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# INTEGRATING PESTLE AND SWOT FOR ADVANCING SUSTAINABLE INLAND WATERWAY TRANSPORTATION: INSIGHTS FROM WEST JAVA, INDONESIA

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## Resume

The potential and challenges of Inland Waterway Transportation (IWT) in West Java, Indonesia were examined in this research, with a focus on sustainability using the SWOT and PESTLE analyses. Key findings show that IWT provides significant environmental benefits, such as reduced carbon emissions, and supports social equity through affordable and accessible transport. However, challenges include sedimentation, water hyacinth proliferation, poor waste management, infrastructure deficiencies and high investment costs. Overcoming these obstacles requires strategic planning that emphasises centralisation of governance, modernisation of infrastructure, environmental management and integration of technology. The findings provide applicable insights for policymakers and stakeholders to foster sustainable and inclusive transport in West Java.

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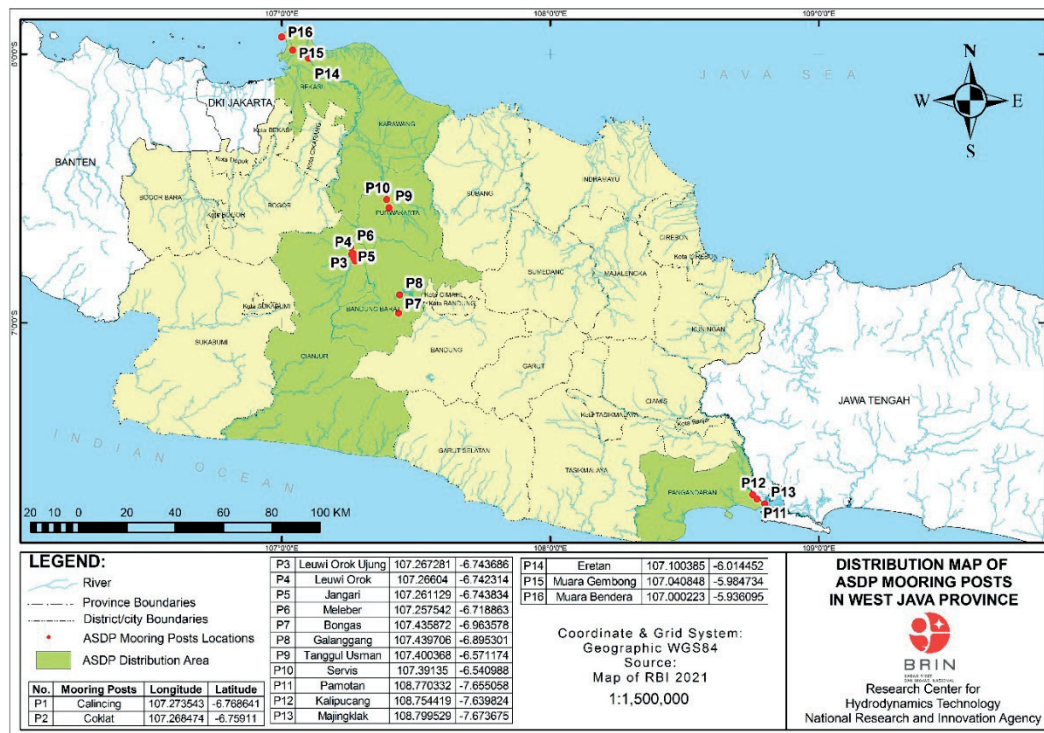
## 1 Introduction

Transportation is a basic human need and a critical element for the economic development of a country [1]. Inland Waterway Transport (IWT) is a key component of sustainable transportation systems, contributing to environmental and economic sustainability, while creating employment opportunities, as well [2]. The IWT offers several benefits, such as enhanced safety and cost savings [3]. Furthermore, its development plays a crucial role in reducing emissions and mitigating the external costs associated with pollution and congestion [4]. Despite its advantages, IWT faces numerous barriers, including challenges related to logistics, infrastructure, and political, economic, environmental, and technological landscape [3].

Indonesia, as an archipelago with over 5,950 watersheds and more than 500 major rivers, has

significant potential to expand its IWT network. However, out of the many rivers, only 214 are currently utilized for transport purposes [5]. In West Java, despite the presence of a promising river network, the development and use of IWT remains limited. This study aim was to identify and address the challenges and opportunities associated with the development of IWT in the region.

