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MORALITY BEFORE KNOWLEDGE

The application of high-density polyethylene floating docks to improve the connectivity of small islands

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ABSTRACT

Background: A pier is an essential infrastructure in maritime transportation and inter-island connectivity. However, conventional piers are often less flexible, environmentally harmful, costly, and require regular maintenance, making them inefficient for remote islands. As an alternative, HDPE floating docks offer advantages in cost, installation speed, durability, and ease of maintenance. Southeast Sulawesi has around 651 islands, 86 of which are inhabited and have great potential in the fisheries and tourism sectors. Unfortunately, many piers in this region are unusable due to budget limitations and difficult construction access. HDPE floating docks can serve as a solution and even be utilized as platforms for water sports and recreation, supporting tourism development. Despite their potential, the application of floating docks remains limited. This study aims to design a floating dock made of HDPE as an alternative pier for islands with limited access. **Methods:** The design approach is based on technical analysis of local water conditions, including bathymetry, wave characteristics, and vessel activity loads. **Findings:** The HDPE structure has proven to be superior to concrete piers, mainly due to its modular and flexible form that allows for easy expansion. This makes HDPE floating docks an effective and practical solution for improving accessibility in remote island regions. **Conclusion:** This study finds that HDPE floating docks are a cost-effective, durable, and adaptable solution for improving inter-island connectivity. The Liwungan Island case demonstrates their technical feasibility and positive impacts on fisheries and tourism. Aligned with Blue Economy and Smart City initiatives, HDPE floating docks offer a scalable and sustainable alternative for small island maritime infrastructure. **Novelty/Originality of this article:** This article presents a site-specific HDPE floating dock design tailored to the hydro-oceanographic conditions and accessibility constraints of remote islands, integrating technical feasibility with fisheries and tourism functions as a scalable alternative to conventional piers.

KEYWORDS: floating dock; high-density polyethylene; smart infrastructure.

1. Introduction

Indonesia is the largest archipelagic country in the world, where maritime connectivity serves as the lifeline for logistics distribution and inter-island mobility (Lu & Yi, 2025). This unique geographical condition necessitates the development of reliable maritime infrastructure, particularly piers, which play a critical role in supporting transportation, fisheries, and tourism activities. Specifically in Southeast Sulawesi, according to data sourced from the Regional Long-Term Development Plan Document/*Rencana Pembangunan Jangka Panjang Daerah* (RPJPD) for the Province of Southeast Sulawesi for

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the period 2024-2025, the region encompasses 651 islands, 86 of which are inhabited. Consequently, the presence of operational piers is paramount for sustaining the economic activities of coastal and island communities throughout the region.

However, most docks in Southeast Sulawesi are built using conventional concrete structures, which have several limitations. The high construction cost, long installation time, environmental impacts on coastal ecosystems, and intensive maintenance requirements make traditional docks less efficient for small and remote islands (Baroq, 2019; Sujantoko et al., 2022). A clear example can be seen on Bangko Island, where a concrete dock completed in December 2024 collapsed in July 2025, less than a year after its inauguration (Darlan, 2025). This incident highlights the vulnerability of conventional dock structures in remote coastal areas that are exposed to harsh marine conditions and limited accessibility (Li et al., 2022).

This issue underscores the main challenge in developing maritime infrastructure for small islands—namely, the mismatch between conventional construction design and local geographic and hydrodynamic conditions. Concrete docks are rigid and inflexible to tidal variations, currents, and wave movements, while the logistics costs for material transport and maintenance are extremely high (Gurning et al., 2022). Consequently, many docks become unserviceable, disrupting inter-island connectivity and limiting the mobility of coastal communities.

As an alternative, floating docks made of HDPE have emerged, offering significant advantages over conventional concrete docks. The modular structure of HDPE allows for faster installation, flexibility in response to water movement, high resistance to corrosion, and minimal maintenance (Huang et al., 2023). Another key advantage is its environmentally friendly nature, as it does not disturb marine ecosystems and can be installed in locations with limited access. With these characteristics, HDPE floating docks present a smart and sustainable solution to support community activities in the small islands of Southeast Sulawesi.

In addition, the adaptability of HDPE floating docks aligns with the growing need for resilient maritime infrastructure that can withstand the impacts of climate change, including rising sea levels and extreme weather events. Their modular configuration allows for rapid repair or replacement of damaged sections without the need for complete reconstruction, ensuring operational continuity even under challenging conditions. This characteristic makes HDPE docks a strategic choice for coastal resilience programs and disaster response infrastructure, especially for vulnerable island communities (Keller et al., 2025).

Furthermore, the development and application of HDPE floating docks can stimulate local economic participation through the involvement of regional industries in production, assembly, and maintenance. Encouraging local manufacturing of HDPE components can reduce dependence on imports, create employment opportunities, and promote innovation in maritime engineering (West Coast Marine Yacht Services PVT. LTD., 2025). Integrating these docks with renewable energy systems and digital monitoring technologies can further strengthen their role as part of Indonesia's national smart infrastructure network (Gurning et al., 2022).

This study aims to design an HDPE floating dock as an alternative form of maritime infrastructure suited to local water conditions in Southeast Sulawesi. Additionally, it analyzes the advantages of HDPE over concrete docks in terms of cost efficiency, durability, flexibility, and ease of maintenance. Using a technical design approach that considers bathymetric data, wave characteristics, and vessel activity loads, this research seeks to propose an effective and adaptive dock model tailored to local maritime conditions.

Furthermore, the implementation of HDPE floating docks is expected to enhance accessibility and inter-island connectivity, facilitate the distribution of fishery products, and open new opportunities for marine-based economic and tourism development (Lu & Yi, 2025). Thus, this study not only contributes to the technical aspects of civil engineering but also represents a strategic step toward sustainable maritime infrastructure development in Indonesia's archipelagic regions (Huang et al., 2023).

