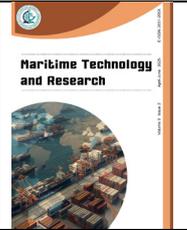




# Maritime Technology and Research

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Research Article

## The success factors for Ro-Ro short sea shipping in the Indonesia-Malaysia-Thailand Growth Triangle

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Article information	Abstract
Received: September 12, 2025 Revision: December 31, 2025 Accepted: January 2, 2026	This paper aims to identify key success factors for international roll on-roll off (Ro-Ro) short sea shipping (SSS) operations in the Indonesia, Malaysia, and Thailand Growth Triangle (IMT-GT) sub-region. A decision-support model has been developed to evaluate the viability of Ro-Ro short-sea shipping routes within the IMT-GT. Using a two-round Delphi panel of regional experts, the research identifies and weights determinants that influence Ro-Ro service performance. Nineteen main factors and sixteen sub-factors, grouped into Infrastructure, Commercial, Regulatory, and Safety and Environment clusters, were retained for the model. The highest-ranked determinants were “administrative harmonization” and “initial government assistance”, while “intermodal connectivity” and “port readiness” emerged as key operational enablers. A sensitivity analysis across four candidate routes confirms the robustness of the ranking outcomes under alternative weighting scenarios. The resulting model translates expert consensus into actionable priorities for policymakers and investors, highlighting that targeted regulatory and infrastructure interventions can offset low initial cargo volumes and accelerate sustainable short sea linkages in the IMT-GT. The study fills a regional evidence gap by quantifying factor importance for cross-border Ro-Ro services and provides a practical tool to sequence investments and reforms.
<b>Keywords</b>	
Delphi; IMT-GT; Ro-Ro; Short sea shipping; Decision-support model	

### 1. Introduction

Short sea shipping has become an increasingly important element in building sustainable transport systems as industries and governments search for alternatives to congested highways and carbon intensive overland freight. It refers to the movement of cargo and passengers across relatively short maritime distances and is widely recognized for its potential to reduce logistics costs, ease road congestion, and improve environmental performance (Batista Santos & Santos, 2024). Yet despite these advantages, many initiatives have struggled to achieve consistent success. Weak port infrastructure, fragmented regulatory structures, and poor intermodal connections have been repeatedly identified as obstacles to implementation (UNCTAD, 2024). Previous studies have acknowledged that these shortcomings hinder the operational and economic efficiency of regional maritime services (Baird, 2023; Mayanti et al., 2025). However, there remains limited empirical evidence that quantifies how these multiple factors interact and how strongly each contributes to the success or failure of short sea shipping projects, particularly in developing maritime corridors.

Technological progress has also transformed the way short sea shipping is organized and managed. Artificial intelligence has been introduced in route planning and emissions control,

allowing operators to reduce costs while meeting environmental targets (ITF/OECD, 2024; Rodriguez Diaz et al., 2024). Digital twin technology, as demonstrated in the Zero Emission Short Sea Shipping initiative in Europe, has further shown the potential of digital modelling for designing low carbon vessels and optimizing operations (Grimaldi et al., 2024). These innovations have made short sea shipping more efficient but, at the same time, have introduced new forms of vulnerability. Cyber incidents such as ransomware attacks and interference with navigational systems have created serious risks for operators and ports (Raymaker et al., 2025). This development illustrates that technological capability and cybersecurity readiness are not secondary concerns but are central conditions for the reliability of modern Ro-Ro operations.

The global shipping sector also faces continuous strain from geopolitical tensions and supply chain disruptions. The recent crisis in the Red Sea forced extensive route diversions that prolonged voyage times and increased congestion at substitute ports such as Singapore and Port Klang (Reuters, 2025; Wang et al., 2024). Although geographically distant from the Indonesia-Malaysia-Thailand Growth Triangle (IMT-GT), the effects were widely felt in Southeast Asia. The rise in fuel consumption, congestion, and scheduling instability exposed the region's heavy dependence on major global routes. This experience underscores the importance of developing alternative and resilient short sea connections that can absorb external shocks and sustain trade flows when global routes are disrupted.

Southeast Asia's maritime environment itself presents additional challenges. The Allianz Safety and Shipping Review (2024) reported that nearly one third of global vessel losses occurred in these waters, mainly due to severe weather, navigational errors, mechanical breakdowns, and insufficient port safety standards. Many incidents took place in narrow straits and shallow passages where traffic density is high and navigational aids remain limited. These conditions point to structural weaknesses in regional maritime governance and port infrastructure. They also justify an urgent call for the establishment of stronger and more resilient shipping frameworks that combine safety management, coordinated regulation, and technological preparedness. For an archipelagic area such as the IMT-GT, which relies heavily on maritime transport for cross border connectivity, strengthening such frameworks is not merely a policy aspiration, but an economic necessity.