The IWT is a form of local transport traditionally use by communities, often reflecting local culture and conditions [6]. It was highlighted in a UN report on informal transport [7]. The IWT is recognized for its resource efficiency, affordability, and adaptability to technological advancements. In Indonesia, these systems are often designed by local communities to meet specific needs, functioning independently and in traditional environments [8-9]. Although the IWT is classified as public transport [6, 10], its underdevelopment remains



**Figure 1** Distribution Map of River, Lake and Ferry Transport Mooring Posts for West Java Province

especially evident in West Java, where the potential of IWT is yet to be fully realized.

The primary objective of this study was to assess the current challenges and opportunities for the development of IWT in West Java. This research has utilized a SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) analysis combined with the PESTLE (Political, Economic, Technological, Social, Legal, Environmental) framework to provide a comprehensive evaluation of the factors influencing the IWT development in this region. By addressing these challenges, the study has aimed to offer actionable recommendations for policymakers, transport operators, and local communities, contributing to the sustainable development of IWT.

## 2 Data and methods

### 2.1 Research location

The research on Inland Waterway Transport (IWT) was conducted in West Java, focusing on 6 (six) service area as shown in Figure 1. These areas include the Cirata service area for Cirata reservoir transportation in Cianjur Regency, the Saguling service area for Saguling for reservoir transportation in West Bandung Regency, the Jatiluhur service area for reservoir transportation in Purwakarta Regency, the Kalipucang and Majingklak service areas for river transportation in Pangandaran Regency, and the Muara Gembong service area for river transportation in Bekasi Regency [11-12].

### 2.2 Theoretical and operational framework

This study employs an integrated approach combining the PESTLE and SWOT frameworks to evaluate and to identify external and contextual parameters, while SWOT categorizes those parameters into strengths, weaknesses, opportunities, and threats.

#### 2.2.1 Theoretical basis for PESTLE and SWOT

Both PESTLE and SWOT are established tools in strategic planning and decision-making processes. **PESTLE**: focuses on macro-level external factors influencing sectoral performance, including political, economic, social, technological, legal and environmental dimensions [13]. **SWOT**: provides a structured method to evaluate internal and external factors by categorizing them into strengths, weaknesses, opportunities, and threats [14]. The Integration Process begins with PESTLE Analysis, which identifies and examines relevant factors to provide a foundational understanding of the contextual environment. Subsequently, SWOT Analysis evaluates the factors identified through PESTLE to classify them into actionable insights, ultimately guiding the formulation of strategic recommendations. This two-step process ensures a comprehensive evaluation of both macro environmental and sector-specific factors influencing IWT development.

### 2.2.2 Operationalization of PESTLE for IWT analysis

In this study is combined a review of existing literature and secondary data from the Central Bureau of Statistics and the West Java Transportation Agency to identify key PESTLE indicators. To enhance the reliability and depth of the analysis, primary data was collected through the semi-structured interviews with the key stakeholders, including government officials, transportation operators, and local communities. The Political Aspect Examined government policies, regulatory frameworks, and IWT development plans to identify enabling and constraining factors. The Economic Aspect includes a Location Quotient (LQ) analysis to assess the economic potential of the region. The LQ values above 1 indicate areas with promising development potential [15-16]. The Social and Technological Aspects Evaluated IWT's authenticity and adaptability to modern technology by analyzing its social acceptance, cultural alignment, and technological readiness [6]. Table 1 shows the characteristics of IWT indigeneity. The legal aspect reviews spatial and regulatory policies affecting IWT at both provincial and district levels. Lastly, the environmental aspect assesses the use of watersheds and reservoirs, water

quality and navigability, focusing on their implications for sustainable IWT operations.

#### Primary Data Collection:

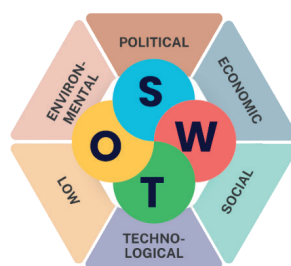
Semi-structured interviews provided valuable insights into the challenges and opportunities directly perceived by local stakeholders. These interviews were conducted with representatives from government agencies, transportation operators, and community members who rely on IWT. Primary data complemented the secondary data analysis, enabling a more nuanced understanding of the current state and future potential of IWT in the region.