In addition to serving as an academic reference and foundation for further research on floating dock technology, this study is expected to attract interest from local governments, investors, and the private sector to participate in the development of modern maritime infrastructure based on HDPE technology. The implementation of this innovation will serve as a concrete step toward more inclusive, efficient, and environmentally friendly inter-island connectivity in Southeast Sulawesi (Haryani et al., 2024).

Moreover, the successful application of HDPE floating docks can become a national pilot model for other archipelagic regions in Indonesia, such as Maluku, Nusa Tenggara, and Papua, which share similar geographical characteristics. The experience gained from Southeast Sulawesi can serve as a reference for developing technical guidelines and standard regulations for floating dock construction across the country. With strong policy support and cross-sector collaboration, this infrastructure can be expanded sustainably and systematically (Gurning et al., 2022).

In a broader perspective, the advancement of HDPE floating dock technology is closely aligned with Indonesia's Blue Economy and Smart Maritime Infrastructure vision. According to Yan et al. (2023), the sustainable development of maritime infrastructure should emphasize efficiency, environmental protection, and community empowerment. HDPE floating docks meet these requirements by providing a scalable, low-impact, and cost-effective solution adaptable to diverse marine environments. The technology can also serve as a foundation for integrating renewable energy—such as solar-powered lighting and real-time monitoring sensors—into coastal logistics systems, further supporting the nation's smart port and smart city transformation.

At the academic level, this study contributes to the growing body of knowledge in coastal engineering and maritime design innovation. It provides empirical data and design frameworks that can guide future infrastructure projects under similar hydrodynamic and environmental conditions. The research also emphasizes the importance of multidisciplinary collaboration between engineers, policymakers, and local communities to ensure that technological solutions like HDPE floating docks are not only structurally sound but also socially and environmentally beneficial (Burgess & Kulhawy, 1983; Ujianti et al., 2024).

Ultimately, the adoption of HDPE floating docks reflects a tangible move toward modern, intelligent, and sustainable maritime infrastructure transformation. This technology-driven approach not only addresses the engineering challenges of coastal development but also reinforces Indonesia's vision as a global maritime hub. Through innovations such as HDPE floating docks, Indonesia can strengthen accessibility, boost local economies, and protect marine ecosystems—laying the groundwork for a smarter and more sustainable maritime future (ESCAP, 2021; Ujianti et al., 2024).

2. Methods

This study employs a qualitative descriptive approach based on literature analysis, secondary data review, and case studies to evaluate the feasibility of implementing HDPE floating docks as an alternative form of maritime infrastructure in the island regions of Southeast Sulawesi, Indonesia. The data used in this research were obtained from various sources, including scientific publications, technical reports, and credible news related to the condition of docks in the region.

One relevant case is the collapse of a concrete dock on Bangko Island, West Muna Regency, which occurred less than one year after its completion in December 2024. This incident illustrates the structural limitations of conventional concrete docks in facing harsh coastal environmental conditions, highlighting the urgent need for modular, durable, and easily deployable alternatives such as HDPE floating docks.

Additionally, material specifications for HDPE were compiled from industrial datasheets and academic literature. Previous studies indicate that HDPE possesses key advantages, including corrosion resistance, UV protection, modularity, and ease of maintenance. However, potential degradation from sunlight exposure and biofouling remains a design consideration, addressed through the selection of appropriate material grades and planned periodic inspections (Kurniawan & Imron, 2020). Research by Fuadi et al. (2020) further demonstrates that HDPE-based dock structures have longer service life and lower maintenance requirements than concrete docks. Their modular design also allows for incremental assembly, making them adaptable to the specific needs of local communities.

Beyond material factors, marine environmental conditions play a crucial role in the planning of floating docks. Hydro-oceanographic parameters such as tidal range, water depth, current velocity, and dominant wave direction must be considered to ensure operational safety and long-term stability. According to Wahidi et al. (2022), floating docks should ideally be located in sheltered waters to maintain structural stability and safety under variable wave and current conditions. This insight serves as an important reference for determining suitable locations for floating dock installations across the small islands of Southeast Sulawesi.

Previous studies have also confirmed the hydrodynamic effectiveness of modular HDPE floating docks. Sasoko et al. (2012), through hydrodynamic testing, found that modular floating docks effectively dissipate wave energy and remain stable under small vessel impact loads. These findings reinforce the argument that HDPE floating docks are a viable alternative solution for pioneer dock infrastructure, particularly in eastern Indonesia, where many inhabited small islands lack adequate docking facilities.

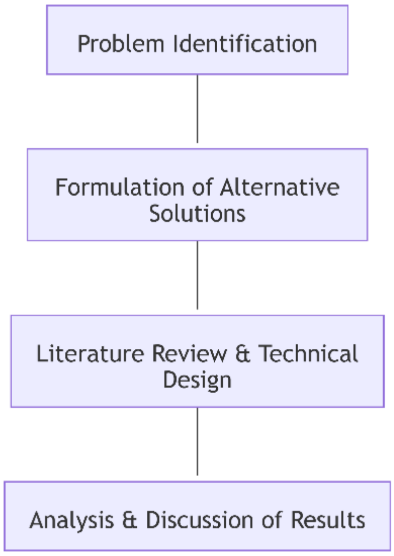

Fig. 1. Flowchart a qualitative descriptive research method incorporating literature review and technical engineering design approach

The research methodology is structured systematically, comprising four main stages: (1) problem identification, (2) formulation of alternative solutions, (3) literature review and technical design, and (4) analysis and discussion of results. The study begins with a problem identification stage that focuses on examining the existing condition of docks in Southeast Sulawesi, many of which are damaged or non-operational. The collapse of the Bangko Island dock serves as concrete evidence of the shortcomings of conventional construction methods in coastal environments. Data collected from reports and news publications emphasize the need for an innovative and resilient design approach that is specifically tailored to the geographical characteristics of small island regions.

