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Reduction Of Outrigger Wide To Maximize Fishing Boat Landing Area Capacity In Prigi Fishing Port

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***Abstract*— Jukung fishing boats, prevalent in Prigi, face challenges due to their wide design (approximately 5 meters on both sides). This excessive width often necessitates berthing further from the coast. To address this issue, this study investigates the feasibility of reducing outrigger width to increase berthing capacity at PPN Prigi while ensuring vessel stability. Through a systematic analysis of various outrigger widths (1.5, 1.25, 1, and 0.75 meters), the study determined that a reduction to 1 meter maintains vessel stability as per HSC 2000 Annex 7 and Annex 749 (18) Ch3 design criteria. A 1-meter reduction in outrigger length can increase berthing efficiency by 66% for a standard 15-meter berth with 30-40 cm ship spacing. Consequently, the east dock of PPN Prigi can accommodate an additional 94 jukung vessels, raising the total capacity from 142 to 236. This research provides valuable insights for optimizing port infrastructure and enhancing the operational efficiency of the fishing community in Prigi.**

Keywords— Jukung fishing boats, Outrigger width, Berthing capacity, Vessel stability, PPN Prigi

I. INTRODUCTION

Jukung boats, traditional fishing vessels prevalent along the southern coast of Java, are commonly constructed in Cilacap using fiberglass as the primary material. This vessel is one of the vessels with outboard motors, which is one of the types of vessels with the largest number in Indonesia with the number of outboard motor boats 476,484 units of the total number of fishing vessels in Indonesia of 1,004,060 fishing vessels in 2021 [1]. These boats are known for their reliance on outriggers to enhance stability, particularly in challenging sea conditions [2]. The outriggers play a crucial role in supporting the stability of these fishing boats, ensuring they can navigate effectively in various marine environments. However, the wide outrigger design exacerbates overcrowding at berthing areas, hindering port efficiency and impacting loading and unloading operations [3]. This study proposes reducing outrigger width to address these challenges.

Research on port congestion emphasizes the significance of optimizing space utilization [4], [5]. Understanding the complexities of fishing activities and their spatial distribution is crucial for effective port management [6]. Addressing port congestion requires a holistic approach considering the interconnectedness of fishing activities, port operations, and supply chain logistics [7].

Investigating the feasibility of reducing outrigger width while considering broader port and fishing dynamics aims to enhance efficiency and sustainability in port operations for the jukung fishing community.

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II. METHOD

The research was conducted at two key locations: PPN Prigi, where ship data collection took place, and the Fishing Technology Laboratory at FPIK Brawijaya University, where data processing and analysis occurred. The study utilized various methods including direct measurements on Jukung fishing vessel, computer-aided ship modeling using Maxsurf and Hydromax software, evaluation of ship stability with different arm length variations, and assessment of berthing area efficiency by comparing space before and after outrigger arm adjustments. The equipment used comprised measuring instruments, cameras for ship photography, and computer-aided ship design applications [8], [9], [10], [11], [12], [13], 14] (Bačkalov et al., 2021; Syahril et al., 2023; Mauro et al., 2019; Afriantoni et al., 2020; Vidhaj & Lapa, 2022; Ruponen et al., 2019; Huang et al., 2022). The importance of intact stability for ship safety is highlighted in the literature, emphasizing the need for owners and operators to ensure vessels have satisfactory stability levels to safeguard both the vessel and individuals on board. The study employed the following methods:

- Measurements on Jukung Ships: Data on the size of jukung ships were obtained through direct measurements.
- Computer-Aided Ship Modeling: Ship stability calculations were performed using Maxsurf and

Hydromax software. These tools allowed for detailed analysis of stability based on the ship's design.

- Variations in Ship Arm Length: Ship stability was evaluated with three different variations in ship arm length, considering the impact of outriggers on stability.
- Berthing Area Efficiency Assessment: The efficiency of the berthing area was quantified by comparing the available space for one ship unit before and after reducing the length of the outrigger arm.

Equipment Used:

- Measuring instruments
- Camera for photographing jukung ships
- Computer-aided ship design application for modelling

III. RESULTS AND DISCUSSION

The Jukung is a traditional Indonesian wooden fishing vessel, characterized by bamboo outriggers on both the right and left sides [15]. Over time, its construction has evolved, with modern Jukung ships now made of fiberglass and featuring bamboo and bent PVC pipe outriggers. In Prigi, most Jukung vessels utilize handline fishing gear, primarily targeting tuna and skipjack tuna [16].

