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Enhancing Management of Safety and Sustainable Inland Waterway Transport: A Case Study of Kalimantan Rivers, Indonesia

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ABSTRACT

In many countries, inland waterway transport could be integrated with land mode, making it more efficient and environmentally friendly. Indonesia has a vast river network, but it remains underutilized, with safety and sustainability concerns often being overlooked. Safety standards for ships operating on waterways have made limited progress, highlighting the need for comprehensive analysis. This study utilizes bibliometric data to examine trends in this area and support the MACTOR method, which helps policymakers select the most effective strategies for preventing accidents and ensuring that regulators and operators maintain safety and sustainability. This study provides insight into the implications of safe ship operation and explores collaboration among stakeholders to improve safety management and promote sustainable transportation systems. Data were collected through focus group discussions with 18 key actors, both directly and indirectly involved in inland waterway transport, followed by in-depth interviews with regulators and ship operators on safety regulations and their implementation. The study reveals that the actors' engagement is not fully integrated, particularly in addressing issues related to ship operation management, ship condition, and traffic congestion. Therefore, a comprehensive and coordinated management approach is necessary to enhance the utilization of ships, a vital resource for most urban and rural communities.

Keywords: *inland waterway transport, management, safety, mactor analysis, sustainability*

1. INTODUCTION

Transportation systems play a crucial role in strengthening international relations, driving socio-economic development, and boosting a country's economy and global maritime trade, with 80% of goods being transported by sea (Chen *et al.,* 2018). Their impact is significant, especially in fostering local growth in areas with untapped natural resources. It helps distribute the benefits of

development more equitably. Many countries rely on inland waterways (IWTs) as a key part of their transportation infrastructure. IWT is more efficient, sustainable, and improves environmental performance compared to other modes of transport (Calderón-Rivera *et al.,* 2024a; Roso *et al.,* 2020), making it strategic for countries seeking to reduce logistics costs while meeting environmental goals. In addition, inland waterways are attractive due to their affordability, driven by economies of scale, as well as their environmental, economic, and social advantages (Calderón-Rivera *et al.,* 2024b; Golak *et al.,* 2022). They can enhance hinterland connectivity, facilitate the distribution of public and industrial products, and improve access to major ports in Indonesia, which are typically located at river mouths (Bedoya-Maya *et al.,* 2023; Yudhistira & Sofiyandi, 2018). As an archipelagic country, Indonesia has five large islands and numerous inland waterways. People utilize inland waterway transport for both cargo and passenger transport, often through river crossings. Terminals provide simple bridging devices to facilitate the movement of passengers, freight, and sometimes vehicles on and off-board. Despite its importance, there has been limited research on inland waterway transport in Indonesia, leaving this area with significant challenges for further investigation. According to Divieso *et al.* (2021), inland waterway transport is considered more economical and environmentally sustainable than other modes of transportation.

In Indonesia's five largest islands, inland waterway transport plays a crucial role, particularly in connecting hinterland areas lacking adequate road infrastructure. It is similar to certain countries where inland waterway transport is appropriate for inaccessible areas and low-income communities (Prince *et al.,* 2024). One of these areas is Kalimantan, that is characterized by extensive river networks, functioning as trade centers (i.e. floating markets), local community activities near these waterways, and primary water transportation (Gunawan *et al.,* 2024; Hidayat *et al.,* 2017). However, safety remains a significant concern, given the high number of accidents that result in fatalities and material losses. The leading causes of accidents are unworthy ship types and human error. These two factors have a significant impact on navigation safety in inland waterways (J. Chen *et al.,* 2019). Indonesia has a safety control tool, namely the Minister of Transportation Regulation Number 61 of 2021 regarding river and lake transportation. It requires Indonesian citizens or business entities to meet ship seaworthiness standards, comply with minimum service standards, and ensure that their ships' technical specifications align with the requirements of the port facilities.

Indonesian waterway transportation has become essential for many users. Still, it continues to face frequent accidents due to inadequate infrastructure and insufficient attention to safety standards and regulations (Arya Dewanto & Faturachman, 2018). In addition, public awareness of transportation safety remains relatively low due to user negligence in river transportation services. Other factors include high sedimentation and climate change, which result in low water levels that interfere with shipping activities. As an archipelagic country, Indonesia has 21,579 km of navigable waterways, making it the seventh-longest in the world (the World Factbook in Berawi *et al.* (2019). It demonstrates the enormous potential for this country to develop inland water transport. However, it hasn't been fully utilized as a primary transportation route. Therefore, it's essential to conduct studies focused on developing IWT as a viable alternative mode of transportation. The IWT system in Indonesia also faces numerous constraints that disrupt smooth ship operations and industrial development. This article will discuss safety management in inland waterway transport by analyzing relevant case studies and considering the geographical conditions of inland waterways and the existing infrastructure, which still require further development. Furthermore, in this study, IWT research is conducted by integrating bibliometric knowledge mapping with MACTOR stakeholder modeling—an approach rarely applied in transport governance studies. While previous studies have either (a) conducted bibliometric reviews to map research trends or (b) applied stakeholder analysis to examine governance dynamics. Few have systematically connected global intellectual structures with local configurations of actor power. Furthermore, this integrated model can provide a transferable analytical framework for safety and sustainable transport governance in developing regions (Abbas *et al.,* 2025; Daimi & Rebai, 2022).

2. LITERATURE REVIEW

Literature review is a systematic research method to collect, evaluate, and synthesize various relevant literature sources through the process of investigating writings that have been published in scientific journals to address diverse research objectives and provide a robust foundation for ongoing inquiries (Chigbu *et al.,* 2023; Yang *et al.,* 2021). Accordingly, we compiled the literature review as follows:

2.1 Inland Waterway Transport (IWT)

IWT is essential for enabling the flow of goods and people, particularly in remote areas that are challenging to access by land transport (Hofbauer & Putz, 2020). It is recognized as an energy-efficient, high-capacity mode of transportation that produces lower greenhouse gas emissions than other modes, such as highways and railways, thereby helping to accomplish the Sustainable Development Goals (SDGs), and the agenda for environmentally friendly transportation (Vilarinho *et al.,* 2024). Despite its significant potential, the use of inland water transport (IWT) continues to face various challenges, including inadequate infrastructure, limited integration with other modes of transportation, and a lack of public policies to support waterway development (Nightingale *et al.,* 2018). Furthermore, the sustainability of this sector is influenced by external factors, such as climate change, as well as by suboptimal management of natural resources and the environment along transportation routes (Barbosa *et al.,* 2024). On the other hand, technological advancements such as Industry 4.0, digitalization, and intelligent navigation systems are being adopted to enhance the efficiency, safety, and operational transparency of IWT (Restrepo-Arias *et al.,* 2022). This technology has the potential to address various existing challenges by enhancing the competitiveness of the IWT sector and promoting operational improvements. The modal shift from road to waterway is also a strategy encouraged by many countries to alleviate congestion and reduce logistics costs. However, its implementation requires multi-actor collaboration and long-term policy support (Nayak *et al.,* 2024). Consequently, the development of effective management strategies is crucial for enhancing safety and ensuring the sustainability of inland transportation systems (Calderón-Rivera *et al.,* 2024b).

Table 1 Objective/Strategy for the Management of Inland Waterway Safety and Sustainability

Strategy/Objective	Sort Label	Description
Ship condition	SHIPCON	Enhancing the condition of inland waterway ships that fail to meet safety and seaworthiness standards increases the risk of accidents, particularly during adverse weather conditions.
Traffic congestion in inland waterways	SHIPTRAFFIC	Several major inland waterways in Indonesia experience high congestion, which can potentially lead to accidents caused by collisions or navigation errors.
Safety awareness	AWARENESS	Activities to increase awareness among passengers and ship operators about the importance of safety management systems.
Law enforcement	ENFORCELAW	Enforcement of ship safety regulations is insufficient, resulting in a lack of accountability for safety violations and a prevailing culture of impunity.
Crew competence	CREWCOMPT	Increasing crew members' competence is essential to meet the required qualification standards.
Ship management system	SHIPMAN'T	The ships are generally traditionally managed by low-income communities but strategically distribute basic needs to areas difficult to reach by conventional shipping.
Aids to navigation	ATON	The lack of adequate and reliable navigation aids, both on ships and in certain zones, poses a significant challenge to efficient navigation. Ensuring the availability and effectiveness of these aids is essential for improving overall safety and operational efficiency.
Policy of Sustainability	SUSTAINABLE	The policy is implemented by improving accessibility, managing IWT optimally, and building better infrastructure. It is essential to address congestion, air pollution, and climate change, which require innovation in transportation management to enhance the quality of life.