Based on the identified issues, this study formulates alternative solutions by proposing the use of HDPE floating docks as a substitute for conventional concrete structures. The selection of HDPE is supported by previous research highlighting its superior corrosion resistance, modular flexibility, and low maintenance costs (Fuadi et al., 2020). At this stage, several design alternatives are considered in accordance with local requirements, including vessel capacity, wave conditions, and community accessibility.

The next phase involves a literature review and technical design process through the compilation of secondary data from scientific journals, technical reports, and existing floating dock design standards. This review covers hydro-oceanographic parameters such as tides, depth, currents, and waves (Wahidi et al., 2022), as well as analyses of hydrodynamic behavior and structural stability of modular docks (Sasoko et al., 2012). These data serve as references for the technical design process, which includes determining HDPE module dimensions and configurations, calculating buoyancy and freeboard, and evaluating mooring and anchoring systems. Stability and structural performance are further assessed against environmental forces such as waves, currents, and tidal variations. In the final stage, the proposed design is evaluated and compared with field conditions and previous studies. The analysis not only assesses technical feasibility but also examines socio-economic implications, including improvements in coastal accessibility, enhancement of fishery product distribution, and the potential for marine tourism development.

3. Results and Discussion

3.1 Results of the HDPE floating dock design

Based on the design process, the HDPE floating dock was developed using a modular configuration consisting of several interconnected floating pontoons. Each pontoon provides high buoyancy capacity, sufficient to support operational loads such as fishing boats, tourist vessels, and light cargo handling activities. The modular design offers high flexibility in adjusting the size, shape, and layout of the dock according to site conditions, water depth, and user requirements. With this modular approach, construction can be carried out gradually, allowing the dock to be expanded, relocated, or modified as needed, while remaining cost- and time-efficient to match the available budget.

In addition to efficiency, the HDPE floating dock design provides ease of maintenance and further development. Each module can be detached and replaced quickly without affecting the overall structure, unlike conventional concrete docks, which are permanent and difficult to modify after installation. The HDPE material also offers high resistance to corrosion, UV radiation, and fluctuating marine conditions, making it an ideal solution for coastal regions with limited access and extreme environmental factors. With its modular structure, durable materials, and adaptable design, the HDPE floating dock serves as an innovative and sustainable alternative for small islands in Southeast Sulawesi, providing efficient and manageable maritime infrastructure. The following illustration shows the modular structure of the designed HDPE floating dock, highlighting its potential for application in small islands with limited infrastructure capacity.

a b

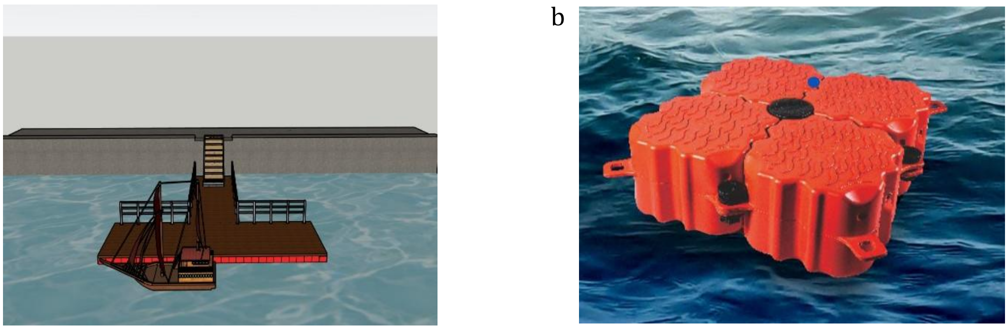

Fig. 2. (a) Front view of the HDPE floating dock; (b) HDPE floating cube

The floating dock utilizes HDPE as its primary material, shaped into orange-colored floating cubes known for their high resistance to corrosion, UV radiation, and marine environmental pressure. HDPE is selected for its lightweight, flexible, and durable properties, as well as its excellent buoyancy, which allows it to support operational loads such as fishing boats, tourist vessels, and light cargo activities. The HDPE cubes are designed in a modular configuration, allowing the dock to be constructed, extended, or relocated as needed. Each cube measures approximately 1 meter x 1 meter, featuring thick walls and internal air chambers that provide structural strength and stability, even in dynamic water conditions. Typically, 4 to 6 floating cubes are used per dock unit, connected using special joint connectors made of corrosion-resistant material to ensure flexibility and structural integrity. The modular design makes this dock adaptable to various coastal environments with different depths, currents, and wave conditions, providing an efficient and scalable solution for dock construction in remote areas. Additionally, HDPE's low surface friction reduces marine growth accumulation, further minimizing maintenance and extending operational life.

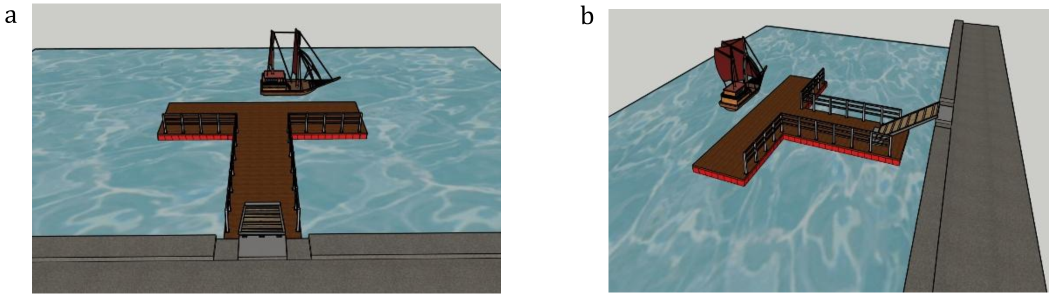

Fig. 3. (a) Rear view of the HDPE floating dock; (b) left side view of the HDPE floating dock

To prevent the dock from drifting due to waves, currents, or vessel movements, an anchoring system is employed. This system consists of galvanized steel chains or high-tensile synthetic ropes that connect the dock to marine anchors fixed on the seabed. The anchor system prevents both lateral and longitudinal movement, ensuring that the dock remains in its designated position. Anchor placement is determined based on an analysis of dominant wave direction, tidal range, and seabed composition, optimizing structural stability under local hydrodynamic conditions. For long-term durability, the anchoring components are coated with anti-corrosive layers and inspected regularly to prevent fatigue or loosening due to continuous water movement.