Figure 1. Jukung docking area

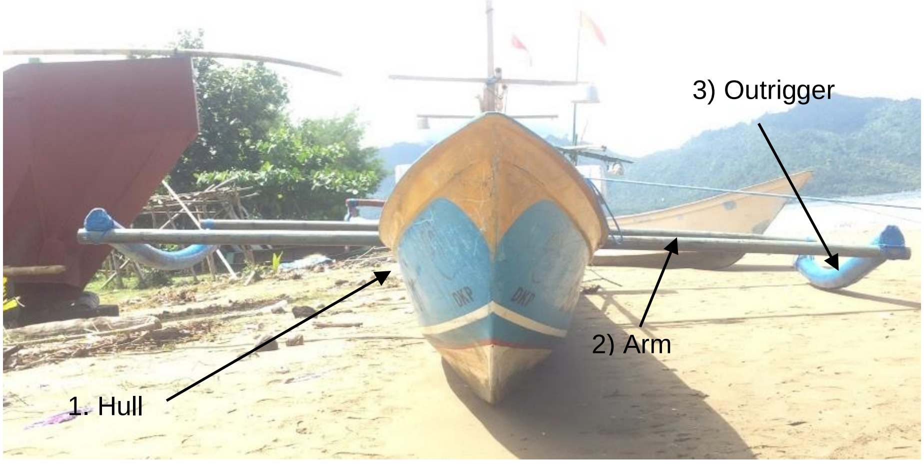

Figure 2. Jukung from front view

Figure 3. Jukung from side view

The measured of Jukung supporting line fishing boats as shown in Figures 2 and 3, with the following dimensions:

1) Hull
   Made of fiberglass with an overall length (LoA) reaching 8.19 m, width (B) 1.04 m, and height (H) 0.73 m.
2) Outrigger arms
   It has 2 arms to support outriggers on both sides of the ship's hull, the ship's arms are made of bamboo that is placed transversely on the hull with an arm length of 500 cm and a diameter of 9 cm.
3) Outriggers
   Made from laminated bamboo with a length of 300 cm and a diameter of 15 cm.

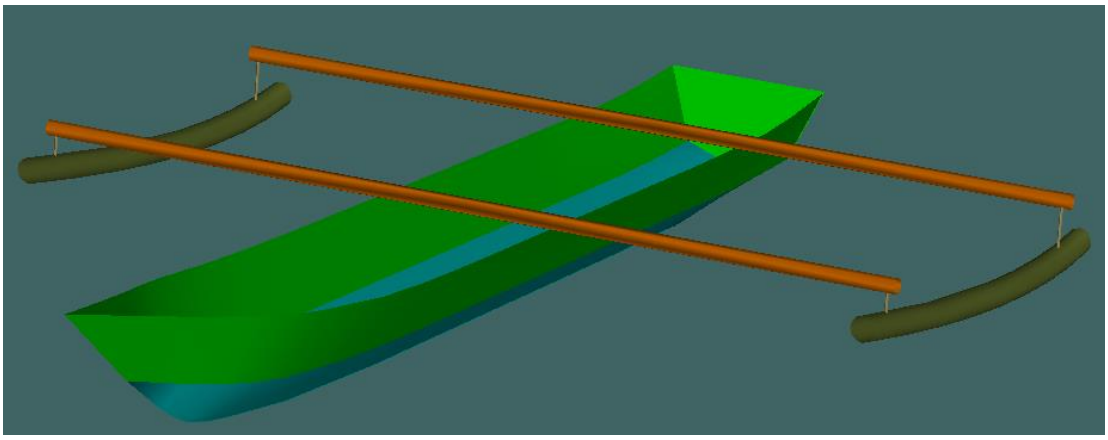

Figure 4. Results of Boat Modeling By Computer Program

Hydrostatic describes the characteristics of the boat on a particular the boat in 0.3 meter draught, the weight 0.6 tons. The hydrostatic parameters of the boat are as Table 1.