2.2 Bibliometric Source

Bibliometric analysis is a quantitative method that is applied to measure the progress of scientific knowledge within a specific research field, encompassing publication trends, research clusters, and related dimensions (Dixit & Prasad, 2025; Donthu *et al.,* 2021). Previous studies (e.g. Chaal *et al.,* 2023; Wulansari *et al.,* 2020) have applied bibliometric analysis to map transportation research trends, primarily focusing on sustainability and infrastructure development. However, these studies tend to treat safety and governance as separate dimensions, with limited attention to their interdependencies. Meanwhile, Priatno *et al.* (2025) and Zhu *et al.* (2024) highlighted the growing importance of governance mechanisms but did not integrate safety management frameworks within stakeholder-oriented approaches. This indicates a critical gap in understanding how safety, sustainability, and governance interact as a unified research domain. Therefore, this study employs bibliometric mapping to systematically identify the intellectual structure and emerging intersections among these themes, contributing to a more integrated conceptual framework. By introducing a systematic review of available literature, bibliometrics enhances the theoretical sustainability of research and explains the contribution made by it to the rest of academic discourse.

In this study context, bibliometric analysis is employed to comprehend how the challenges of safety, sustainability, and governance have been theorised and related in the previous academic work. Bibliometric approach acts as a conceptual foundation that directs subsequent analytical steps without predetermining the empirical findings, and its results form the basis for FGD-supported processing to identify actors, objectives, and relationships among concepts, which are then further analysed using the MACTOR approach (Sarturi *et al.,* 2025; Sukarsih *et al.,* 2026).

The bibliometric mapping conducted in this study employed VOSviewer software to perform keyword co-occurrence analysis on the corpus retrieved from WoS and Scopus using the search strings "Inland waterway transport," "Inland Waterway Safety," and "Inland Waterway Sustainability." The integration of this bibliometric mapping allows for a systematic visualization of research sub-themes and keyword co-occurrences, which effectively structures the operational boundaries of complex management and governance systems (Rehman *et al.,* 2024; Sordan *et al.,* 2022). The analysis produced eight distinct thematic clusters, each representing a recurring intellectual domain in the literature: (1) ship safety and seaworthiness, (2) navigation infrastructure and congestion, (3) safety culture and human behavior, (4) governance and regulatory compliance, (5) human resource development, (6) transport operations and logistics management, (7) technology and navigation aids, and (8) sustainability and SDG integration. These clusters were not merely descriptive—they served as a structured input to the FGD agenda, ensuring that the strategic discussion with stakeholders was grounded in empirically validated research themes rather than ad hoc concerns. Each cluster was presented to FGD participants as a thematic prompt, and the eight MACTOR strategic objectives listed in Table 1 were subsequently formulated to operationalize these clusters within the Indonesian IWT governance context. In this regard, by operationalizing the eight bibliometric thematic clusters identified through VOSviewer co-keyword analysis of WoS and Scopus datasets–into eight corresponding MACTOR strategies/objectives (detailed in Table 2), this study establishes a transparent methodological bridge between the global intellectual structure of IWT research and the local governance needs of Indonesian inland waterway management.

Table 2 Bibliometric Thematic Clusters to MACTOR Strategic

Bibliometric Thematic Cluster (from VOSviewer co-keyword analysis)	Dominant Keywords in Cluster	Derived MACTOR Objective	MACTOR Label
Ship Safety & Seaworthiness.	Accident, seaworthiness, vessel condition, ship type.	Ship condition	SHIPCON
Navigation Infrastructure and Congestion.	Waterway management, navigation, traffic, lock scheduling.	Traffic congestion in inland waterways	SHIPTRAFFIC
Safety Culture and Human Behavior.	Safety awareness, passenger perception, safety management, and risk behavior	Safety awareness	AWARENESS
Governance and Regulatory Compliance.	Regulation, enforcement, policy, maritime law.	Law enforcement	ENFORCELAW
Human Resource Development.	Crew competence, training, certification, qualification.	Crew competence	CREWCOMPT
Transport Operations and Logistics.	Management system, logistics, cargo, traditional shipping.	Ship management system	SHIPMAN'T
Technology & Navigation Aids.	Digitalization, AIS, navigation aids, Industry 4.0.	Aids to navigation	ATON
Sustainability and SDG Integration.	Sustainability, modal shift, emissions, SDGs, climate change.	Policy of sustainability	SUSTAINABLE

2.3 MACTOR Analysis

To support strategic decision-making in IWT management, MACTOR (Matrix of Alliances and Conflicts: Tactics, Objectives, and Recommendations) is an effective method of analysis. It can identify key actors, their relationships, and their strategic objectives within the IWT system (Torres-Salgado, 2025). This Method facilitates mapping influences, dependencies, and potential alliances and conflicts among stakeholders in the waterway transportation sector. In this context, the actors involved include central and local governments, ship operators, international agencies, and local communities that rely on waterways for economic activities. It also provides a comprehensive analysis of the direct and indirect relationships among actors, while also identifying the levels of convergence (similarities in goals) and divergence (differences in goals) between them (Riadh, 2022). With advances in MACTOR, mathematical approaches such as the Choquet integral and Shapley value have been integrated to provide a more comprehensive account of interactions among actors, thereby offering a more accurate depiction of the combined strength of actors in influencing the system (Kadaifci, 2024). This approach increasingly enriches the analysis by providing a deeper understanding of the dynamics of power, alliances, and conflicts within the context of waterway transportation.

The application of MACTOR in this research aims to inform the formulation of more inclusive and sustainable policies within the IWT sector, taking into account the diverse influences and interests of various stakeholders (Ismayanti *et al.,* 2025). By analyzing levels of convergence and divergence among actors, MACTOR can offer more effective policy recommendations to manage potential conflicts and strengthen alliances among stakeholders. Therefore, this research will employ MACTOR analysis to map relationships among actors and formulate management strategies to boost safety and sustainability of waterway transportation in Indonesia.

As explained above, several authors have not previously examined the safety management of inland waterway transport using stakeholder analysis. Therefore, this study is expected to enrich scientific knowledge by assessing the impact of IWT management, particularly for rural communities that rely on this mode of transportation to enhance connectivity between rural and urban areas, as observed on Kalimantan Island.

2.4 Stakeholder and Institutional Perspective in IWT Governance

This study is theoretically grounded in two complementary frameworks: stakeholder salience theory and institutional theory. These frameworks are not simply reviewed here but are applied as analytical lenses that shape both the design of the MACTOR analysis and the interpretation of its results in Sections 4 and 5.

Stakeholder salience theory, as revisited and elaborated by Wood *et al.* (2021) from Mitchell *et al.* (1997), proposes that the degree of priority managers and governance systems give to competing stakeholder claims is determined by three attributes: power (the ability to impose one's will), legitimacy (the socially accepted right to participate), and urgency (the time-sensitivity of a stakeholder's claim). Actors possessing all three attributes are classified as definitive stakeholders commanding immediate attention, while those possessing only one or two attributes occupy peripheral positions. This framework has been applied in recent IWT governance research to classify actors–including infrastructure managers, regulators, operators, and users–along the same attribute dimensions (Cryns *et al.,* 2025). In the present study, this framework maps directly onto the MACTOR method: the Matrix of Direct Influence (MDI) operationalizes the power dimension by quantifying the degree to which each actor can affect others; the Actor–Objective Matrix (2MAO) captures urgency and legitimacy by measuring how strongly each actor positions itself relative to each strategic objective. The quadrant positions produced by MACTOR's influence–dependence map are therefore

interpreted not merely as technical outputs but as empirical expressions of stakeholder salience configurations within Indonesia's IWT governance system.

Institutional theory, drawing on Aksom and Vakulenko (2024), explains why organizations within a field tend toward similar structures and behaviors through three isomorphic pressures. Coercive isomorphism arises from formal regulatory authority and legal mandates. Normative isomorphism arises from professional standards and expert knowledge networks. Mimetic isomorphism arises from uncertainty-driven imitation of successful models. In the context of Indonesian IWT governance, institutional theory helps explain why particular actors occupy their stakeholder positions: the dominance of regulatory bodies reflects coercive isomorphism embedded in national transportation law, while the peripheral positioning of academic institutions and insurers reflects the weak normative channels through which technical knowledge and risk expertise enter the policy process. These theoretical propositions are tested against the MACTOR findings in Sections 4 and 5, allowing this study to move beyond describing who is influential to explaining why the current power configuration exists and what institutional conditions would need to change to produce a more integrated governance system.