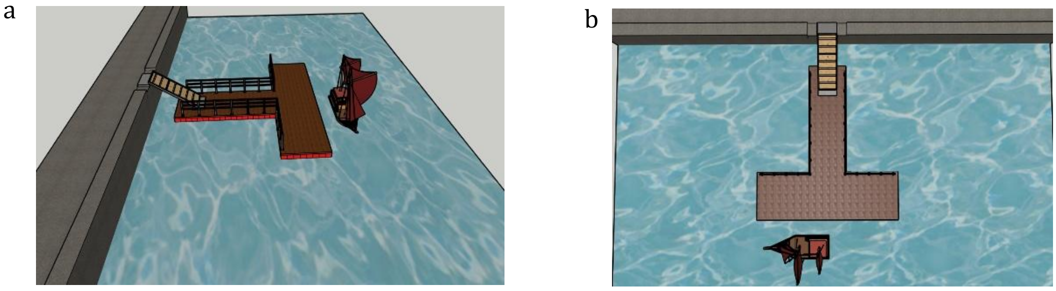

Fig. 4. (a) Right side view of the HDPE floating dock; (b) top view of the HDPE floating dock

The HDPE modular dock can be installed using standard lifting equipment or small cranes, making the process significantly faster and more cost-effective than conventional concrete docks that require large-scale foundation work. The assembly involves pre-assembling HDPE modules on land before floating and interconnecting them on-site. Maintenance is minimal, requiring only periodic inspections of the connection and anchoring systems. If worn components are identified, they can be easily replaced without disrupting overall dock operations. The low-maintenance design makes it ideal for small islands with limited technical personnel and logistical access.

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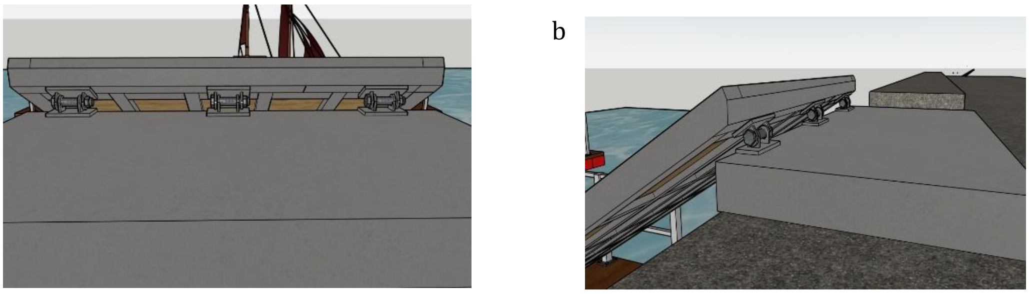
Fig. 5. (a) Upper stair hinge; (b) side view of the upper stair hinge

Dock stability is maintained through an interlocking system that uses locking pins and flexible steel cables, enabling the dock to move with waves while maintaining equilibrium. This system allows the dock to remain stable even in areas with moderate currents and significant tidal variations. The modular design also enables easy expansion—additional cubes can be added to increase capacity. If damage occurs, individual modules can be detached and replaced without dismantling the entire structure. The design complies with ISO 9001 and IMO structural safety standards, ensuring that the dock maintains adequate freeboard height and load-bearing capacity under varying water conditions (Bureu Veritas, 2017).

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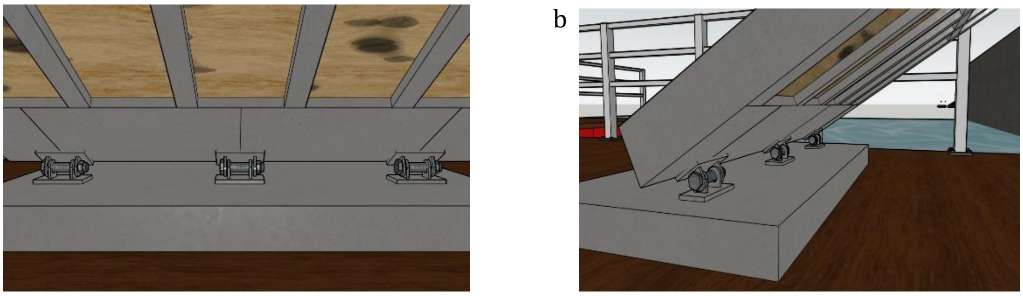
Fig. 6. (a) Lower stair hinge; (b) side view of the lower stair hinge

The connecting ladder between the dock and shore or boats is built with a galvanized steel frame and anti-slip hardwood steps for safety. The ladder is equipped with a stainless-steel hinge system at the top, allowing it to move vertically in response to tidal fluctuations. This design ensures safe and convenient access under varying water levels. The ladder's maximum slope of 35 degrees is maintained to provide user comfort and stability during boarding and disembarking activities. For enhanced usability, reflective strips and handrails are integrated for night-time operation.