Within this context, the IMT-GT Implementation Blueprint 2022 to 2026 sets a clear objective to enhance sub-regional connectivity through improved transport corridors and the development of Ro-Ro ferry services (IMTGT, 2022). However, several persistent issues have delayed progress. The proposed Dumai and Melaka route illustrates these obstacles. Despite joint discussions, the preparation of terminal sites, and partial funding allocations, service commencement has been postponed repeatedly (PwC Indonesia, 2024). The primary causes include inadequate Customs, Immigration, and Quarantine facilities, differing national regulations, and limited infrastructure readiness (RiauPos.co, 2025). Moreover, the relative influence of these factors, whether institutional, infrastructural, operational, or market related, remains unclear. Without a structured and empirical understanding of their combined effects, policymakers and investors face difficulty in prioritizing the most effective interventions.

From a theoretical standpoint, the principles of sustainable transport and regional integration emphasize that the viability of any maritime corridor depends on coordinated interaction among infrastructure, institutions, operations, and market forces (Banister, 2008; Rodrigue, 2022). Yet this theoretical relationship has not been empirically examined within the Southeast Asian context, particularly in the IMT-GT sub-region. Addressing this gap is, therefore, crucial for understanding how international Ro-Ro services can be effectively planned and implemented.

In terms of the problem statement, the IMT-GT sub-region has prioritized the physical integration of infrastructure to strengthen maritime connectivity, particularly through Ro-Ro short sea shipping (ASEAN Secretariat, 2023). As part of this regional transport initiative, the Ro-Ro link between Dumai, in Indonesia, and Melaka, in Malaysia, remains a priority project, but its implementation continues to face significant delays, caused by incomplete port infrastructure and

unresolved regulatory matters. As reported by the Indonesian Ministry of Transport, rehabilitation of the Dumai and Melaka terminal had reached approximately sixty one percent progress in 2024, while cross border vehicle and cargo agreements were still under negotiation (ANTARA News, 2024).

Although Ro-Ro services are recognized for their advantages, such as improved operational efficiency and potential modal shift from road to sea, their adoption has been constrained by institutional and regulatory challenges, cost factors, and limited modal integration (Batista Santos & Santos, 2024; Izdebski et al., 2024; Wahid et al., 2023). These difficulties mirror global trends in short sea shipping, where infrastructure gaps and inadequate policy frameworks continue to hinder sustainable growth (Huang, 2024; Zhao, 2024). Within the IMT-GT context, the working group on transport connectivity convened in Melaka in July 2023 to review progress on the Dumai and Melaka Ro-Ro link under the Implementation Blueprint for 2022 to 2026 (IMTGT, 2023). However, the service remains non-operational due to unfinished port ramp construction, incomplete Customs Immigration Quarantine and Security facilities, and the absence of cross border vehicle approvals (ANTARA News, 2024).

Conventional explanations, such as insufficient payload or the use of ageing vessels, only partially account for these persistent failures. Therefore, it is necessary to identify systematically the underlying determinants that influence the success of international Ro-Ro short sea shipping services within this sub-region. This study intends to examine these determinants, evaluate their relative importance, and develop a decision making model using the Delphi technique to assess the potential of identified Ro-Ro routes in the IMT-GT corridor. The use of a Delphi based decision making framework for international Ro-Ro operations is still limited in existing literature, representing a novel methodological and practical contribution (Batista Santos & Santos, 2024; Izdebski et al., 2024; Zhao, 2024).