3. METHODOLOGY

3.1 Characteristics of the Case Study

Kalimantan, or the Island of Borneo, constitutes 73% of the total area that belongs to Indonesia, while the other parts are divided between Malaysia and Brunei (Spencer *et al.,* 2023). It is famously known as the 'Island of a Thousand Rivers'; its geographical features include an extensive network of waterways and tributaries, along which many urban and rural communities have settled to live and work (Arifin, 2024; Timmer & Rosbergen, 2021). Such features present a challenge for dedicated stakeholders seeking to develop an integrated IWT system that connects with other transportation networks, aiming to encourage efficient and sustainable operations (Caris *et al.,* 2014). The most important rivers on the island are the 1,143-kilometer Kapuas River in West Kalimantan, the 980-kilometer Mahakam River in East Kalimantan, and the 909-kilometer Barito River in Central Kalimantan. Many people live along these waterways and their tributaries, relying on them for transportation, trade, and daily activities. Pontoons and other types of vessels are commonly used to transport cargo in inland waterway transport (Solomon *et al.,* 2021). The uniqueness of Indonesian rivers is that many traditional ships are used by local communities for various activities, such as trade and travel, and people sail alongside these vessels. This situation presents multiple issues and necessitates a comprehensive approach and stakeholder collaboration to ensure the effective and sustainable management of inland waterway transport systems.

3.2 Data Collection

There are two stages used to collect both quantitative and qualitative data: multi-stakeholder group discussions (FGDs) and in-depth interviews, which took place in August and December 2024. The first phase, a focus group discussion in August 2024, was attended by 40 participants representing the key stakeholders involved in inland waterway transport systems, including government officials, shipping operators, port authorities, and safety regulators. Through FGD, akin to the methodological approach of Hwang *et al.* (2020), the researchers aimed to identify potential problems and challenges in inland waterway management related to safety and sustainability based on stakeholders' discussions. The second phase, which took place in December 2024, consisted of in-depth key informant interviews to verify and expand upon the findings from the FGD. These interviews provided more profound insights into the challenges and concerns identified earlier. The MACTOR framework was then applied to analyze the data and model stakeholder interactions, helping to identify relationships and collaborations among key actors, as well as strategic alliances and conflicts (Castaño-castellanos & Becerra-ardila, 2020).

3.2.1 Focus Group Discussion (FGD)

FGD are complex and challenging, requiring skilled facilitation to yield meaningful results (Muijeen *et al.,* 2020). Therefore, researchers conducted follow-up in-depth interviews to verify the consistency of the key issues discussed and to gain a deeper understanding of the opportunities and challenges faced in achieving safety and sustainability goals. FGD with several stakeholders and in-depth interviews are the data gathering methods used in this study to improve the analysis and discussion of inland waterway transport management, with an emphasis on sustainability and safety. The FGD aimed to identify key stakeholders and set achievable strategic goals to improve management in the inland waterway sector. The FGD participants represented a broad range of stakeholders, including the Head of BPTD, Port Authority and Harbormaster (KSOP), Country Transportation Agency (DISHUBKAB), Provincial Transportation Agency (DISHUBPROV), Directorate General of Land Transportation (DJTD), Directorate General of Sea Transportation (DJTL), Directorate General of Regional Autonomy (DJOD), Ship Operators (SHIPOP), Crew Members (CREW), Academicians (ACADEMIC), National Transportation Safety Committee (KNKT), Transportation Policy Agency (BAKETRANS), and Insurance Provider (JASRA).

3.2.2 In-dept Interviews

The insights gained from the FGD are further validated through in-depth interviews to ensure consistency in the discussion results, particularly regarding the opportunities and challenges related to the safety and sustainable development of inland waterway transport. In addition, both methods are used to understand the nonconformity in order to formulate preventive countermeasures and identify innovative solutions to achieve the desired goals (Vinh *et al.,* 2025). Key informants were purposively selected for in-depth interviews based on their level of engagement and expertise in safety and sustainability of inland waterway transport. The key informants for these interviews are chosen from participants in the FGD, including representatives from BPTD, KSOP, regional governments (represented by DISHUBKAB and DISHUBPROV), operators, ship masters, service users, and safety support agencies such as the Transportation Human Resources Development Agency (BPSDM), the Meteorological Agency (BMKG), and the National Search and Rescue Agency (BASARNAS). These experts are asked about their knowledge of the study topic and the issues that emerged during the FGD discussions.

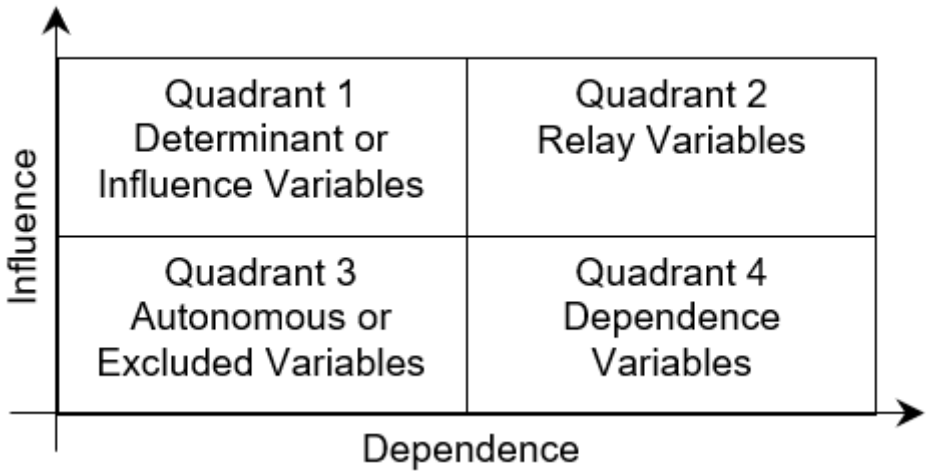

Figure 1 Influence vs Dependece Map

3.3 Method of Analysis

3.3.1 Implementation of Mactor Method

MACTOR is one of the tools for analyzing stakeholders and has been widely applied in many studies to evaluate potential conflicts, balance of power, and strategic alliances among involved actors (Godet, 1991; Jin *et al.,* 2023; Sossa *et al.,* 2024). This Method provides a detailed analysis of actors' strategies, involving multiple stakeholders from different agencies with diverse perspectives. Despite its complexity, MACTOR helps reduce uncertainty and predict potential outcomes (Rees & MacDonell, 2017). In inter-agency cooperation, key actors in inland waterway transport management play a crucial role in shaping policies that promote safety and sustainable transportation systems. The MACTOR method provides a comprehensive overview of the significance and potential outcomes of various issues, along with expected strategies, power relations, and possible alliances or conflicts. By evaluating these factors, the Method aids in forecasting the system's evolution and developing more coherent and effective policy scenarios. The MACTOR method demonstrates that actors can influence each other's strategies through mutual interactions, creating opportunities to align their preferences and support toward shared objectives. It also helps map the roles of each stakeholder and analyze how their interactions contribute to improving water transportation safety. (Puriningsih *et al.,* 2024). Besides, MACTOR identifies the level of support each stakeholder provides for each objective, providing insight into how stakeholders might collaborate or conflict over achieving their goals (Lakner, 2013).

3.3.2 Elaboration of Influence and Dependece Factors

In this study, the MACTOR approach is used to analyze the data through two main steps (akin to Fetoui *et al.,* 2021). The first step is to map relevant stakeholders and actors in this study area. This step is based on expert knowledge in multi-stakeholder focus group discussions. The research team aims to identify actors, strategic challenges, and associated objectives. The multi-stakeholder analysis, conducted using the Mactor method, focuses on the influence between actors and the effects of these actors on the management strategy for inland waterway transport safety and sustainability. As an analysis tool for multi-actors and multi-objectives, MACTOR analyses actors' strategies and characterizes their balance of power while examining their convergences and divergences regarding specific associated stakes and objectives. The second step involves analyzing stakeholders' relationships by creating an "Influence vs Dependence Map" and "Correspondence Map of Stakeholders/Objectives." These tools help define partnerships more effectively and promote teamwork or collaborative action. Stakeholders' positions are represented graphically via the "Influence and Dependency Map" according to their direct influence and interdependencies. This analysis employed a stakeholder matrix known as the "MIDI Matrix," which categorises relationships into five levels based on the degree of influence and dependence (Elmsalmi & Hachicha, 2014). These levels were explained through focus group discussions and in-depth interviews. The stakeholders were asked to rate the influence of other actors on their communities by completing the Matrix of Direct Influence (MDI) (Godet, 1991; Godet, 2006). The influence of Actor (i) on Actor (j) was scored with a number 0 (lowest) to 4 (highest), defined according to the following conditions (akin to Triyono *et al.,* 2023):

- Actor (i) exerts no influence on Actor (j) (score = 0).
- Actor (i) exerts minimal influence on actor (j), resulting in negligible effects on operational procedures (score = 1).
- Actor (i) exerts a moderate influence on actor (j), resulting in noticeable effects on work-related activities. (score = 2).
- Actor (i) exerts a strong influence on actor (j), profoundly affecting their mission (score = 3).
- Actor (i) exerts a very strong influence on actor (j), impacting its fundamental existence (score = 4).