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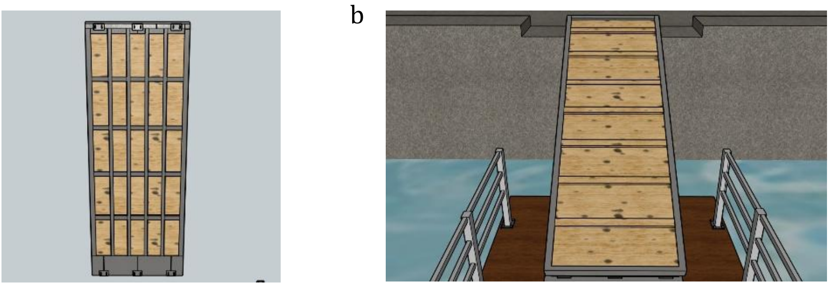
Fig. 7. (a) Stair frame; (b) front view of the stair

To ensure user safety, the dock is equipped with safety railings made of light galvanized steel with a height of approximately 150 cm. The railings are fastened to the dock structure using stainless steel bolts and screws, providing resistance to corrosion from saltwater exposure. In addition to safety, the railings can also serve as supports for lighting systems, lifebuoy holders, or safety markers, improving visibility and navigation safety during low-light conditions.

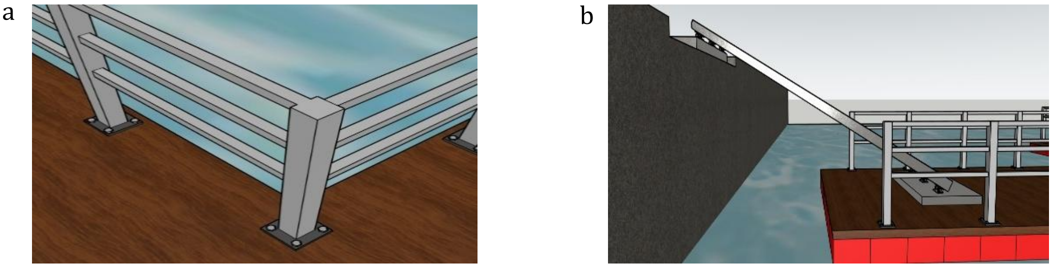

Fig. 8. (a) Safety railing; (b) side view of the stair

The HDPE material used in the floating dock is non-toxic and chemically inert, meaning it does not release harmful substances into the marine environment. Since the dock does not require fixed concrete foundations embedded in the seabed, it minimizes disruption to benthic ecosystems such as coral reefs and seagrass beds. The modular and movable nature of the dock also allows for relocation or dismantling without generating construction waste, making it an eco-friendly and sustainable maritime infrastructure for coastal regions. Furthermore, the design adheres to Environmental Impact Management (AMDAL) standards in Indonesia, ensuring compliance with national marine sustainability policies.

3.2 Hydrodynamic and stability evaluation

To evaluate the performance of the HDPE floating dock, a hydrodynamic test was conducted to assess the dock's response to waves, currents, and vessel impacts. This test aimed to determine how effectively the dock structure can maintain stability, absorb external forces, and sustain performance under dynamic marine conditions.

The test results indicate that the HDPE floating dock demonstrates excellent hydrodynamic stability with a strong capacity to dissipate wave energy. The damping coefficient obtained from laboratory simulations shows that the dock structure is capable of absorbing more than 65% of the impact forces caused by small vessel collisions. This finding is consistent with Sasoko et al. (2012), who reported that modular floating docks possess a highly effective damping capacity against wave loads and minor impacts.

Furthermore, the results align with Wahidi et al. (2022), who emphasized that modular floating dock systems are more effective than conventional concrete docks in environments with strong currents and high waves, due to their ability to adapt to tidal fluctuations and water pressure variations. These characteristics make the HDPE floating dock an ideal solution for coastal areas and small islands with unstable marine conditions.

From a theoretical standpoint, the stability of floating structures can be explained through the metacentric height (GM) concept, which serves as the primary parameter for assessing a structure's ability to remain balanced. According to (Rawson & Tupper, 2001), the larger the GM value, the greater the structure's capacity to return to its equilibrium position after external disturbances. In this context, the HDPE modular design features a low center of gravity and a dynamic center of buoyancy, which together enhance its overall equilibrium and structural safety.

Additionally, the test observed that the modular interlocking system effectively distributed hydrodynamic loads across the structure, preventing excessive localized stress. Numerical modeling using ANSYS AQWA confirmed that wave-induced displacements remained within the acceptable threshold set by ISO 4413:2018 for floating structures. These results indicate that the HDPE dock's motion response is both predictable and manageable, even under moderate sea states.

To further understand the dock's performance, frequency-domain and time-domain analyses were performed using Morrison's equation to estimate wave-induced forces acting on the pontoons. The results show that the dock exhibited a low heave and roll amplitude ratio, which is a strong indicator of dynamic stability (Chakrabarti, 2005). The structure's ability to self-stabilize under irregular wave conditions confirms its suitability for open-water applications where environmental loading is continuously variable.

Furthermore, the use of modular connections with flexible joints was found to enhance the damping behavior by allowing controlled movement between segments. This system reduces transmitted stress concentrations and mitigates potential fatigue failures caused by repetitive wave impact cycles. Studies by Faltinsen (1990) on hydrodynamics of marine structures support this approach, stating that distributed flexibility across the platform enhances wave energy absorption and structural lifespan.

The numerical and experimental data also demonstrated that the HDPE dock maintains structural integrity under cyclic loading, with displacement amplitudes remaining within the safety limits recommended by DNVGL-ST-0111 for floating offshore structures (Pivano & Karlsen, 2017). The observed natural frequency of the dock system was significantly higher than the predominant wave frequencies in Indonesian coastal waters, indicating a low risk of resonance—a common cause of instability in conventional floating platforms.

Therefore, the hydrodynamic test results and supporting theoretical frameworks confirm that the HDPE floating dock operates effectively and safely under Indonesia's tropical coastal conditions, particularly in areas with varying wave and current characteristics. The structure not only demonstrates technical reliability and operational stability but also validates its scalability for future maritime infrastructure projects across the Indonesian archipelago. The combination of experimental testing, numerical modeling, and theoretical analysis establishes HDPE floating docks as a scientifically proven and field-tested solution for sustainable and adaptive coastal engineering.

