as substitute materials for wood in the construction of the outrigger. An example of the use of resin on the flotation part of the outrigger construction is provided in Figure 1.



Fig. 1. The float outrigger made of resin on the outrigger boat in Palabuhanratu, Indonesia.

## V. EFFORTS TO MODIFY THE OUTRIGGER

The outrigger plays a significant role in the boat's balance. The quality of a boat's stability depends on the amount of the rolling duration when the boat performs a rolling motion. During this motion, the boat's stability lowers with the rising of the rolling duration [38]. This is what triggers the development and modification of the outrigger to improve the stability of the boat. Authors in [39] modified the outrigger boats' construction with a portable system added on the boat and investigated its effect on the resistance of the squid fishing boats found in the Cirebon area. It was observed that the boat maintained stability during the net-dragging process. Additionally, the portable outrigger provided fishermen with greater flexibility to achieve the desired speed with minimal resistance and/or improved stability. These findings present a significant challenge for future studies aiming to utilize active stabilizers, such as gyro-

based hydraulic fins, rather than an outrigger construction, in order to reduce the rolling motion and enhance the comfort on boats [40]. However, such a technology tends to be complex and costly, making it less suitable for traditional fishermen. As an alternative, the portable outrigger approach developed in this study offers a more practical and economical solution that meets the needs of small-scale fishermen in coastal areas, like Cirebon [39]. Thus, this local innovation remains consistent with the fundamental principles of improving the vessel stability and movement efficiency, despite employing simpler methods compared to the modern technologies.

Authors in [30] installed movable outriggers on a 3GT boat to enhance the boat's performance during fishing and to test the better outrigger configuration without disrupting the boat's operations. The outrigger technology was deployed by varying the distance of the outrigger from the boat's center line into three positions: the first position with the outrigger attached to the boat's hull, the second position with a distance of 2 m from the center line, and the third position with distances of 2.5 and 3 m from the center line. The percentage increase in the total resistance of a 3 GT fishing boat for a variety of outrigger configurations can be seen in Table III.

TABLE III. PERCENTAGE OF BOAT RESISTANCE WITH DIFFERENT OUTRIGGER DISTANCES

Speed (knot)	Outrigger attached to the boat's hull (%)	Outrigger distance 2 m (%)	Outrigger distance 2.5 m (%)	Outrigger distance 3 m (%)
1	+20%	+40%	+60%	+80%
2	+20%	+40%	+50%	+60%

At a distance of 2 m, the outrigger had the lowest total resistance value compared to other outrigger distance

TABLE IV. DEVELOPMENT OF RECENT RESEARCH EFFORTS ON THE MODIFICATION OF OUTRIGGER

Year	References	Modification	Key finding/innovation
2012	[39]	Portable outrigger system for squid fishing boats	Improved stability during net-dragging
2016	[30]	Movable outrigger placement on 3 GT fishing boats	Optimal outrigger distance for minimal resistance
2017	[32]	Optimization of the outrigger support length	Improved efficiency/stability (specifics not detailed)
2017	[42]	Movable outrigger for improved harbor basin utilization	Enhanced space efficiency in harbors
2021	[41]	Replacing outrigger function with a gyroscope	Potential alternative to traditional outriggers
2020	[43]	Effective placement position of outrigger for resistance	Optimal placement is closer to the stern
2020	[7]	Hydrodynamic efficiency improvements	Reduced drag, improved fuel efficiency, faster speeds
2023	[44]	Power generation system integrated into the outrigger	Harnessing the water flow for electrical energy generation

Table IV illustrates how the research on the outrigger modification has evolved from 2012 to 2023, highlighting the various approaches and innovations explored. A shift from basic additions and adjustments to more sophisticated design analyses and alternative technologies is observed.

## VI. CONCLUSION

This study offers an in-depth analysis of the design, functionality, and technological evolution of the outrigger boats in Indonesia, emphasizing their critical role in the maritime stability and operational efficiency. Their historical significance is highlighted and their origins are being traced by exploring prehistoric Austronesian maritime practices and contemporary innovations that integrate advanced materials, such as resin (fiberglass) and Polyvinyl Chloride (PVC) pipes. The key findings indicate that the strategic placement and

variations. In addition, an outrigger length of 0.48 m from the length of the boat was obtained, and the placement of the outrigger from the back of the boat to its superstructure was determined (4.8 m). Authors in [32] optimized the length of the outrigger supports. In [41], gyroscopes were employed as a substitute for outriggers. Authors in [42] worked on creating movable outriggers to better utilize the space in the harbor. Finally, authors in [43] investigated the best position for outriggers to reduce the ship resistance. The configuration of the outrigger in the longitudinal position ratio (s/L) and transverse position ratio (t/B) directions was examined, using computing technology and numerical Computational Fluid Dynamics (CFD). The simulation results indicated that placing the outrigger configuration closer to the stern could reduce the resistance on the outrigger boat.

A focused has been placed on the hydrodynamic efficiency [7]. Modifications that streamline the shape of the outrigger can reduce the drag, allowing for a better fuel efficiency and faster travel speeds. For example, the integration of adjustable outriggers has been proposed, enabling fishermen to modify the width based on specific operational needs or sea conditions. This adaptability can lead to an improved performance and safety, as the boat can be optimized for different fishing environments. Innovations in the outrigger modification entail the integration of a simple power generation system [44]. By modifying the shape of the outrigger, the water flow can be harnessed to turn a turbine that generates electrical energy. This energy can be used for lighting the boat, which is particularly beneficial for fishermen operating at night. Research indicates that outrigger modifications not only enhance the stability, but also provide additional benefits in terms of energy efficiency.

modification of the outriggers significantly enhance the vessel stability by reducing the motion responses including heave, roll, and pitch, thereby preventing the capsizing and improving safety for the fishing and transportation activities. The study also underscores the importance of adhering to the International Maritime Organisation (IMO) stability standards to ensure that the outrigger designs meet both environmental and operational demands.

The identified innovations, such as portable outrigger systems, optimized support lengths, and integrated hydrodynamic improvements, contribute to reducing the drag and fuel consumption, which are vital for sustainable maritime operations. The incorporation of power generation systems utilizing the water flow within the outriggers represents a step towards multifunctional vessel components, enhancing the energy efficiency and supporting the night fishing activities.

Despite these advancements, the study acknowledges the limitations related to the material availability and regional variations in the outrigger design, which necessitate further investigation.

Future research should focus on refining these modifications, exploring alternative sustainable materials, and expanding the application of energy-harvesting technologies to bolster the resilience and functionality of the Indonesian fishing vessels. In conclusion, this study significantly improves the knowledge of the outrigger boat technology by combining historical maritime practices with modern engineering innovations. The findings are important for both academic research and practical applications, fostering continued development in maritime stability, energy efficiency, and sustainable fishing practices in Indonesia and beyond.

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