Regarding the study's results projected onto the influence and dependence map, Arcade *et al.* (2009) divide the map into four quadrants, each with specific categories of variables based on their roles in the system to be developed (Figure 1).

- Determinant or Influence Variables (top-left quadrant): High influence, low dependence. These actors act as primary drivers of the system – they shape outcomes for others but are relatively unconstrained by other actors' decisions. In IWT governance, actors here set rules and standards that the rest of the system must follow.

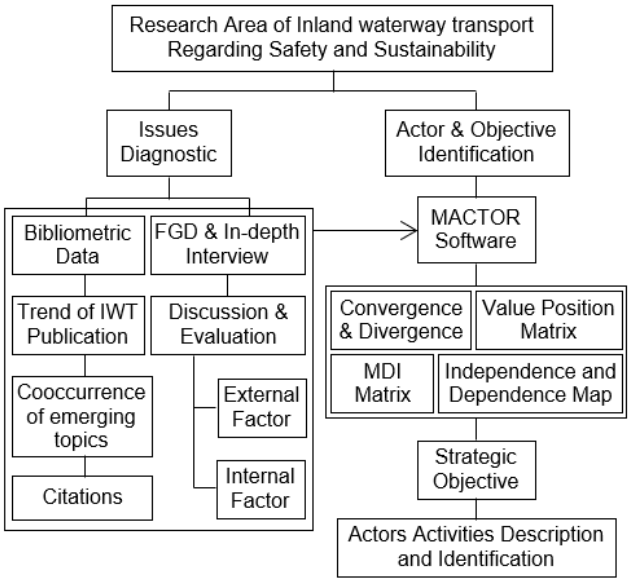

Figure 2 Research Analysis Procedure

- Relay Variables (top-right quadrant): High influence and high dependence. These are the most strategically critical actors – powerful enough to shape the system but also sensitive to changes made by others. Their position is inherently unstable, meaning that shifts in their behavior can amplify or dampen safety and sustainability outcomes across the network.
- Autonomous (Excluded) Variables (bottom-left quadrant): Low influence and low dependence. These actors are largely disconnected from the main governance dynamics. Changes to these actors have little effect on the system, and the system's decisions have little effect on them.
- Dependent Variables (bottom-right quadrant): Low influence, high dependence. These actors are strongly shaped by decisions made elsewhere in the system, particularly by relay actors, yet have limited capacity to influence those decisions in return. They are the primary recipients of governance outcomes rather than participants in producing them.

The prospective MACTOR analysis approach is used to assess the relative strength of stakeholders or actors with respect to strategic objectives. Stakeholders evaluate their attitudes toward the management goals of inland waterways by completing the valued position matrix (2MAO). Eight strategic objectives were identified in this study. The objectives were clarified for the participants in sufficient detail, allowing for thorough assessments. Meanwhile, in the 2MAO Matrix, A1 to An indicates the Actor, while O1 to On suggests the purpose of the system being studied. The procedure to fill in 2MAO by using a score of 0–4 with the following conditions (based on MACTOR software):

- The goal has a small outcome (score = 0).
- The goal intervenes in the actor's vital procedure for their operational procedures (score = 1).
- The goal intervenes in the actor's success, which is vital for the project's success (score = 2).
- The goal intervenes in achieving the actor's mission and cannot be neglected for the Actor's mission (score = 3).
- The goal intervenes in the actor's survival / cannot be neglected for the actor's survival (score =4).

After filling in the MDI and 2MAO, the MACTOR software calculates the values from the MACTOR framework. MDI is used to determine the balance of power between actors. Furthermore, MACTOR will calculate the convergence and divergence matrix, which is carried out in three stages. MACTOR is a calculation method to show where different actors stand and how much influence they have over key strategic objectives (Arcade *et al.,* 2009). The software for free download is available on the LIPSOR website. The following is how the MACTOR input data is organized in accordance with the given standards:

- Qualitative descriptive data regarding the actors' plans, motivations, constraints, and strategies are systematically compiled in the actors' strategy table.
- Actors' positions regarding strategic objectives are quantified and compiled into an actor-by-objectives table, indicating whether each Actor supports (+), remains neutral (0), or opposes (–) a given objective. Additionally, the table shows the relative importance or salience of each actor's aim, measured on a scale from 0 (unimportant) to 4 (very important).
- The influence of actors on one another is represented as numerical data in an actor-by-actor influence table, with influence measured on a scale from 0 (no influence) to 4 (powerful influence).

3.4 Combining Method

Previous studies have primarily focused on environmental issues, with relatively few addressing the development of sustainability in waterway transportation (Calderón-Rivera *et al.,* 2024b). Therefore, exploring the combination of safety and sustainability offers a valuable opportunity for further research, providing stakeholders with critical insights to govern the development of a safer, more sustainable waterway transportation system. The above bibliometric review of inland waterway transport reveals that most of the analyzed publications are journal articles. Between 2014 and 2024, this research topic received an average of 589.64 citations annually, according to Scopus and Web of Science data, indicating increased scholarly interest. There appears to be a considerable increase in interest in this topic worldwide, as evidenced by the growing

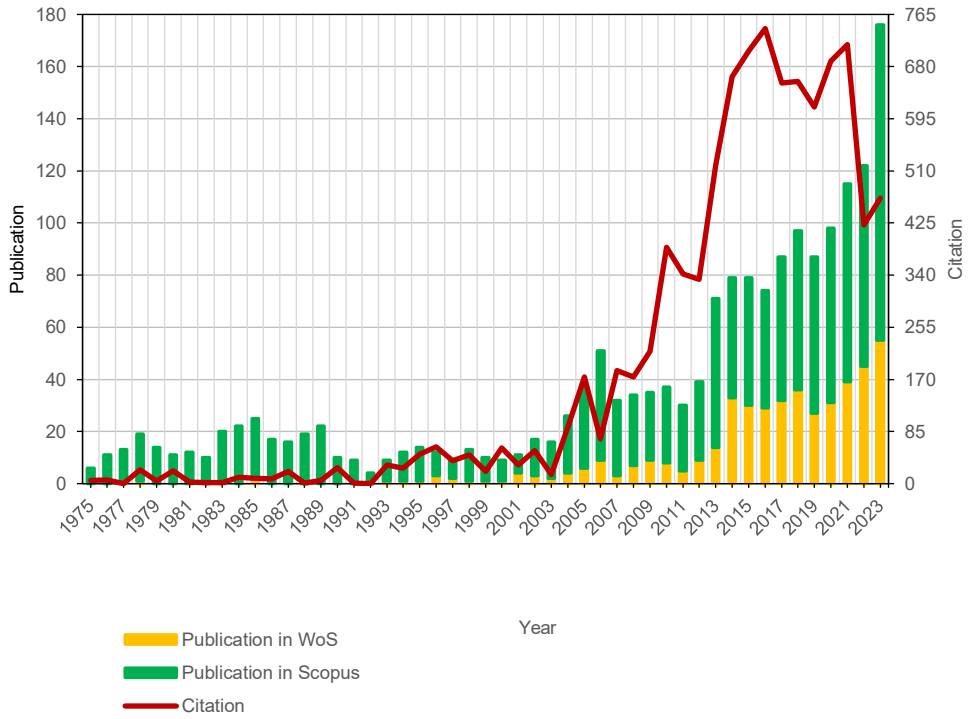

Figure 3 Trends in Publication and Citation

number of publications published in internationally indexed journals. Given this trend, further research on river transportation management is necessary, particularly regarding safety and sustainability. This study follows the research flow shown in Figure 2 and employs an analytical framework consistent with the identified bibliometric trends.

The operationalization of bibliometric thematic clusters into MACTOR strategic objectives followed a structured three-step process. First, the eight thematic clusters identified through VOSviewer keyword co-occurrence analysis (see Table 2) were compiled into a thematic brief, distributed to FGD participants prior to the August 2024 session. This ensured that the strategic discussion was anchored in globally validated research concerns rather than solely local perceptions. Second, during the FGD, participants were asked to validate whether each bibliometric theme was relevant to the Kalimantan IWT context and to propose how it should be framed as an actionable management objective. Third, the research team reconciled participants' responses with the bibliometric cluster definitions to produce the eight MACTOR objectives listed in Table 1. For example, the bibliometric cluster on governance and regulatory compliance—frequently co-occurring with keywords such as "policy," "enforcement," and "maritime law"—was operationalized into the ENFORCELAW objective: "Enforcement of ship safety regulations is insufficient, resulting in a lack of accountability for safety violations." Similarly, the sustainability cluster, anchored in keywords such as "SDGs," "modal shift," and "emissions," was operationalized into the SUSTAINABLE objective. This process ensured that MACTOR's empirical inputs were not determined solely by local stakeholder consensus but were also informed by the international body of IWT scholarship.