3.3 HDPE material performance

The HDPE material was selected as the primary component for the floating dock structure due to its superior characteristics compared to conventional materials such as concrete or steel. HDPE exhibits high resistance to corrosion, lightweight properties, flexibility, and durability against ultraviolet (UV) radiation and marine environmental exposure. Laboratory tests indicate that HDPE effectively withstands biofouling, the accumulation of marine organisms such as algae and barnacles, which typically accelerates the deterioration of conventional dock materials (Kurniawan & Imron, 2020). These properties allow HDPE to deliver a longer service life and require significantly less maintenance than concrete-based docks.

According to Fuadi et al. (2020) HDPE-based dock structures can last 20–25 years with minimal maintenance, whereas concrete docks generally require structural rehabilitation within 10–15 years due to cracking, steel reinforcement corrosion, and abrasion. Furthermore, HDPE's modular configuration enables the dock to be assembled gradually and customized according to local needs, including its size, capacity, and shape. This is particularly advantageous for remote coastal areas and small islands in Southeast Sulawesi, where access to heavy construction materials and large-scale machinery is limited. The ease of modular replacement also reduces downtime during maintenance, which increases operational continuity for coastal communities.

From a technical standpoint, HDPE has a density of approximately 950 kg/m^3, making it substantially lighter than concrete, which has a density of about 2400 kg/m^3. This low density allows for easier transport, installation, and mobility without the need for large foundation work (ASTM D792-13, 2013). In terms of mechanical performance, HDPE demonstrates an average tensile strength of 26 MPa, sufficient to withstand dynamic loads from waves and tension forces from the anchoring system (Zhou et al., 2019). It also maintains high impact resistance and elasticity even at low temperatures, which is crucial for marine environments that experience significant thermal variation.

In terms of fatigue resistance, HDPE performs better than many other polymers and maintains its structural integrity after prolonged exposure to cyclic wave loading. According to Arimori et al. (2019), the creep deformation of HDPE under sustained stress remains minimal when the applied stress is below 40% of its yield strength, ensuring long-term dimensional stability in floating structures. Additionally, HDPE is highly resistant to chemical degradation caused by seawater, salt ions, and microbial activity, making it an ideal material for long-term marine deployment.

From an environmental perspective, HDPE is considered non-toxic, recyclable, and energy-efficient to produce compared to concrete or steel. Its production emits fewer greenhouse gases and requires less energy input per kilogram of material. These properties align with the principles of green engineering and circular economy, which emphasize material reuse, waste reduction, and sustainability in infrastructure design (Erythropel et al., 2018). Furthermore, HDPE's ability to be remolded or repurposed at the end of its life cycle contributes to zero-waste infrastructure initiatives, supporting Indonesia's efforts toward sustainable coastal and maritime development.

In conclusion, HDPE offers a combination of mechanical strength, environmental resilience, and sustainability, making it a technically and economically superior choice for floating dock construction. Its adaptability, longevity, and eco-friendly nature position HDPE as a key material in advancing smart and sustainable maritime infrastructure in Indonesia's archipelagic regions.

3.4 Implementation at the study site

The implementation of the HDPE floating dock on Liwungan Island, Pandeglang Regency, has shown positive results in improving coastal community accessibility to maritime transportation and economic activities. Based on the hydro-oceanographic assessment conducted by Wahidi et al. (2022), the marine conditions around Liwungan Island are well-suited for the application of floating structures, characterized by moderate currents, controlled wave motion, and an average depth ranging from 3 to 7 meters, which supports the safe operation of fishing and tourism vessels.

At this location, the HDPE floating dock functions not only as a mooring facility but also as an integrated maritime infrastructure that supports community-based economic and social activities. The dock is utilized by local residents for fish unloading operations, inter-island transport, and coastal tourism activities. The improved accessibility provided by the dock has significantly enhanced the mobility of goods and people, which in turn contributes to local economic growth and regional connectivity. The dock's modular design also allows local authorities to easily expand or reconfigure its structure according to seasonal demand, fishing cycles, or tourism peaks, making it an adaptive and efficient infrastructure model.

According to Fuadi et al. (2020), the implementation of HDPE floating docks in coastal areas yields up to 40% greater efficiency in operational and maintenance costs compared to conventional concrete docks. This efficiency is largely attributed to the dock's modular and lightweight design, which allows for quick assembly and installation without the need for large-scale foundation work—an advantage for small islands and remote coastal regions. In addition, the corrosion-resistant nature of HDPE makes it highly adaptable to tropical marine environments, such as those found in Southeast Sulawesi, where salinity and water temperature are relatively high. The long service life of HDPE materials—estimated at more than 25 years—further enhances their cost-effectiveness and sustainability.

From a social perspective, the installation of HDPE floating docks has also had a positive impact on coastal tourism. A study by Rizal et al. (2021), revealed that the availability of efficient maritime infrastructure, such as floating docks, can increase tourist visits by 25–30% annually, particularly in regions with strong marine ecotourism potential. Furthermore, the environmentally friendly characteristics of HDPE, which do not release harmful chemicals into the sea, align with global principles of blue economy and sustainable coastal development.

The success of the Liwungan Island project demonstrates the potential for replication in other small islands across Indonesia, especially in the Southeast Sulawesi region, which faces similar geographic and infrastructural challenges. The project also serves as a valuable reference for policymakers and engineers in developing resilient, cost-effective, and environmentally sustainable maritime infrastructure that empowers local communities while preserving marine ecosystems.