TABLE 1.
HYDROSTATICS OF JUKUNG FISHING VESSEL

Measurenment	Value	Unit
Displacement	0.596	Ton
Volume (displaced)	0.582	m^3
Draft Amidships	0.300	m
Immersed depth	0.300	m
WL Length	7.058	m
Beam max extents on WL	2.135	m
Wetted Area	6.030	m^2
Max sect. area	0.102	m^2
Waterpl. Area	4.518	m^3
Prismatic coeff. (Cp)	0.809	
Block coeff. (Cb)	0.301	

Load distribution is important for calculating boat stability with computer aided ship design. All loads on boat and their locations from zero point are modeled in the Hydromax application for stability calculations, the next is to analyze the stability of the ship based on the safety criteria applicable to ships with double hull (HSC 2000 Annex 7 Multihull. Intact) and the stabilization criteria for all types of ships (A .749 (18) Ch3). This approach was informed by the understanding that a comprehensive assessment of factors such as weight distributions, operational measures, regulatory frameworks, hull design, and adherence to international safety criteria is necessary to analyze the stability of a ship [17], [18], [19], [20]
, [21], [22]

TABLE 2.
DISTRIBUTION OF BOAT LOAD WHEN THE BOAT ON FISHING GROUND

Weight Component	Weight (ton)	Length from 0 x (m)	Length from 0 y (m)	Length from 0 z (m)
LWT	0.200	4.1	0.283	0
Right Outgrigger	0.008	3	0.36	**2**
Left Outgrigger	0.008	3	0.36	**-2**
Arm aft	0.003	1.299	0.686	0
Arm fore	0.003	3.701	0.686	0
Person 1	0.070	1	0.3	0
Person 2	0.070	2	0.3	0
Coolbox	0.080	1.798	0.521	-0.24
Coolbox	0.080	1.798	0.521	0.24
Coolbox	0.080	2.498	0.521	0
Fishing gear	0.001	2.498	0.521	0
Machinery	0.040	0.027	0.312	0
Fuel Oil	0.007	1.04	0.425	0

The load in the above table is the load of boat on the fishing ground, the remaining fuel is left at 30%, the weight of the fish in the three cool boxes weighing 80 Kilograms each. The variation of the length of the outrigger arm that will be changed for each calculation of the stability of the ship is the distance of the outrigger weight point (z-center weight) for the right outrigger and the left outrigger:

- Outrigger arm length is 1.5 meters, so the center of gravity z = 2 meters
- Outrigger arm length is 1.25 meters, so the center of gravity z = 1.75 meters
- Outrigger arm length is 1 meter, so the center of gravity z = 1.5 meters
- Outrigger arm length is 0.75 meters, so the center of gravity z = 1.25 meters

Each outrigger arm length is calculated one by one to get all required ship stability parameters.

1. Variation of outrigger arm length

The existing outrigger length is 2 meters from the side of the ship or 2.5 meters from the center line. Outrigger length variations that will be modeled and calculated stability parameters are outrigger with an arm length of 1.5 meters, 1.25 meters, 1 meter and 0.75 meters, as shown in the figure below.

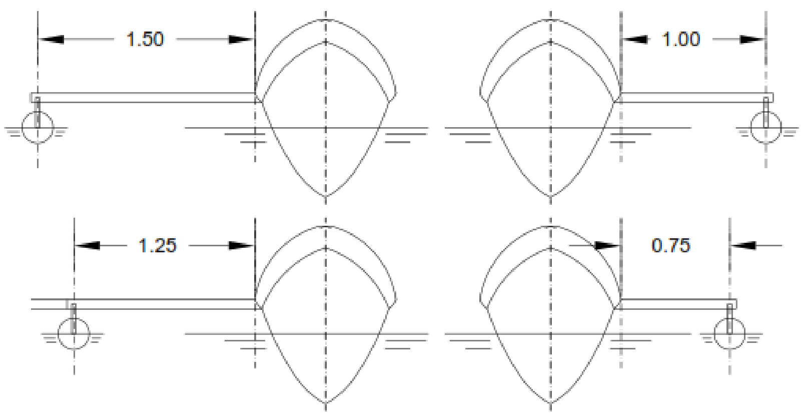

Figure 5. Variation of outriggers length arm

2. Stability Curve

Stability curves are the results of stability calculations using computer aided ship design applications. The stability curves for the four variations in arm length are as follows:

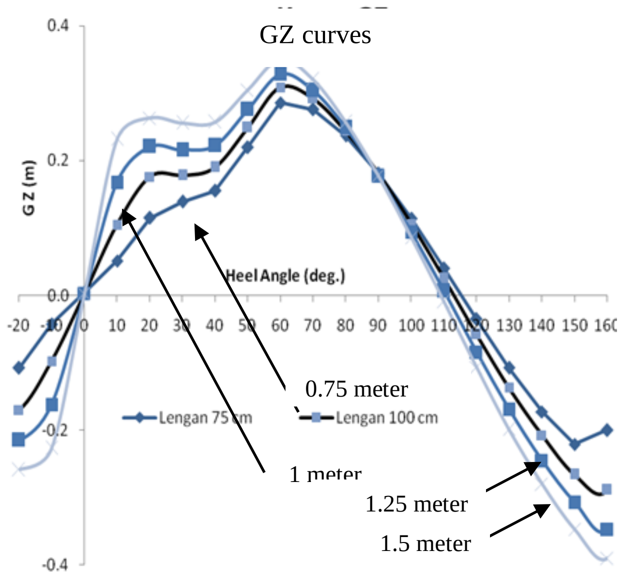

Figure 6. Stability Curve for each variation outgriggers arm length

Based on the stability curve mentioned above, the best boat stability is outrigger with 150 cm arms. This is indicated by the area under a larger curve and a higher GZ height than the others. Further analysis if the values of some stability parameters are compared with applicable safety standards. Referring to HSC 2000 Annex 7 for double hull ships and design criteria for all types of vessels, the stability parameter values for each outrigger arm length variation are as follows:

TABLE 3.
VESSEL STABILITY PARAMETERS FOR VARIOUS OUTRIGGER ARM LENGTH VARIATIONS

Code	Criteria	Standard Value	Unit	75 cm	100 cm	125 cm	150 cm
HSC 2000 Annex 7 Multihull. Intact	1.1 Area 0 to 30	3.151	m.deg	2.228	3.7059	5.206	6.6587
	1.2 Angle of maximum GZ	10	deg	63.6	62.7	61.8	60.9
A.749 (18) Ch3 – Design criteria applicable to all ship	3.1.2.1: Area 0 to 30	3.1513	m.deg	2.228	3.7059	5.206	6.6587
	3.1.2.1: Area 0 to 40	5.1566	m.deg	3.672	5.5309	7.4291	9.2812
	3.1.2.1: Area 30 to 40	1.7189	m.deg	1.444	1.825	2.2231	2.6226
	3.1.2.2: Max GZ at 30 or greater	0.2	M	0.296	0.318	0.34	0.363
	3.1.2.2: Angle of max GZ	25	deg	63.6	62.7	61.8	60.9

A comparative analysis was conducted between the computed stability parameters and the established stability criteria for each outrigger arm length. This analysis determined compliance or non-compliance with the stipulated stability requirements. The subsequent section presents a summary of stability criteria for each outrigger arm length.

TABLE 4.
BOAT STABILITY CRITERIA FOR VARIOUS OUTRIGGER ARM LENGTH VARIATIONS

outrigger arm length (m)	Stability Criteria					Criteria
	Area (0-30) (3.15 m.rad)	Area (0-40) (5.16 m.rad)	Area (30-40) (1.72 m.rad)	max GZ > 30 (0,2 m)	angle max GZ (25)	
0.75	*2.2281*	*3.6719*	*1.4438*	0.296	63.6	Failed
1	3.7059	5.5309	1.825	0.318	62.7	Pass
1.25	5.206	7.4291	2.2231	0.34	61.8	Pass
1.5	6.6587	9.2812	2.6226	0.363	60.9	Pass

The stability analysis revealed a clear dependence between outrigger arm length and compliance with established stability criteria. Outriggers with an arm length of 1 meter successfully met all relevant requirements. However, outriggers with an arm length of 0.75 meters exhibited insufficient stability.
Specifically, the analysis based on Code HSC 2000 Annex 7 Multihull (criteria area 0-30) demonstrated a deficiency in the area under the GZ curve between 0 and 30 degrees. The calculated value fell below the minimum threshold of 3.151 meter-degrees. Similarly, the analysis based on Code A.749 (18) Ch3 identified non-compliance with multiple stability criteria for the 0.75-meter outriggers. These criteria included:

- 3.1.2.1: Area under the GZ curve between 0 to 30 degrees (below the minimum of 3.151 meter-degrees).
- 3.1.2.1: Area between 0 to 40 degrees (below the minimum of 5.1566 meter-degrees).
- 3.1.2.1: Area between 30 to 40 degrees (below the minimum of 1.7189 meter-degrees).
- This non-compliance highlights the critical role of outrigger arm length in ensuring vessel stability.