### 2.2.3 SWOT analysis and integration with PESTLE

The SWOT framework was employed to systematically evaluate the parameters identified through PESTLE. Strengths and weaknesses represent internal factors such as infrastructure capacity, operational efficiency, and resource availability, while opportunities and threats capture external factors, including governmental support, environmental risks, and socio-economic

**Table 1** Indigeneity Characteristics of IWT, source: [6-9]

| Indigeneity                | Attributes  | Characteristics   |
|----------------------------|---|---|
| Locally Grown              | Appropriate use of local resources                            | Being resource-efficient by using existing resources appropriately  |
|                            | Domestically produced   | Modes of transport are localized in response to the local community's needs.  |
| Operated Locally           | Serving the area without transportation infrastructure worthy | Transport facilities and infrastructure for the area served are not available or appropriate. Such as not having roads or bridges. So, the transport system is almost inadequate. |
|                            | Serve as transit passengers                                   | Serves as transit transport or is used to complement other modes of transport in response to the surrounding community's needs.   |
| Accepted Socially          | Reachable   | Affordable transport for the surrounding community.   |
|                            | Source of livelihood for the lower middle class               | As a privately operated livelihood and operating in a traditional environment   |
|                            | Benefit vulnerable groups                                     | Benefit vulnerable groups such as children, women, and the elderly  |
| According to local culture | Support local culture   | As a cultural part of the local community that grows and operates in a traditional environment  |
| Adjust with technology     | Adapt to the latest technology                                | Transport modes adapt to the latest technology to support greater capacity and shorten journey times.   |



**Figure 2** Integration of PESTLE - SWOT Method

dynamics. The integration of PESTLE and SWOT, as illustrated in Figure 2, provides a structured approach to understanding the challenges and opportunities for the IWT development in West Java. By categorizing and analyzing the key parameters, the combined framework provides actionable insights to support evidence-based policymaking and stakeholder engagement.

### 3 Results

#### 3.1 Political aspects

The management of the Cirata Reservoir involves multiple institutional stakeholders, including the Cirata Reservoir Management Agency (BPWC – Badan Pengelola Waduk Cirata), PT Pembangkit Jawa Bali Cirata (PT PJB – Perseroan Terbatas Pembangkit Jawa Bali Cirata), the West Java Provincial Government, and the local governments of Cianjur, Purwakarta, and West Bandung districts. This multi-stakeholder management structure gives rise to various governance issues. Although the reservoir spans three districts, its management authority has been delegated to the West Java Provincial Government. Consequently, local policies, such as Regent Decrees and district-level regulations, do not apply to the reservoir.

Despite holding full authority, the West Java Provincial Government's programs often fail to address stakeholder needs due to limited human resources and conflicts arising from regional autonomy. Approximately 30% of local regulations are misaligned with provincial directives, further exacerbating inefficiencies. The BPWC, appointed by PT PJB with the Governor's approval, plays a crucial role in maintaining the reservoir but is limited to tasks like cleaning, greening, and monitoring water quality and quantity. However, stakeholders perceive the BPWC as the "owner" of the reservoir, overshadowing the provincial government. Overlapping policies and interests among stakeholders exacerbate tensions, complicating the integrated utilization of rivers and lakes in West Java.

Given the diverse functions of these water bodies - including navigation, water balance, and fisheries - formulating a shared sustainability vision is essential to resolving conflicts. Drawing lessons from the Netherlands, where a centralized water authority harmonizes policies across jurisdictions, [17] West Java could adopt a similar integrated governance framework to reduce policy fragmentation and improve stakeholder collaboration. Such an approach is particularly crucial for balancing the multifunctional roles of water bodies in navigation, fisheries, and water resource management.

Programs like Citarum Harum, based on Presidential Regulation No. 15/2018 on Controlling Pollution and Damage in the Citarum River Watershed, exemplify government efforts to improve water management. These initiatives have achieved significant progress,

including a 25% improvement in water quality over five years, reducing pollution in the Citarum to a lightly polluted level. However, governance conflicts and limited resources hinder its broader impact. Additionally, the development of IWT is a key agenda in the 2024 West Java Regional Government Work Plan and in district-level plans, such as Pangandaran District Regulation No. 48/2022 on the 2023 Work Plan.

An integrated governance framework, inspired by successful models like the Netherlands, could help to align local and provincial policies, optimize resource allocation, and strengthen stakeholder collaboration. Such a framework is crucial for ensuring the sustainability and multifunctional utility of the Cirata Reservoir and other water bodies in West Java.