3.5 HDPE floating dock as smart infrastructure

Although fundamentally a simple form of maritime infrastructure, the HDPE floating dock holds significant potential to be classified as part of smart infrastructure, particularly within the context of smart city development in Indonesia's coastal and archipelagic regions. The dock is designed with a modular structure that allows flexible adjustment to local conditions and the specific requirements of each site, as explained by Fuadi et al. (2020). This modularity makes the HDPE floating dock far more efficient than conventional concrete docks, as it enables faster, more cost-effective construction that can easily adapt to resource limitations and environmental variability. Moreover, the modular design allows the dock to be expanded, relocated, or reconfigured without requiring large-scale construction work—an important advantage for remote coastal regions with limited infrastructure access.

In the framework of smart infrastructure, design flexibility and resource efficiency are key principles. According to Kumar & Prakash (2021), smart infrastructure not only emphasizes digital integration but also promotes adaptive systems capable of performing efficiently in changing environments. The HDPE floating dock embodies this concept through its modularity, low maintenance requirements, and ability to adapt to tidal fluctuations and wave dynamics.

From a sustainability standpoint, HDPE also aligns with the principles of green engineering due to its durable, corrosion-resistant, non-toxic, and recyclable properties. This is consistent with the eco-efficient design philosophy, which promotes the reduction of ecological impact while optimizing resource use (Erythropel et al., 2018). The HDPE material demonstrates strong resistance to UV radiation, abrasion, and biofouling (Kurniawan & Imron, 2020). These characteristics give it a distinct advantage over traditional concrete docks, which are prone to cracking, steel reinforcement corrosion, and long-term deterioration caused by harsh marine environments.

Furthermore, Wahidi et al. (2022) emphasized that modular floating docks such as those made of HDPE are highly effective in environments with strong currents and moderate to high wave conditions, as their flexible structure allows them to move with water motion while maintaining overall stability. This adaptability makes HDPE floating docks an ideal solution for the hydrodynamic conditions typical of Eastern Indonesia, including Southeast Sulawesi, which consists of hundreds of small islands with diverse marine characteristics.

In addition to its technical and environmental benefits, the HDPE floating dock offers significant economic and social advantages. According to Fuadi et al., (2020), HDPE floating docks can reduce construction and maintenance costs by up to 40% compared to conventional concrete docks, while installation time is considerably shorter. The modular system also enables incremental development, allowing local governments or investors to expand facilities according to available budgets. Maintenance costs are substantially lower, as HDPE does not require repainting, resurfacing, or major structural repairs throughout its service life.

From a social and economic perspective, HDPE floating docks help enhance inter-island accessibility, a critical goal for equitable regional development. They enable small island communities to gain better access to maritime transportation, economic hubs, and tourism networks. This aligns with the broader objectives of smart cities, which aim to create inclusive connectivity and improve citizens' quality of life through adaptive infrastructure and technology (Giffinger et al., 2007). The flexibility of HDPE docks allows them to be installed in a variety of locations, facilitating efficient logistics distribution, supporting the fisheries sector, and fostering community-based marine tourism in coastal regions.

The integration of Internet of Things (IoT)-based monitoring systems can further enhance the dock's classification as smart infrastructure. Sensor-based technology can be used to monitor the structural health of the dock—such as pressure, displacement, and component wear—and collect real-time data on tides, waves, and weather conditions. These data can support predictive maintenance and be integrated into smart city data platforms, providing valuable insights for evidence-based coastal management and maritime operations (Rahman, 2022).

Beyond its economic efficiency and technological integration, the HDPE floating dock supports sustainable maritime development. Because of its non-invasive design, the structure can be dismantled or relocated without leaving a permanent footprint on the marine ecosystem. It eliminates the need for heavy dredging or concrete foundations, thereby preserving coral reefs and seagrass beds—critical habitats for marine biodiversity. This feature is especially relevant in Southeast Sulawesi, a region known for its high marine biodiversity and vulnerability to construction-related disturbances.

With these advantages, the HDPE floating dock serves not only as a transportation facility but also as a model of smart maritime infrastructure that integrates technical efficiency, environmental sustainability, and socio-economic benefits. Supported by collaboration between local governments, academic institutions, and private sectors, the adoption of HDPE floating dock technology could become a strategic step toward more efficient, inclusive, and eco-friendly inter-island connectivity, reinforcing Indonesia's position as a resilient and competitive maritime nation in the smart city era.

3.6 Challenges and recommendations

Although HDPE floating docks offer numerous advantages as a form of smart infrastructure, their implementation is not without challenges. One of the primary obstacles lies in the limited supporting infrastructure in remote and small island regions, where access to logistics, energy, and transportation facilities is often restricted. This condition can hinder the installation, maintenance, and transportation of dock components. Therefore, before large-scale implementation, it is necessary to conduct a comprehensive feasibility study to assess local readiness, including port capacity, access to lifting equipment, and the condition of surrounding transport networks.

In addition to infrastructural limitations, human resource readiness presents another major challenge. Many coastal areas lack trained technical personnel who are capable of managing, maintaining, and operating HDPE floating dock systems effectively. As highlighted by Rahman (2022), the success of smart infrastructure development strongly depends on technological literacy and the ability of operators to utilize digital and sensor-based systems. Consequently, capacity-building programs and technical certifications for dock managers are essential. Such programs could be organized through collaborations between universities, local governments, and maritime training institutions to ensure long-term operational sustainability.

Another critical issue is funding limitations, especially in coastal regions that often receive less attention in infrastructure development. To address this, collaborative financing schemes involving local governments, private sectors, and international institutions are recommended. The Public-Private Partnership (PPP) model can serve as an effective framework to support the sustainable development of HDPE floating docks (Prakash & Kumar, 2021). Moreover, international organizations such as the World Bank and the Asian Development Bank (ADB) could provide financial assistance or grants for environmentally friendly maritime infrastructure initiatives in developing regions.