4. RESULTS AND DISCUSSION

4.1 Trends and Citations in the Publication of Inland Waterway Transport

The use of bibliometrics to find new research possibilities and strengthen the justification for research topics is growing. Bibliometric analysis aids in understanding publication and citation trends in the context of inland waterway transportation, which support local economic development (Prince *et al.,* 2024). In order to pinpoint regions that require improvement, especially in nations like Indonesia that have vast river systems, this study looks at trends in inland waterway transport research. Bibliometrics is frequently used to map collaboration networks, identify research trends, carry out literature reviews, and evaluate research impact (Donthu *et al.,* 2021; Hidrobo-Morales *et al.,* 2025; R. Wu *et al.,* 2023). Vosviewer is a widely recognized bibliometric analysis tool utilized by researchers for various purposes, including identifying research trends, conducting literature reviews, mapping collaboration networks, and assessing research impact. It is commonly used in conjunction with scientific databases such as Google Scholar, Scopus, and Web of Science (Kamila *et al.,* 2025).

In Indonesia, the inland waterway is abundant, and most rural areas rely on it as the easiest alternative for many activities; it plays a crucial role in agricultural and rural industries that cannot be accessed by other transportation networks (Fathoni *et al.,* 2017). Users of this transportation mode can easily engage in their activities and trade along the river, creating a floating market and providing accessibility to new settlements near the rivers (Effendy, 2022). This mode of transportation appears to be receiving less attention due to the prevailing inclination to use motor vehicles on roads (Fathoni *et al.,* 2017). Consequently, governmental

inland waterway transport, serving users and reducing their reliance on motor vehicles, which are costly and unsustainable (Vilarinho *et al.,* 2024).

The comparative advantage of bibliometrics lies in its ability to provide a comprehensive overview of literature on prior research topics and assist researchers in identifying intriguing research topics for subsequent publications that build upon the novelty found (Chigbu *et al.,* 2023; Khizar *et al.,* 2024). The bibliometric review facilitates the detection of novel insights within previous research (Yang & Yang, 2025), identifies collaboration patterns among institutions, and provides a comprehensive overview of the research landscape and interdisciplinary partnerships (Gautam *et al.,* 2025). This study also examines these trends and patterns to inform the MACTOR analysis, evaluating the potential for stakeholder collaboration in implementing safety systems and ensuring the sustainability of river transportation in the survey area. Before conducting a bibliometric review, researchers established keywords for this analysis. The authors gathered some related articles from the WOS and Scopus databases for this purpose. Keywords that are considered a central theme are 'Inland waterway transport' AND 'Inland Waterway Safety' AND 'Inland Waterway Sustainability.' This study begins with bibliometric analysis of inland waterways to address substantial questions, such as (i) advancements in inland waterway transport research (current and future), and (ii) the most prevalent themes and subjects of inland waterway research. The Web of Science (WoS) and Scopus databases are used in this study's selection method as they both offer thorough coverage of pertinent scholarly papers without duplication, potentially producing richer results across literature domains (Kumpulainen & Seppänen, 2022). This approach ensures that our research incorporates a broad range of high-quality sources, thereby enhancing the validity and reliability of our findings. By utilizing these databases, we aim to capture a diverse range of perspectives and methodologies within the field.

Global publications on inland waterway transport showed a fluctuating trend from the early 1970s to the 1980s. However, the Trend declined in the following years, reaching a low point before the 2000s, potentially due to limited research impact or citations. Over time, there was a decline until before the 2000s, possibly due to the low impact of research or citations (Chirukandath *et al.,* 2024). After 2000, research on Inland waterway transport (IWT) experienced rapid growth as more researchers became interested in this thematic area, accompanied by a significant increase in citations (Figure 3). Although there was a decline in 2024, this might be due to the limited number of researchers citing publications from that year. Nevertheless, research on IWT, particularly related to the three keywords above, has developed significantly, especially since 2010. The increasing number of publications highlights the importance of developing inland waterway transport systems that incorporate interdisciplinary and multi-stakeholder approaches.

4.2 Mapping Engagement of Stakeholders and Strategies for Objectives

In transportation, regular route services enhance regional accessibility and socio-economic conditions, particularly in underdeveloped areas, thereby accelerating trade activities and addressing disparities with more economically advanced regions (Oh & Cho, 2024; Paddeu *et al.,* 2018). Enhancing transportation access to rural, inland, and remote areas is vital for bridging the gap between developed and underdeveloped regions. Moreover, a comprehensive transportation network holds significant potential to attract investment, stimulate industrial growth, and optimize the use of natural resources and labour. However, the challenge lies in developing policies that improve transportation performance, meet public expectations, and support sustainable economic development. According to Bandari *et al.* (2022) and Xue & Lai (2023), effective performance is driven by policies that emerge from collaborative interactions between stakeholders, each contributing their unique perspectives. These interactions are crucial in promoting trade, fulfilling public expectations for shipping operations, and strengthening the local economy. To make strategic, public-oriented decisions, organizations need to involve a broad range of internal and external actors, particularly when navigating the regulatory complexities and institutional dynamics inherent in developing logistics markets (Nguyen *et al.,* 2024). Strategic choices that support shipping activities and comply with regulations involve various stakeholders who influence one another in complex ways (Bendahan *et al.,* 2005). Therefore, these stakeholders need to understand, anticipate, and analyze the decision-making process, especially given the differing interests and priorities. To achieve mutually beneficial outcomes, engaging in open and interactive discussions and negotiating agreements that accommodate the needs of all parties is vital. Considering this, the first step in this study is mapping key stakeholders involved in the transportation management process, focusing on safety and sustainability, as outlined in Table 3.

The MACTOR approach to stakeholder analysis relies on two key matrices: Direct Influence Matrix (MDI), maps the direct influence among actors, and Matrix of Actor–Objective (2MAO), which outlines each actor's stance toward specific objectives (supportive, opposing, neutral, or indifferent) and the hierarchy of those objectives. In this study, eight objectives directly related to safety aspects and sustainable management have been identified (see Table 2). Stakeholders' commitment to these objectives is determined based on their level of involvement and influence. Direct and indirect influences are analyzed to assess the nature of relationships among actors. The influence-dependence map visually represents actors' positions based on their direct and indirect influence and dependence. The two axes enable the identification of stakeholders' positions within the network.

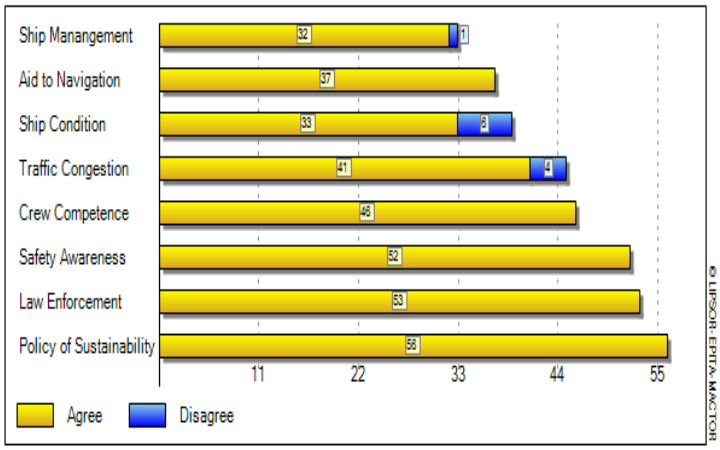

Figure 4 Histogram of Actor's Implication toward Its Objective 2MAO

Indonesia, with its extensive network of inland waterways, faces the challenge that many remote rural areas depend on the waterways as their primary mode of transportation. Consequently, it is necessary for stakeholders to prioritize enhancing transport mode services in these areas, given that this mode of transportation is relatively overlooked (Fathoni *et al.,* 2017). The survey results, as illustrated in Figure 4, reveal a consensus among stakeholders regarding the key objectives, including promoting safety awareness, strengthening the enforcement of maritime safety regulations, ensuring the competence of crew members, providing navigation support for safe vessel operations, and advancing a sustainable policy for integrated inland waterway transport systems. This alignment underscores the shared commitment to enhancing river transport services and emphasizes the importance of collaborative efforts in achieving these goals. However, there are pros and cons for actors for this purpose. The Figure shows that not all actors agreed on the objectives, such as the ship operation management system, poor ship condition, and traffic congestion in inland waterways. Ships operating in inland waterways are generally categorized as traditional ships. Rural communities have felt the impact of their role due to their function as transportation infrastructure in these areas. Their significant contribution has greatly facilitated the economic activities of local communities and provided high accessibility to regions that were previously inaccessible by other modes of transportation, such as roads. Traditional ships are an integral part of the national transportation system; however, their traditional nature renders them more susceptible to accidents due to inadequate adherence to ship safety management requirements by ship owners, crew members, and relevant stakeholders (Wahid *et al.,* 2024). They expressed concern about the condition of the vessels and proposed improvements to vessel seaworthiness, safety equipment, navigation systems, and ship maintenance and certification.