#### 3.2 Economic aspects

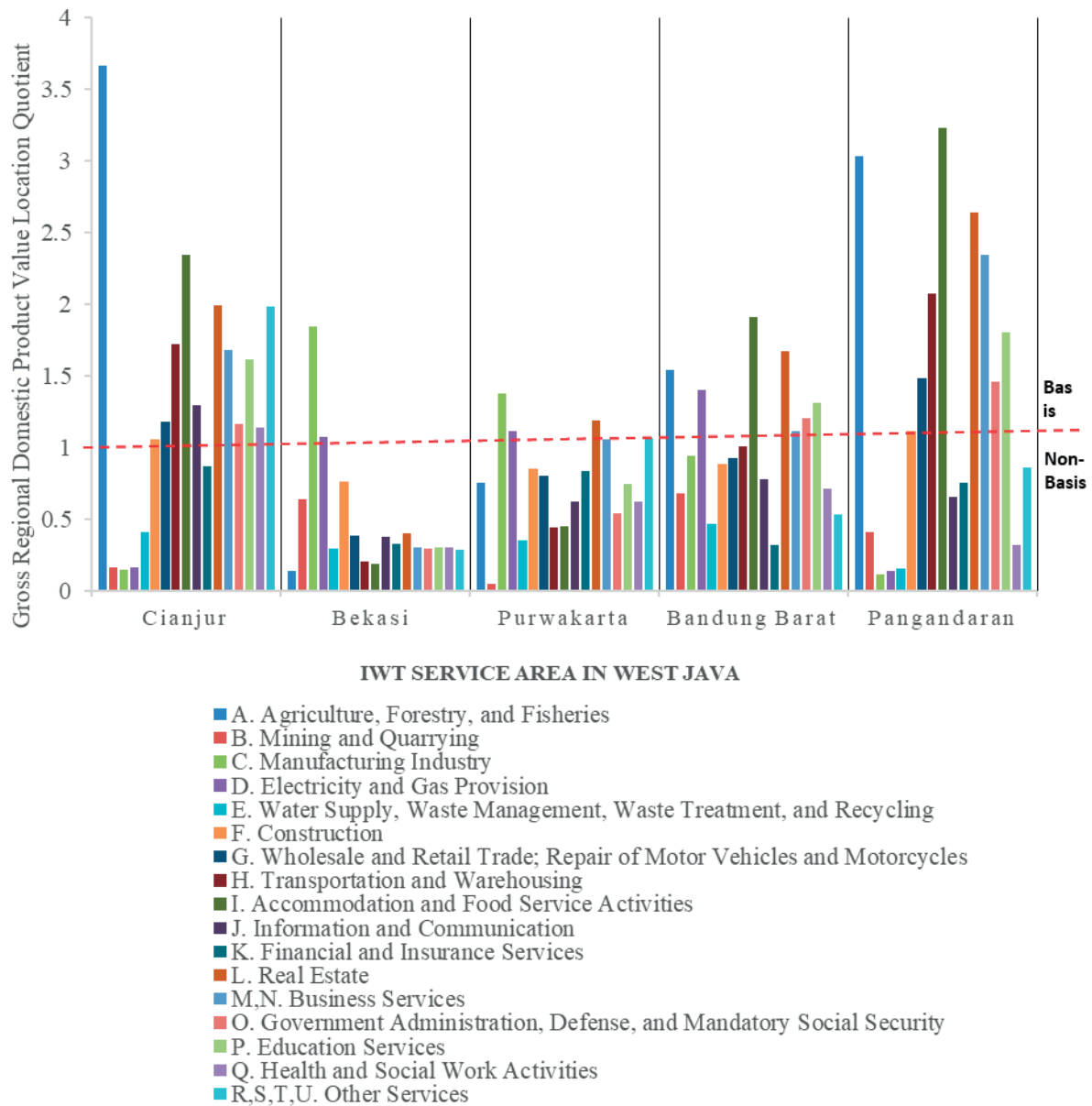
Economic sector analysis, using the Location Quotient (LQ) metric, highlights strong development potential in various regions of West Java. For instance, Cianjur demonstrates a significant advantage in agriculture, forestry, and fisheries ( $LQ \geq 1.5$ ), while Bekasi showcases strengths in manufacturing and electricity supply ( $LQ \geq 1.2$ ). Purwakarta, West Bandung, and Pangandaran also display similar patterns, where agriculture, forestry, and fisheries dominate their respective regional economies. The findings suggest that Inland Waterway Transport (IWT) can play an important role in reducing logistics costs and facilitating market access, especially for export goods [18]. Figure 3 illustrates these economic benefits, emphasising the potential for sectoral growth through improved transport infrastructure.