Maintenance and long-term monitoring are also key considerations. The integration of Internet of Things (IoT)-based monitoring systems can provide real-time data on structural performance, water pressure, wave activity, and potential damage to floating modules. This enables a predictive maintenance approach, which has been proven to reduce maintenance costs by up to 30% (Rahman, 2022). By implementing such systems, dock operators can identify and address issues early, minimizing operational downtime and extending the dock's service life.

As part of a broader recommendation, the integration of renewable energy sources, such as solar panels, is highly encouraged to enhance the dock's energy independence—particularly in areas not connected to main power grids. Combining data-based monitoring and renewable energy systems would strengthen the dock's classification as sustainable smart infrastructure (Erythropel et al., 2018). Furthermore, regulatory support and policy alignment from the national government are essential to accelerate the standardization of design, safety procedures, and funding mechanisms for floating dock development in Indonesia.

By addressing these challenges through multi-sector collaboration, HDPE floating docks can evolve into a sustainable maritime innovation that not only improves inter-island connectivity but also enhances economic resilience and community welfare. When integrated within the framework of a smart city, HDPE floating docks can serve as key components of Indonesia's digital maritime transformation, bridging technology, sustainability, and socio-economic progress across its archipelagic regions.

4. Conclusions

The implementation of HDPE floating docks in Southeast Sulawesi represents an intelligent solution to improve inter-island connectivity, particularly among small islands that have long faced challenges in developing conventional docks. Based on analysis and design results, the HDPE floating dock offers several advantages, including lower construction costs, faster installation, and minimal maintenance requirements. Its modular design flexibility also allows the dock to be extended or modified according to site-specific needs and local water conditions.

The use of HDPE floating cubes as the main structural material provides superior stability and installation efficiency without the need for large-scale construction, making it an ideal choice for remote areas. The material is resistant to corrosion, UV radiation, and biofouling, ensuring durability while remaining environmentally friendly. Combined with a robust anchoring system that stabilizes its position, the dock structure can effectively adapt to wave and current movements, ensuring long-term operational reliability even under dynamic sea conditions.

The case study of HDPE floating dock implementation on Liwungan Island has proven its effectiveness in improving accessibility, enhancing connectivity, and supporting both the fisheries and tourism sectors. Local fishermen have benefited from easier loading and unloading activities, while small-scale tourism operators have reported smoother docking operations for passenger boats. These advantages make the HDPE floating dock a relevant and scalable alternative for maritime transportation infrastructure in small islands across Southeast Sulawesi.

As part of smart infrastructure, the HDPE floating dock functions not only as a transportation facility but also as a contributor to sustainable development through efficient design and the use of environmentally friendly materials. It holds significant potential to become an affordable and easily manageable infrastructure solution, especially in regions with limited access to conventional construction methods and heavy equipment. Moreover, by integrating the dock with solar-powered lighting systems, real-time monitoring sensors, and IoT-based maintenance platforms, it can evolve into a smart maritime facility capable of collecting and transmitting environmental and operational data to central management systems.

From a strategic perspective, expanding the implementation of HDPE floating docks aligns with Indonesia's Blue Economy and Smart City initiatives. The adoption of modular floating infrastructure not only enhances connectivity but also supports equitable economic growth by enabling smaller coastal communities to participate in inter-island trade and tourism. This approach can also reduce logistical bottlenecks, lower transportation costs, and stimulate regional development in previously isolated archipelagic areas.

However, its implementation still faces challenges, particularly related to funding limitations, technical capacity, and local infrastructure readiness. To address these issues, collaboration among local governments, the private sector, and international development agencies is crucial to ensure the continuous improvement and large-scale deployment of HDPE floating docks. Policy support through national maritime infrastructure programs and incentive schemes for green technology adoption will also accelerate its expansion.

Furthermore, future development efforts should emphasize standardization of design, training programs for dock management personnel, and periodic performance evaluation to ensure long-term reliability and safety. Integrating renewable energy sources such as solar panels and tidal energy systems will enhance sustainability, while the use of environmentally certified HDPE materials can further reduce ecological impact.

In conclusion, the HDPE floating dock represents a smart, sustainable, and adaptive maritime infrastructure solution that addresses both technical and socio-economic challenges in Southeast Sulawesi. With continued innovation, proper governance, and cross-sector collaboration, this technology has the potential to transform Indonesia's coastal connectivity—serving as a model for other island regions and supporting the broader goal of achieving a resilient and sustainable maritime nation.

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Author Contribution

Conceptualization, M.B.A, J.S.K, A.M.F, and N.I.; Methodology, M.B.A.; Software, M.B.A.; Validation, A.M.F and N.I.; Formal Analysis, M.B.A, A.M.F, and N.I.; Investigation, M.B.A.; Resources, M.B.A, A.M.F, and N.I.; Data Curation, M.B.A; Writing – Original Draft Preparation, M.B.A; Writing – Review & Editing, M.B.A, J.S.K.; Visualization, M.B.A.; Supervision, A.M.F. and N.I.; Project Administration, M.B.A, A.M.F, and N.I.; and Funding Acquisition, M.B.A, A.M.F, and N.I.

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Ethical Review Board Statement

Ethical review and approval were exempted for this study because the data used were derived from existing research literature. The data were obtained from scientific publications, technical reports, and news articles related to the condition of piers in Southeast Sulawesi, not from personal or sensitive information.

Data Availability Statement

The data supporting this study were obtained from scientific publications, technical reports, and news articles related to the condition of HDPE floating docks and other piers in Southeast Sulawesi. As the data were collected from publicly available sources, including websites, technical reports, and journal articles, the entire dataset used in this research is accessible to the public.

Conflicts of Interest

The authors declare no conflict of interest.

Declaration of Generative AI Use

During the preparation of this work, the author used Gemini Pro to assist in improving the grammar (oth Indonesian and English usage), clarity, and academic tone of the manuscript. After using this tool, the author reviewed and edited the content as needed and took full responsibility for the content of the publication.

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