Additionally, in inland waters, many types of vessels operate. Reducing the impact of congestion is one effective solution, and organizing public transportation is one way to do so. One promising alternative is to maximize the use of inland waterway transport, which has proven to enhance connectivity, be environmentally friendly, and reduce congestion (Barros *et al.,* 2022; Plotnikova *et al.,* 2022). What is needed is a more comprehensive, well-coordinated management approach to optimize its performance.

4.3 Level of Influence and Dependence Between Stakeholders

The stakeholders involved in this study consist of individuals and institutions that play roles in the management of inland waterway transport and have the capacity to mobilize resources that influence policy outcomes and operational practices. A total of 18 actors and 8 strategic objectives were identified (Tables 3 and Table 1). The relationships among actors were analyzed using the MACTOR method through the Direct Influence Matrix (MDI) and the Actor–Objective Matrix (2MAO), which were subsequently visualized in the influence–dependence map, as illustrated in Figure 6. The interpretation of the map reveals a structured distribution of power and interdependence among stakeholders in the inland waterway transport system. The results highlight several important insights relevant to understanding stakeholder dynamics and formulating effective management strategies. First, central government institutions and regulatory authorities occupy positions with relatively high levels of influence in the system. Actors such as KSOP, DJTL, BPTD, and KNKT are located in the quadrant associated with strong influence, indicating their critical role in shaping policy direction, enforcing safety regulations, and guiding infrastructure development in inland waterway transport. This finding suggests that the effectiveness of safety and sustainability initiatives largely depends on the coordination capacity and regulatory authority of these institutions. Second, the analysis identifies a group of actors that function as intermediaries between policy formulation and operational implementation. Regional government agencies, training institutions, and technical organizations tend to appear in positions where both influence and dependence are relatively balanced. These actors play an important role in facilitating coordination, supporting capacity development, and strengthening the operational implementation of inland waterway transport programs. Third, operational stakeholders such as ship operators, crew members, cargo owners, and passengers tend to demonstrate higher levels of dependence compared to their influence. This indicates that the operational sustainability of inland waterway transport is strongly shaped by regulatory decisions, policy frameworks, and infrastructure support provided by government institutions. Although these actors interact directly with the transportation system, their ability to influence strategic policy decisions remains limited.

Table 3 List of Stakeholders or Actors and Description

No.	Stakeholder/Actor	Code	Level	Status	Role Description
1	Land Transportation Management Agency	BPTD	Technical Implementation Unit	Under the DJTD	Managing and controlling transportation systems, including roads, rivers, lakes, and crossings.
2	Port Authority	KSOP	Technical Implementation Unit	Under the DJTL	Coordinating government activities at ports; regulating and supervising port activities and maritime safety as well as security.
3	Regency/City Transportation Agency	DISHUBKAB	Local Government	Under the regency/city government	Implementing transportation policies at the regency/city regions level, including public transportation licensing, traffic management, transportation facilities, and infrastructure.
4	Provincial Transportation Agency	DISHUBPROV	Regional Government	Under the regional government	Implementing transportation policies at the level of provincial regions, including public transportation licensing, traffic management, transportation facilities, and infrastructure.
5	Directorate General of Land Transportation	DJTD	Central Government	Under the Ministry of Transportation	Developing national policies, regulations, and standards in land transportation and controlling their implementation.
6	Directorate General of Sea Transportation	DJTL	Central Government	Under the Ministry of Transportation	Developing national policies, regulations, and standards in water transportation and controlling their implementation.
7	Directorate General of Regional Autonomy	DJOD	Central Government	Under the Ministry of Home Affairs	Formulating and implementing regional autonomy policies related to transportation matters, per the provisions of laws and regulations.
8	Transportation Policy Agency	BAKETRANS	Central Government	Under the Ministry of Transportation	Formulating transportation policies and providing recommendations for developing effective, efficient, and sustainable transportation systems.
9	Ship Operator	SHIPOP	Private	Private	Operating the ship and crew management.
10	Crew Member	CREW	Private	Private	Ship operation and maintenance.
11	Academician	ACADEMIC	National	Reseach	Conducting research and providing policy advice to the government based on scientific data and analysis.
12	National Transportation Safety Committee	KNKT	Central Government	Central Government	Investigating transportation accidents and providing recommendations based on the findings to relevant stakeholders.
13	Transportation Human Resources Development Agency	BPSDM	Central Government	Under the Ministry of Transportation	Preparing and implementing technical policies, plans, and human resource development programs in the transportation sector.
14	Meteorological & Climatological Agency	BMKG	Central Government	Central Government	Providing services and information on the weather forecast.
15	Insurance Provider (Jasa Raharja)	JASRA	Private	Private	Providing financial protection to traffic accident victims through compensation for medical expenses, permanent disabilities, death, and providing social security.
16	National Search and Rescue Agency	BASARNAS	Central Government	Central Government	Coordinating search & rescue efforts for transportation accident victims and providing emergency response to disasters and other calamities.
17	Cargo Owner	CARGOWNER	Private	Private	Transportation service users.
18	Passenger	PASSENGER	Private	Private	Transportation service users.

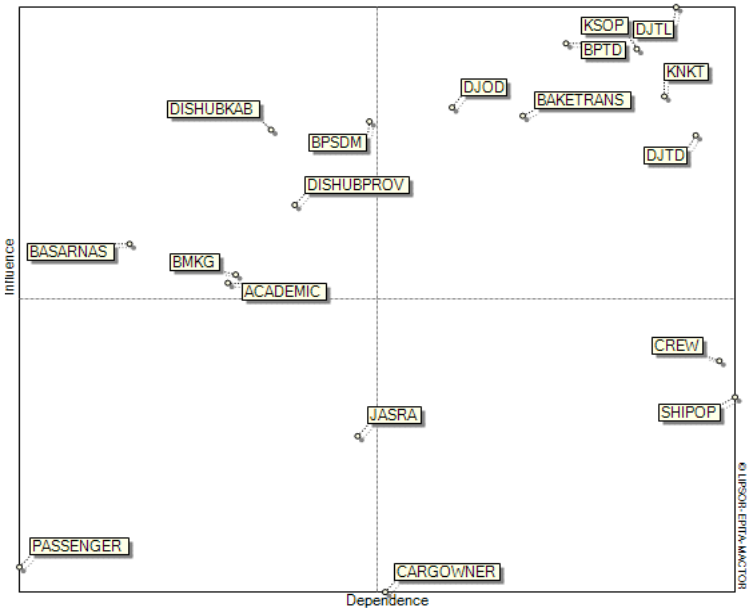

Figure 5 Map of Influence vs Dependence between Stakeholders

In addition, several supporting institutions, such as academic organizations, BMKG, and BASARNAS, appear in positions with relatively moderate to lower influence and dependence. Their contributions are mainly associated with providing scientific knowledge, safety-related information, environmental and weather data, and emergency response support. While they may not serve as primary decision-makers, their role is essential in strengthening the overall resilience and safety of the inland waterway transport system. Overall, map of influence–dependence indicates that the development of inland waterway transport requires a collaborative governance approach involving regulatory actors, operational stakeholders, and supporting institutions. The interaction between highly influential regulators and highly dependent operational actors is key to successfully implementing strategies for improving accessibility, enhancing safety, and promoting sustainable transport. Policy effectiveness is largely determined by the alignment between these actors. Therefore, the government should prioritize developing the inland waterway transport sector through infrastructure expansion, fleet modernization, and improved service connectivity, given its potential to provide more efficient and cost-effective transport compared to other modes (Nayak *et al.,* 2024; Parvasi *et al.,* 2025).

Transportation development must be based on advancement, sustainability, and competitiveness, as it is essential for supporting accessibility, safety, affordability, and reliability—all of which are necessary for meeting the community's daily needs (Agyei *et al.,* 2024). Transport policy is shaped by input from various disciplines and stakeholders. Most stakeholders involved in FGD and in-depth interviews felt their opinions were valued. In some cases, their viewpoints sparked debates, allowing for a balanced discussion of both the advantages and challenges. To evaluate the types of relationships between stakeholders, the direct and indirect influences are analyzed. The map of influence and dependence (Figure 5) provides a graphical representation of actors' positions based on their direct and indirect influences and dependencies. The two axes enable them to identify stakeholders' positions. The two crossing lines divided the axis into four quadrants, indicating that actors with little influence and dependence are "out of the game." Conversely, the farther an actor is from the crossing line, the more engaged they become in influential activities and the greater their ability to take action.