The IWT implementation also supports local economic development by addressing logistical bottlenecks. Strengthening transport networks, especially waterways, not only improves the distribution of goods but also reduces road congestion. Figure 3 further underlines the potential for leading sectors to benefit from this infrastructure, facilitating inter-regional trade and export opportunities.

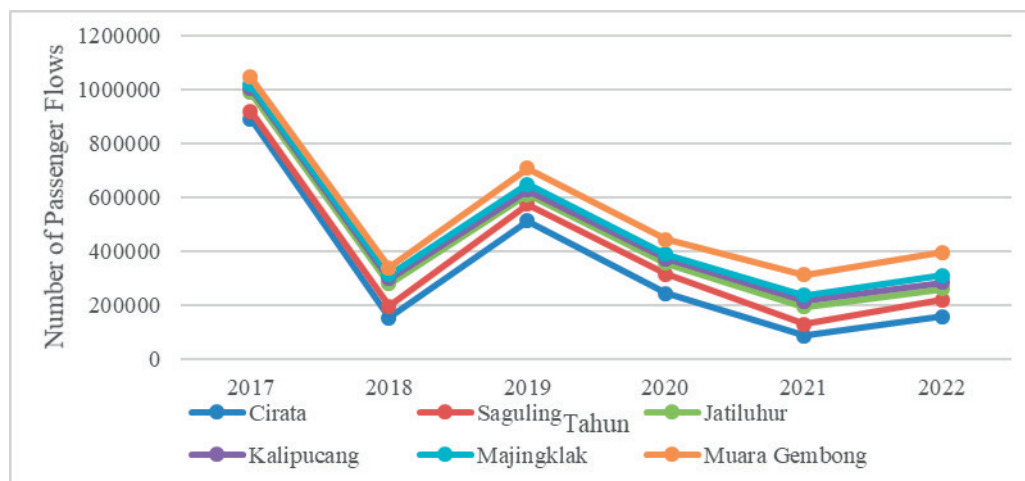
Passenger data (Figure 4) reveals seasonal fluctuations caused by sedimentation and water hyacinth growth, which reduce the channel depth by an average of 30%. The irregular positioning of the floating nets further exacerbates operational inefficiency, hampering the ship movements and passenger comfort. These factors have contributed to the decline in the number of passengers served in recent years [19-25].

Despite these challenges, the IWT fares remain highly affordable, ranging from IDR 5,000 to 7,000 (EUR 0.30–0.41), depending on the route and service area. For example, fares in Saguling range from IDR 5,000 to 7,000 (EUR 0.30–0.41), while boat rentals in Jatiluhur costs IDR 25,000 (EUR 1.47) for both long and short routes. In Kalipucang, fares start at IDR 15,000 (EUR





**Figure 3** Location Quotient Gross Regional Domestic Product Value



**Figure 4** Number of Passenger Flows in Cirata, Saguling, Jatiluhur, Kalipucang, Majingklak, Muara Gembong Service Areas, [28-29]

0.88), with an additional charge for motorbike transport. These affordable rates ensure equitable access for lower - income populations, fostering economic inclusivity [21, 25].

Global experiences highlight the transformative potential of IWT integration. For example, the Rhine River in Europe has successfully connected trade hubs through multimodal transport systems, combining waterways with road and rail networks. This approach has significantly enhanced regional economic competitiveness and seamless trade connectivity [26-27]. West Java could adopt a similar framework to harmonize its transport infrastructure and maximize IWT's economic impact.

The environmental benefits of IWT are equally noteworthy. By offering a low-carbon alternative to road transport, IWT contributes to the reduction of greenhouse gas emissions, aligning with West Java's environmental goals. The integration of IWT has already resulted in a 15% reduction in road congestion, further enhancing transport efficiency across the region. These initiatives underscore the importance of sustainable transportation systems in supporting economic growth and environmental sustainability.

In conclusion, while challenges such as sedimentation and fluctuating passenger demand persist, the development of IWT presents significant opportunities for West Java. By leveraging affordable fares, enhancing transport infrastructure, and drawing lessons from global best practices, the region can foster economic equity, improve trade connectivity, and achieve its environmental objectives.