To enhance spatial utilization within the subsequent fishing port, a design modification was implemented involving a reduction in outrigger width from 2 meters to 1 meter as shown in Figure 7.

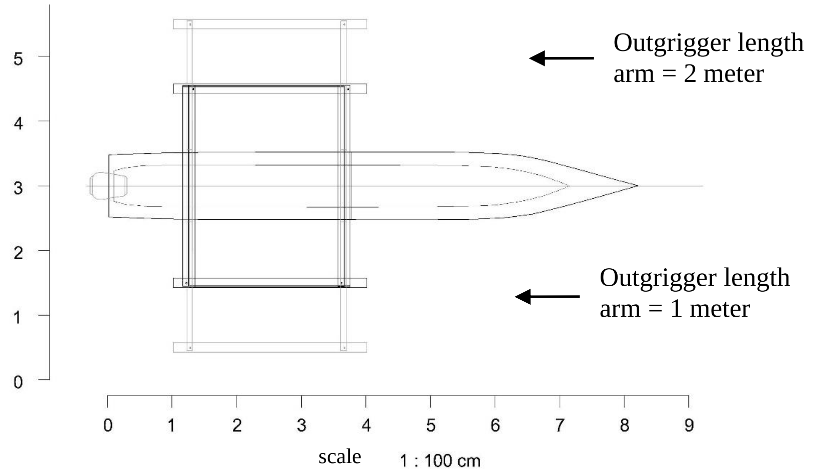

Figure 7. Comparison of width of ougriggers with 2 and 1 meter

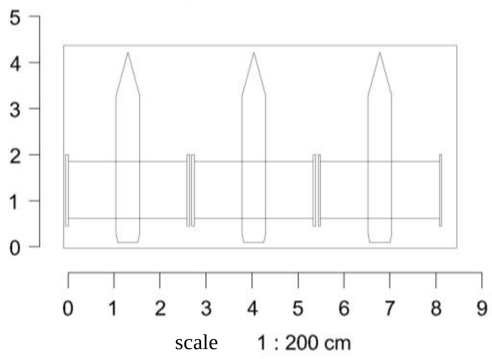

Figure 8. width of ougriggers 2 meter

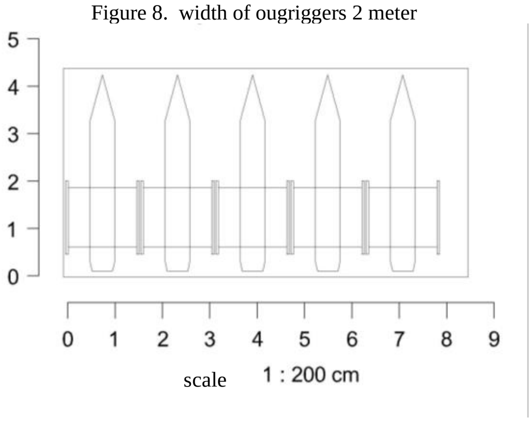

Figure 9. width of ougriggers 1 meter

With an outrigger arm length of 2 meters, the overall boat width was determined to be 5 meters (Figure 8). Given a berth length of 16 meters, a boat width of 5 meters accommodated three Jukung vessels, while a reduced width of 3 meters enabled the berthing of five Jukung vessels (Figure 9). This configuration resulted in a 66% increase in berth capacity, achieved by accommodating two additional Jukung boats compared to the previous arrangement.

Comparison of the use of outrigger with r arm length of 200 cm (now) and outrigger arm length of 100 cm in PPN Prigi is as follows:

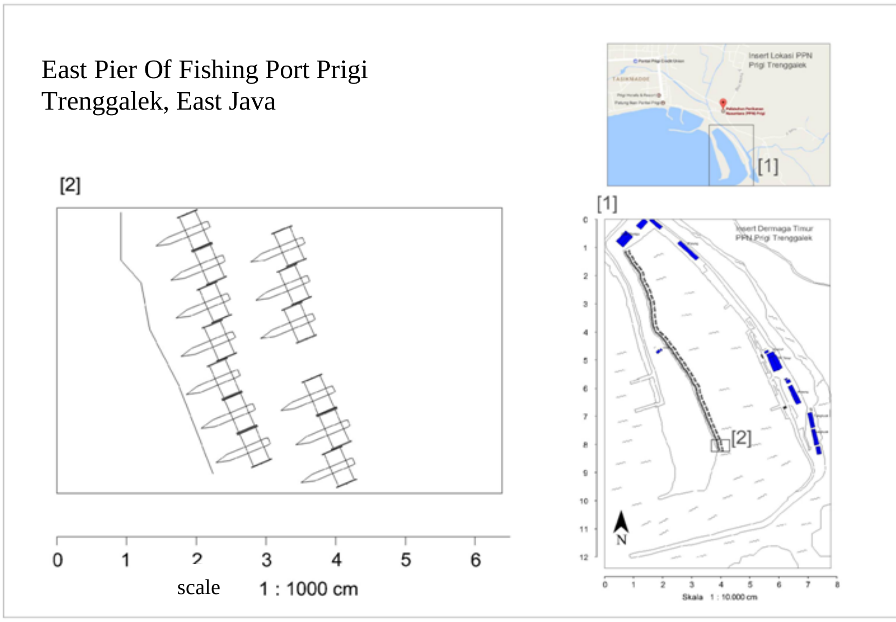

Figure 10. Layout of Landing Area with breadth of boats 5 meter

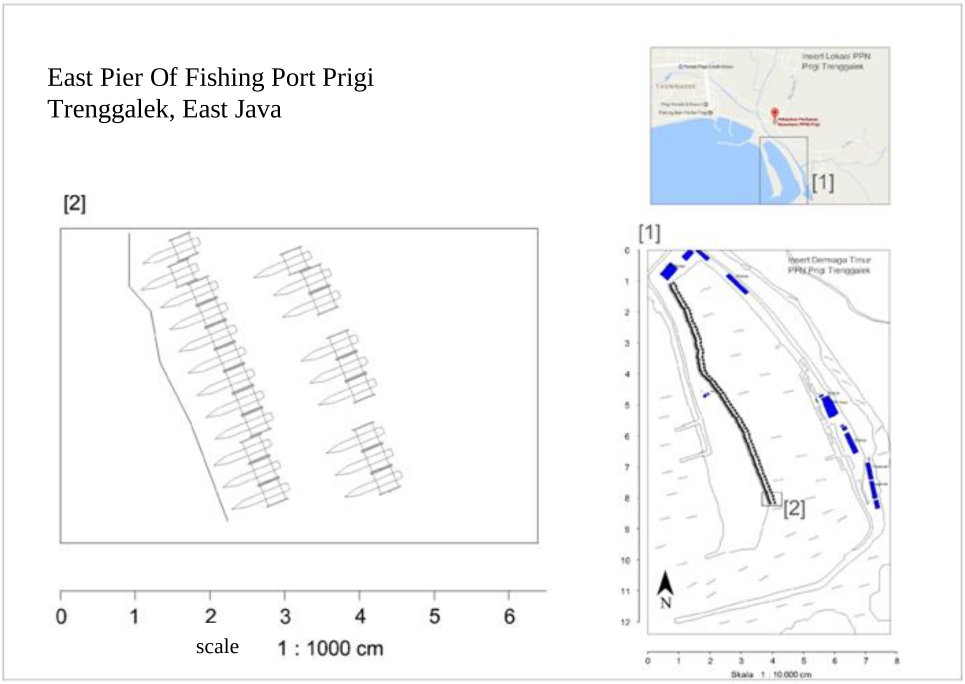

Figure 11. Layout of Landing Area with breadth of boats 3 meter

A fishing vessel "Jukung" with a 500 cm outrigger width could accommodate 142 vessels within the 738-meter-long eastern pier of the Prigi Nusantara Fisheries Port (PPN Prigi), Trenggalek. Reducing this width to 300 cm, with a vessel spacing of 20-130 cm, increased capacity to 236 vessels. Consequently, a modification from 500 cm to 300 cm outrigger width resulted in a 94-vessel increase, representing a 66% capacity enhancement at the eastern pier as shown in Figure 10 and Figure 11.

While a wider outrigger generally improves stability, it also increases vessel resistance [23] and overall height [24], [25]. Moreover, broader outriggers can amplify vessel motion, leading to extended oscillation periods, heightened passenger discomfort, and potential motion sickness (MSI) [26].

IV. Conclusion

Stability calculations, referencing triple hull ship standards (HSC 2000 Annex 7 and design criteria for all ship types), determined a minimum feasible outrigger arm length of 100 cm for Jukung vessels. Implementing this reduction at the eastern pier of PPN Prigi resulted in a 66% capacity increase, accommodating 236 Jukung vessels compared to the previous 142.

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