Mapping of Figure 5 indicates significant level of influence and dependence among stakeholders. Determinant (or influential) stakeholders are considered the most essential due to their high influence and low dependence, including DISHUBKAB, DISHUBPROV, BPSDM, BMKG, BASARNAS, and ACADEMIC. However, several stakeholders can be categorized as autonomous, as reflected by their relatively low involvement in efforts to enhance safety management and promote sustainable inland waterway transport (such as passenger and insurance). The roles of the passenger and insurance in ensuring inland waterway safety and sustainability in Indonesia are already established within the regulatory framework, but have not yet been fully implemented in practice due to their negligence, low awareness, weak oversight or limited law enforcement. (Djunaidi *et al.,* 2021; Rahmanita *et al.,* 2023)

4.4 Converge of Stakeholder' Role in the IWT Management

The convergence analysis provides insight into how stakeholders align in pursuing the strategic objectives of IWT management. Using the MACTOR method, the relationships among actors were analysed to identify the intensity of agreement and the potential formation of alliances within the system. Figure 6, shows a dense stakeholder relationship network in IWT governance, indicating strong convergence among most actors, especially regarding safety, infrastructure development, and transport sustainability. This condition supports collaborative policy implementation, alliance formation, and public awareness improvement. However, insurance institutions and academicians demonstrate limited convergence, potentially creating conflicts and hindering shared objectives. Despite these differences, strategic cooperation remains essential to

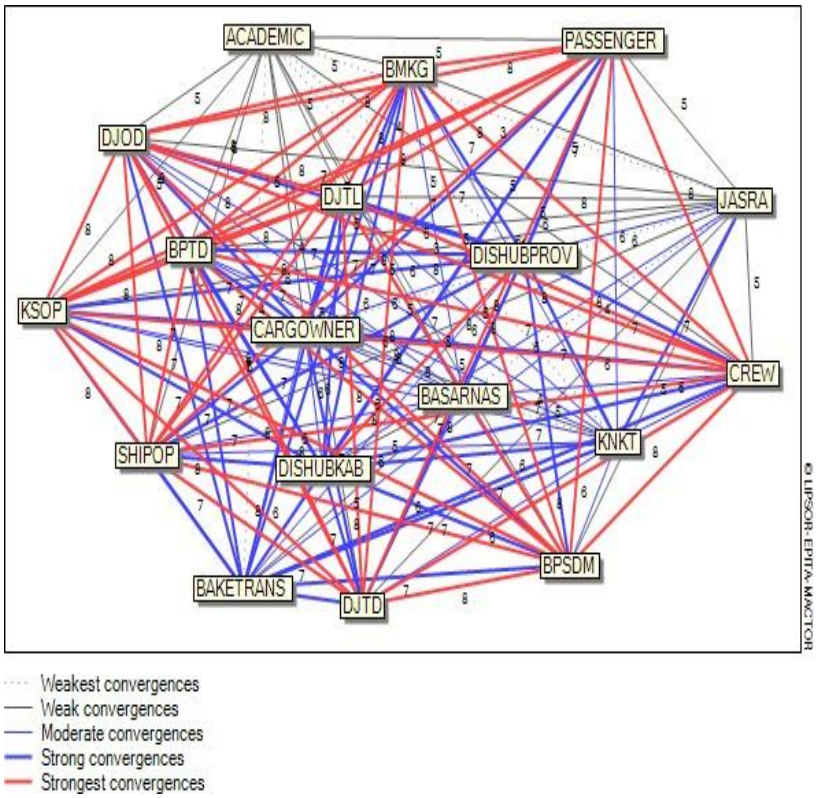

Figure 6 Convergence between Stakeholders

improve organizational performance, transparency, law enforcement, and sustainable development integration (Parviainen *et al.,* 2018; Rebecca *et al.,* 2023). The convergence map also highlights the central role of government and regulatory institutions in driving policy alignment and coordination.

At the operational level, ship operators, crews, and cargo owners show strong convergence with regulatory institutions, reflecting shared interests in safety, service reliability, and transport efficiency. However, actors related to knowledge support and financial mechanisms demonstrate lower convergence, indicating the need for stronger integration in research support, risk management, and policy evaluation. Overall, the findings suggest that improving institutional coordination and broader collaboration beyond regulatory actors is essential for sustainable inland waterway transport management, where regulatory institutions remain dominant while operational stakeholders tend to be dependent actors.

4.5 Competitiveness of Stakeholders' Role in the IWT Management

The need for innovation in transportation systems to raise efficiency, reduce traffic congestion, and improve quality of life has increased due to technological advancements and global socioeconomic developments (Cascetta & Henke, 2023). However, transforming the transportation sector remains complex due to infrastructure limitations, regulatory challenges, and varying levels of institutional readiness. In this context, stakeholder competitiveness becomes an important indicator for understanding which actors have stronger strategic capacity to influence the development of inland waterway transport (IWT).

The analysis conducted using the MACTOR method evaluates the relative competitiveness of stakeholders based on their influence, alliances, and strategic positioning within the system. The results presented in Figure 7 show that several government and regulatory institutions demonstrate higher competitiveness values compared to other actors. This pattern indicates that the governance of inland waterway transport is largely driven by institutional actors responsible for policy direction, regulatory enforcement, and system coordination. The higher competitiveness of these actors suggests that the effectiveness of IWT development strategies strongly depends on their capacity to coordinate policies, allocate resources, and maintain institutional alignment. At the same time, stakeholders with moderate competitiveness levels, such as technical agencies, academic institutions, and operational actors, play an important supporting role in translating strategic objectives into operational practices. Another important insight derived from the competitiveness distribution is the emergence of three key priorities that consistently appear across stakeholder interests: safety, sustainability, and regulatory enforcement. These priorities represent areas where stakeholder commitment and institutional capacity intersect. Safety remains a central concern due to operational risks and the need to protect passengers and the environment, while sustainability reflects the long-term viability of inland waterway transport systems. Meanwhile, regulatory enforcement ensures that operational practices comply with established standards and governance frameworks (Bernacki & Lis, 2024; Trivedi *et al.,* 2021).

The results also indicate that collaboration among stakeholders is a critical factor in strengthening system performance. Previous studies highlight that strategic

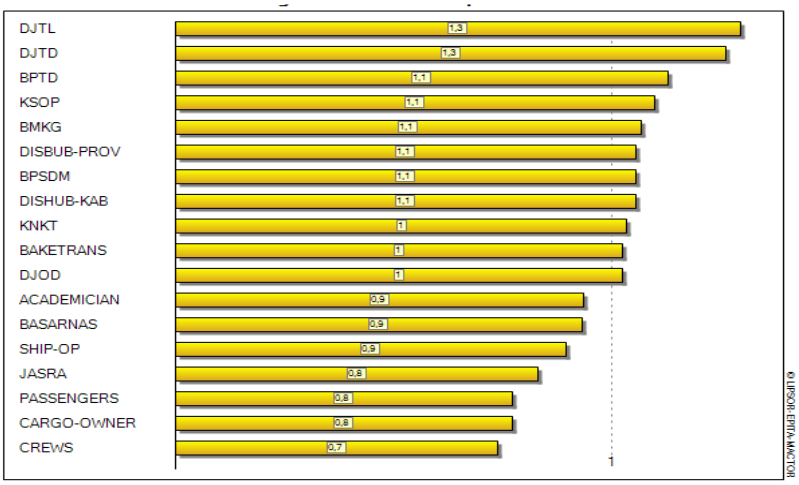

Figure 7 Histogram of MMDII's Competitiveness

alliances among actors enable the sharing of resources, knowledge, and institutional capabilities, which ultimately improve collective competitiveness within a sector (Wu, 2012). In the context of inland waterway transport, the relatively strong competitiveness observed among several stakeholders suggests favourable conditions for collaborative governance. Based on these findings, several strategic implications can be identified. Strengthening infrastructure development, improving navigability through regular dredging, enhancing intermodal connectivity, and reinforcing regulatory coordination are essential for improving the overall performance of inland waterway transport (Wide *et al.,* 2021). In addition, increasing collaboration between government institutions and the private sector can accelerate innovation and investment within the sector. Overall, the competitiveness analysis demonstrates that the future development of inland waterway transport is shaped not only by operational improvements but also by the ability of key institutional actors to coordinate strategies and align stakeholder interests toward shared objectives.