### 3.3 Socio-cultural aspects

The Inland Waterway Transportation (IWT) in West Java reflects significant socio-cultural characteristics, including community acceptance, local operation, and cultural compatibility. Previous studies have demonstrated IWT's vital role in supporting community mobility, particularly between Saguling and Batujajar, facilitating market access and educational activities, and stimulating local economic movements [18, 30]. Beyond providing access, IWT fosters economic integration between regions and strengthens social ties.

Affordability is another key aspect, ensuring accessibility for various socio-economic groups, particularly the middle and lower classes. For instance, fares in Saguling range from IDR 5,000 to 7,000 (EUR 0.30–0.41), while boat rental rates in Jatiluhur are IDR 25,000 (EUR 1.47) for both long and short routes. In Kalipucang, fares start at IDR 15,000 (EUR 0.88), and increase if transporting motorbikes. These affordable rates highlight IWT's role in promoting social equity and inclusivity.

The IWT complements other modes, particularly in areas with limited land infrastructure. It connects regions

unreachable by road, facilitates goods distribution, and encourages social mobility. For instance, in Saguling, 60% of users rely on IWT for accessing markets and educational facilities.

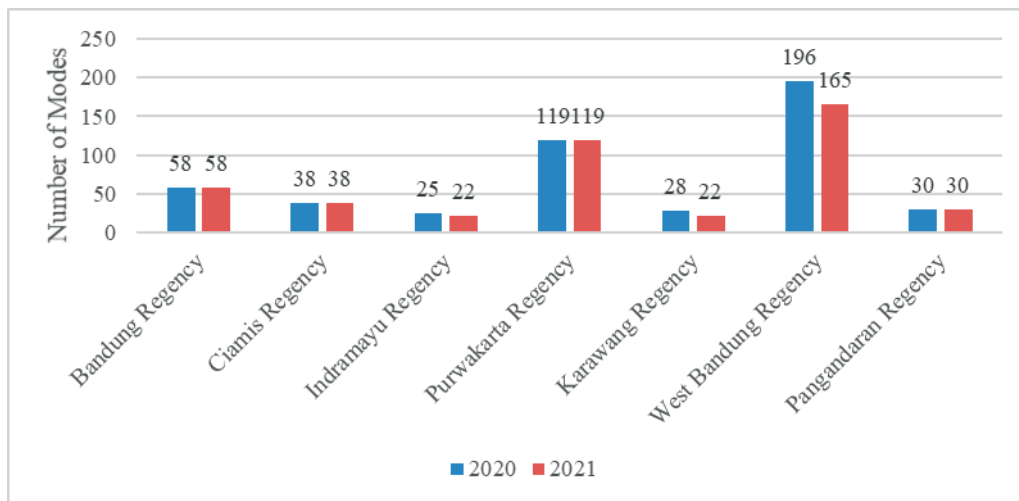
The IWT is also deeply integrated with local cultural life. In the Cirata Reservoir, various recreational activities and traditional ceremonies, such as annual boat races organized by the Indonesian Rowing Sports Association at Jangari, underline the cultural significance of waterways [31]. Traditional boats like the Comprang in Majingklak and Kalipucang, and the Eretan in Muara Gembong, not only serve functional purposes but also preserve cultural heritage, reflecting traditions from the Javanese culture of Cirebon and the Tarumanegara Kingdom [32-33].

Despite these benefits, the IWT faces socio-environmental challenges. Waste mismanagement, particularly in the Citarum River Basin, causes severe pollution, disrupting ecosystems and affecting water quality. Of the 445,000 tons of waste generated annually, only 27% is processed, leading to health and environmental issues [34]. Learning from initiatives like India's Namami Gange program [35-37], West Java could adopt community engagement and technological interventions to mitigate pollution while preserving its socio-cultural identity.