5. DISCUSSION AND POLICY IMPLICATIONS

The MACTOR results indicate that government-related institutions occupy dominant positions in the influence–dependence structure of inland waterway transport (IWT) governance. This pattern reflects the institutional characteristics of transportation management, where regulatory authority, infrastructure development, and operational oversight are primarily coordinated by public agencies. Hence, this study highlights that IWT management effectiveness is strongly influenced by the interaction between institutional coordination, risk-based safety governance, and technological integration. Similar findings have been reported in stakeholder analyses within the transportation sector, where government institutions tend to act as key drivers in shaping policy and system performance (Gregory *et al.,* 2020; Hermans & Thissen, 2009). Consequently, operational actors such as crews, ship operators, and cargo owners appear more dependent because their activities are strongly influenced by regulatory frameworks, safety standards, and infrastructure provision.

An important finding emerging from the convergence analysis is the relatively low alignment between academicians and insurance providers with other stakeholders. This may indicate limited integration of research-based knowledge and risk management mechanisms in the current governance of river transportation. Previous studies highlight that the effectiveness of transport governance increases when scientific input and institutional risk management are incorporated into policy processes (Kujala *et al.,* 2022; Zikargae *et al.,* 2022). Furthermore, another finding from Indonesia indicates weaknesses in the involvement of other actors in waterway transportation, which results from negligence, low safety awareness, and limited coordination. This condition parallels wider global waterway safety challenges, where similar underlying risk factors, including human error, neglect, and technical limitation (Dominguez-Péry *et al.,* 2021). However, safety effectiveness outcomes differ due to the implementation and governance capacity. In Indonesia, existing regulations are often not fully enforced, leading to an implementation gap characterized by weak oversight, low safety awareness, and limited stakeholder coordination, and in other countries, such as China and European countries, different systems are found. In China, studies indicate that operational risk, crew competence, and equipment conditions are the main contributors to accidents; however, stronger regulatory enforcement, structured training systems, and stricter technical standards enable more effective safety implementation (Ma *et al.,* 2026; Yin *et al.,* 2026). European countries apply integrated, risk-based safety management systems supported by advanced monitoring and active insurance mechanisms. In this context, insurance plays a critical role in influencing operator behavior through liability structures and premium incentives, while also enhancing regulatory compliance. (Bapumia *et al.,* 2025; Domenighini, 2024).

Compared with earlier MACTOR applications in transportation and infrastructure planning, this study shows that stakeholder dependence in the Indonesian IWT system is relatively high among operational actors, suggesting the need for stronger governance integration. This finding contributes theoretically by demonstrating how MACTOR can reveal interaction dynamics and strategic positioning among stakeholders in inland waterway systems, particularly in developing transport contexts.

From a policy perspective, several strategic actions can be proposed. First: the findings reinforce the argument that IWT is not only a transport mode but also a system-level enabler of sustainable logistics, particularly in archipelagic countries such as Indonesia, where its integration with maritime connectivity systems is essential for improving economic efficiency and promoting balanced regional development (Malisan *et al.,* 2023). The weakness that still occurs is coordination among actors, which results in overlapping regulations, inconsistent policy implementation, and inefficiencies in infrastructure development. It is consistent with international evidence showing that multi-level governance frameworks are critical to the performance of transportation systems (Veeneman & Mulley, 2018). Role of IWT in Indonesia is strong and important, but it still faces many structural problems and requires policy, institutional, and funding reforms in order to develop optimally and sustainably. It is necessary to establish a structured multi-level stakeholder coordination mechanism to improve alignment among government agencies, private operators, academics, and supporting institutions (akin to (Cryns *et al.,* 2025; Nguyen & Nguyen, 2020). The governance framework integrated can ensure the coordination of stakeholders and agencies, which is important for successful transportation operations and multi-level collaborative network management. Second: the main problem with developing inland waterway transport is the inadequate of safety regulation enforcement, which needs to propose a transformation from a compliance-based approach to a more proactive, risk-based one. Such a transformation should be supported by robust insurance mechanism, enabling safety and operational efficiency to be pursued simultaneously, as seen in countries with well-established and well-managed inland waterway systems (Ahmed *et al.,* 2024; Yan *et al.,* 2017). Expanding the role of insurance institutions in preventive safety management could improve risk mitigation and compliance. These measures are consistent with recommendations in sustainable transport governance that emphasize collaboration, institutional integration, and long-term system resilience (Sterling *et al.,* 2017). Third, it also indicates that port facilities and fleet modernization limitations as well as lack of integration with road transport networks, constrain the competitiveness and underutilization of IWT, although its intrinsic advantages in cost and environmental performance. This study proposes that actors involved in IWT management should collaborate to improve port infrastructure, promote fleet renewal and safety performance through financial incentives and green technologies, and strengthen connectivity with other modes of transport. In addition, regulatory reforms are needed to simplify procedures and enhance coordination among institutions, while economic incentives can encourage a modal shift from road to waterways (Calderón-Rivera *et al.,* 2024b; Rogerson *et al.,* 2020) Overall, enhancing the involvement of all stakeholders can strengthen coordination and help resolve conflicts of interest, thereby simplifying the complex relationships among various actors to achieve more effective waterway management (Willems *et al.,* 2018).

6. CONCLUSION

This study highlights the significant potential of inland waterway transport in Indonesia, particularly in Kalimantan river network, as a competitive, efficient, and sustainable alternative to land-based transportation systems. MACTOR analysis indicates that the successful implementation of environmental policies and safety frameworks cannot be achieved by a single authority, but requires strong and integrated collaboration among multi-sectoral stakeholders. These stakeholders include central regulatory bodies such as Directorate General of Land Transportation and Directorate General of Sea Transportation, research institutions such as Transportation Policy Agency and local authorities, including Regency/City Transportation Agencies and surrounding communities. To address persistent safety challenges and diverse economic demands, governance needs to shift toward more inclusive, user-oriented service standards accompanied by consistent regulatory enforcement. Ultimately, synchronized cooperation among government agencies, transport operators, and local communities is essential to enhance safety performance, strengthen regional trade connectivity between rural and urban areas, and support sustainable long-term national economic growth.

7. LIMITATIONS AND FUTURE RESEACH

This study offers insightful information about the dynamics of stakeholders in inland waterway transport governance; however, several methodological issues should be acknowledged.

First, it relies on a single geographic case region, namely the three main river corridors in Kalimantan (Kapuas, Mahakam, and Barito). Although Kalimantan was intentionally selected due to the complexity of its inland waterway transport system and governance structure, the findings may not be directly transferable to other Indonesian regions such as Sumatra or Papua, which differ in infrastructure development, population density, regulatory enforcement capacity, and stakeholder composition. Furthermore, the extent to which the actor configurations and strategic objective rankings can be generalized to other developing-country IWT contexts still requires further testing. Future research is encouraged to replicate the MACTOR framework in at least one additional IWT region to strengthen comparative validity.

Second, the MDI (Matrix of Direct Influence) and 2MAO (Actor–Objective Matrix) are inherently subject to scoring subjectivity, as they were developed based on Focus Group Discussions (FGDs) and in-depth interviews. The assigned scores for actor-actor influence and actor-objective relationships inevitably reflect participants' perceptions at a particular point in time and may be influenced by social desirability bias, institutional loyalty, or limited awareness of other actors' actual influence, even though this approach adheres to established MACTOR practice (Godet, 2006; Rees & MacDonell, 2017). As a result, considerably

different matrices and, thus, various influence-dependence patterns could result from variations in participant composition. Perceptual bias cannot be completely eradicated, despite this study's efforts to lessen it through interviews and iterative FGD validation. It is advised that future research triangulate MACTOR results with documentary evidence, such as budget allocation data, regulatory audit reports, and accident investigations.

Third, the MACTOR inputs were not subjected to a sensitivity analysis. Actor positioning and ranking results can be impacted by even little changes in critical values since MACTOR outputs, such as influence–dependence maps and convergence indices, are mathematically constructed from input matrices. A variation of ±1 on a single high-weight cell in the MDI matrix, for example, the influence score assigned to KSOP over ship operators, could shift actors across quadrant boundaries and alter the convergence rankings. The absence of sensitivity analysis means that the precision of the quadrant assignments and policy conclusions should be interpreted with appropriate caution. Future studies applying MACTOR to IWT governance should incorporate systematic sensitivity testing, for instance, by applying the approach of Fetoui *et al.* (2021) who varied input parameters across plausible ranges to assess the stability of MACTOR-derived actor positions.

Fourth, the study captures a static snapshot of a dynamic governance system. Data collection occurred across two phases in August and December 2024. Governance arrangements, actor relationships, and strategic priorities in Indonesia's IWT sector are subject to change as national policy evolves – for example, the ongoing revision of regional autonomy regulations and infrastructure investment priorities under Indonesia's national development planning cycle could shift the relative influence of regional versus central government actors. A longitudinal application of MACTOR at two or more time points would allow future research to track how stakeholder configurations and objective alignments evolve in response to policy interventions, making the framework more useful as a monitoring tool rather than a one-time diagnostic.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENTS

The data that support the findings of this study are available on request from the corresponding authors.

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