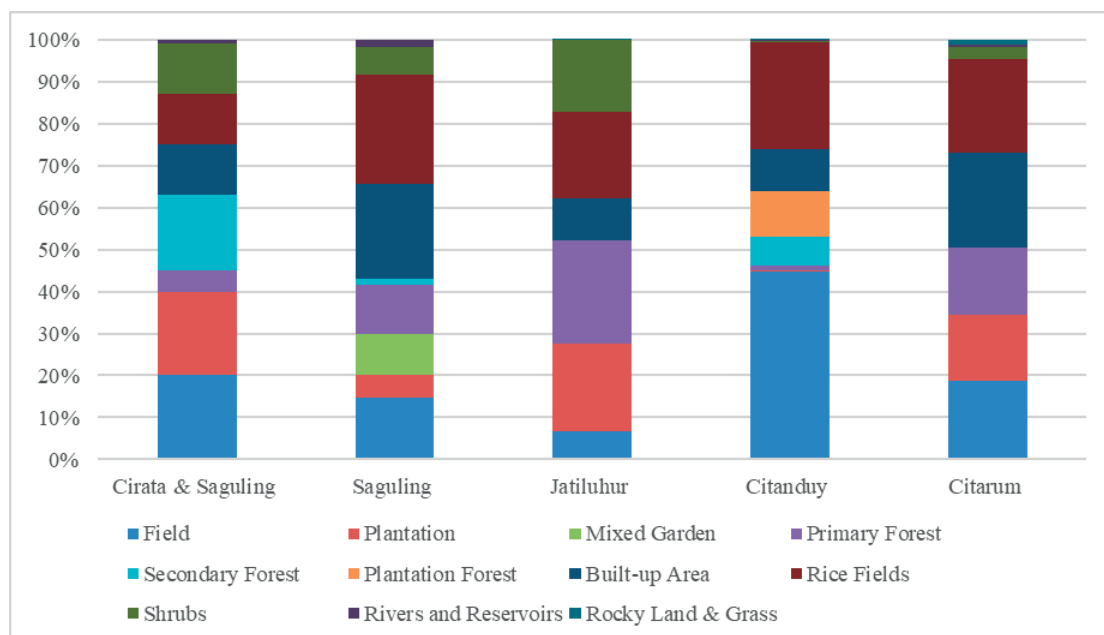
### 3.4 Technology aspects

West Java's IWT systems reflect a blend of traditional craftsmanship and modern technology. Traditional watercraft, such as boat taxis in Cirata, Saguling, and Jatiluhur, Comprang boats in Kalipucang and Majingklak, and bamboo rafts in Muara Gembong, showcase local ingenuity. These vessels are often crafted by artisans in Cipeundeuy and Baleendah, emphasizing the region's skill in boat-making [38-39]. Motorized boats and fiberglass vessels have enhanced operational efficiency, but traditional crafts remain prevalent, particularly in areas like Muara Gembong. However, maintenance costs and inadequate infrastructure hinder their utilization, with 40% of vessels in Saguling underutilized due to inadequate infrastructure, as illustrated in Figure 5 [40].

Technological advancements in countries like Bangladesh - including digital navigation systems and maintenance subsidies - offer insights for revitalizing the IWT systems [41-42]. Implementing such innovations in West Java, along with operator training programs, could enhance efficiency and sustainability. Challenges such as irregular mooring facilities, insufficient docks, and inadequate equipment (e.g., fenders, jetties, and traffic signs) [43] persist in service areas like Cirata, Saguling, and Jatiluhur [30]. Addressing these infrastructure deficiencies is essential for improving operational reliability.



**Figure 5** Number of Modes of IWT, [12]



**Figure 6** Land Use of the West Java IWT River Basin / Reservoir, [55-59]

### 3.5 Legal aspects

Provincial and district spatial plans in West Java incorporate zoning regulations to support the IWT development by safeguarding waterway corridors and restricting disruptive activities. Those plans outline critical infrastructure programs, such as river and lake crossing piers and transport routes, while enforcing restrictions to protect water bodies and shipping lanes [44-49].

However, enforcement remains inconsistent, with 35% of zoning violations attributed to inadequate regulatory oversight. The Mississippi River in the United States demonstrates the effectiveness of real-time monitoring and strict enforcement in maintaining waterway safety and efficiency [50]. By adopting similar practices, such as real-time tracking and robust regulatory frameworks, West Java could strengthen compliance and protect critical transport infrastructure

### 3.6 Environmental aspects

Environmental challenges significantly impact the IWT systems in West Java. Sedimentation, accumulating at 1.2 million cubic meters annually, and invasive water hyacinths reduce navigable capacity by up to 40% during peak seasons. These issues increase operational costs and disrupt services. For example, reservoirs like Cirata, Saguling, and Jatiluhur face declining waterway accessibility due to sediment build-up and water hyacinth growth [19, 51-52].

Land use surrounding watersheds, including agriculture, forestry, and urbanized areas, exacerbates these challenges by contributing to sedimentation and pollution. Figure 6 illustrates the impact of land use on transport demand, emphasizing the need for sustainable practices. Furthermore, overuse of driftnets in reservoirs exacerbates water pollution, complicating IWT operations [53-54].

Strategies from the Danube River, such as dredging and riverbank restoration, provide a model for addressing sedimentation and maintaining navigability. Adopting these measures in West Java, alongside regulating fishing activities and controlling water hyacinth growth, could enhance waterway resilience and operational sustainability [60-64].

#### 4 Discussion

The PESTLE analysis presented in Section 3 was integrated into a SWOT matrix for IWTs in West Java, Indonesia (Table 2). The results highlighted key strengths, such as central government support for watershed management, affordable tariffs, and cultural

integration of IWTs. Challenges faced, including overlapping policies and environmental issues, such as water hyacinth and sedimentation, were identified as weaknesses. Opportunities for the IWT development include promoting social equity and strengthening regulations. However, threats such as management inefficiencies and environmental degradation must be addressed to ensure sustainable growth of IWT services.

#### 5 Conclusion

In this study is underscored both the significant potential and challenges in developing Inland Waterway Transportation (IWT) in West Java. Key opportunities

**Table 2** Matrix PESTLE\_SWOT IWT West Java Indonesia

| Strengths      |  |
|----------------|--|
| Political      | P1: Support from the central government on watershed management  |
| Economic       | Ec1: Have affordable fares for local people  |
| Socio-Cultural | S1: Transport that is socially acceptable and integrated with local culture  |
| Technological  | T1: Transport modes have the characteristic of adjusting to technology   |
| Legal          | L1: Direction of controlling the spatial utilization of the shipping channel area in provincial and district spatial planning  |
| Environmental  | E1: Reduce carbon emissions  |
| Weaknesses     |  |
| Political      | P2: Overlapping policies and interests of various stakeholders   |
| Economic       | Ec2: Passenger flows tend to fluctuate (unstable)  |
| Socio-Cultural | S2: Lack of public awareness of the importance of water resources (The habit of throwing garbage in the watershed or reservoir and the industrial community does not yet have a waste disposal permit) |
| Technological  | T2: Inadequate mooring facilities  |
| Legal          | L2: The complexity of licensing and approval procedures may slow down IWT development.   |
| Environmental  | E2: Water hyacinth and garbage growth and sedimentation  |
| Opportunities  |  |
| Political      | P3: The West Java IWT development program is one of the important agendas of the West Java local government work plan  |
| Economic       | Ec3: Encourage regional base sector commodity distribution   |
| Socio-Cultural | S3: Promoting social equality  |
| Technological  | T3: The mode or boat is a local innovation   |
| Legal          | L3: Opportunities to strengthen regulations favoring IWT transportation development through advocacy and collaboration with relevant stakeholders.   |
| Environmental  | E3: Diversity of land uses that have activities indicating potential transport demand  |
| Threats        |  |
| Political      | P4: Implementation of management policies that are considered ineffective  |
| Economic       | Ec4: The investment cost of maintaining shipping lanes by widening and dredging rivers and lakes, which is costly  |
| Socio-Cultural | S4: Social conflicts or protests from local communities who feel aggrieved by the IWT arrangement  |
| Technological  | T4: The number of modes owned tends to remain fixed and decrease and there are still areas with modes that are not adaptive to technology.   |
| Legal          | L4: Risk of lawsuits from parties who feel aggrieved by the IWT arrangement  |
| Environmental  | E4: Distribution of driftnet cages   |



include strong governmental support, affordable fares promoting social equity, and alignment with local cultural and technological contexts. The IWT's potential to reduce carbon emissions and facilitate economic growth through improved commodity distribution further enhances its strategic value. However, environmental issues, such as sedimentation, water hyacinth proliferation, and waste mismanagement, pose significant barriers, compounded by infrastructure inadequacies, policy fragmentation, and economic challenges, including high investment costs and fluctuating passenger demand. These factors collectively impede the development of a sustainable and efficient IWT system in the region.

To address these challenges, a multi-faceted strategy is essential. This includes centralizing governance to align policies, modernizing infrastructure, and implementing sediment and waste management programs to enhance the environmental sustainability. Environmental protection is a crucial and inseparable part of any economic activity that significantly impacts the environment; therefore, economic development must be conducted in an environmentally safe manner [65]. Technological advancements, such as

motorized boats and digital navigation systems, should be promoted, alongside preserving cultural heritage through traditional boat integration. Strengthening multimodal connectivity and exploring new trade routes can further boost economic viability. With a coordinated and evidence-based approach, the IWT in West Java can become a cornerstone of sustainable transportation, fostering economic equity, reducing environmental impacts, and preserving the local cultural identity.

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### Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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