### **1.1 Theoretical framework**

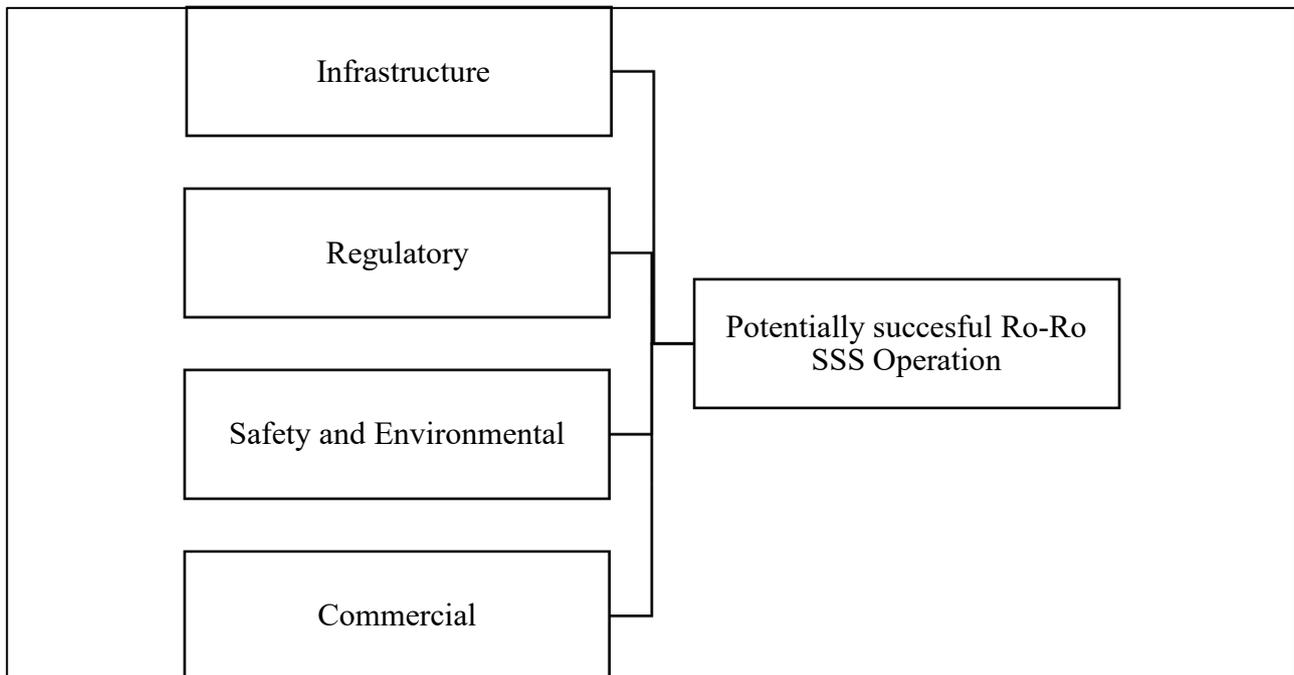
The conceptual foundation of this study is built upon the theories of sustainable transport systems and regional integration, both of which stress that successful maritime corridors rely on the balanced interaction of infrastructure, governance, market dynamics, and safety management. Within this framework, four major clusters explain the feasibility of Ro-Ro services in the IMT-GT region. Based on the **Figure 1**, the first cluster, infrastructure, represents the physical base consisting of port facilities, intermodal links, and access routes that enable the efficient movement of cargo and passengers. The second cluster, regulatory and institutional alignment, includes government support, policy harmonization, and coordination of administrative procedures that create a stable operational environment. The third cluster, safety and environmental management, ensures operational reliability and long-term sustainability through compliance with safety and environmental standards. The fourth cluster, commercial and market viability, covers demand stability, service quality, and the availability of financial and human resources. The interaction among these four dimensions determines the degree to which Ro-Ro initiatives can achieve economic feasibility and operational sustainability. This theoretical framework guides the Delphi investigation by providing a structured lens through which expert judgments on the relative importance of factors can be interpreted and integrated into a data-driven decision-support model for policy and investment prioritization.

## **2. Literature review**

### **2.1 Global perspectives on Ro-Ro and short sea shipping**

Ro-Ro shipping is recognized for its ability to reduce port turnaround times and streamline cargo flows. In Indonesia, Rustina (2023) analyzed Ro-Ro performance management at the Merak–Bakauheni Crossing Port and identified vehicle and passenger throughput and ship turnaround times as operational constraints. At the international level, the European Union has promoted short sea shipping through the Motorways of the Sea policy. However, scholars argue that infrastructural

bottlenecks and insufficient integration with road and rail transport continue to restrict the full potential of this initiative (Batista Santos & Santos, 2024).



**Figure 1** Theoretical framework.

Source: Authors' work

Recent studies also highlight the centrality of environmental sustainability. Research on Ro-Pax ferries emphasizes the role of alternative fuels, such as liquefied natural gas and liquefied biogas, in reducing lifecycle emissions. Policy instruments, including carbon pricing mechanisms introduced in 2023, have reinforced the urgency of greener operations (Mayanti et al., 2025). The International Maritime Organization advanced this agenda with the Net Zero Framework adopted in 2025, which will implement mandatory carbon pricing for vessels beginning in 2028 (IMO, 2025).

Short sea shipping has also been recognized globally as a critical component of sustainable logistics, capable of shifting freight from congested roads to energy-efficient maritime routes (Myriouni & Theofilatos, 2025). In Europe, studies show that Ro-Ro and Ro-Pax services contribute significantly to regional integration and carbon reduction objectives, although their long-term viability depends on effective policy alignment and intermodal linkages (Mayanti et al., 2025). In the Mediterranean, similar initiatives have demonstrated measurable benefits for trade and employment when supported by transparent governance and efficient port systems (Wang et al., 2024). Nevertheless, researchers caution that frameworks developed for advanced economies may not be fully suitable for emerging maritime regions due to unique institutional and infrastructural constraints in regions such as Southeast Asia (Vakili et al., 2025). The global literature, therefore, confirms the relevance of Ro-Ro networks, while also revealing a lack of empirical models that quantify how infrastructure, regulation, and market readiness interact to influence route success, which this study aims to address.

## 2.2 Technological, regulatory, and security challenges

Although digital innovations, such as digital twins and AI-based navigation systems, promise operational improvements, they also expose shipping to greater risks. Cyber threats have been

identified as a significant barrier to the adoption of digital technologies in maritime operations (Raymaker et al., 2025). Regulatory fragmentation is another obstacle, particularly in regions with multiple jurisdictions. Harmonized procedures and relaxed cabotage restrictions are repeatedly cited in the literature as prerequisites for successful Ro-Ro implementation (UNCTAD, 2024).

Security and resilience are equally important. The disruptions in the Red Sea illustrate how regional instability can lead to widespread impacts on international supply chains by forcing rerouting and increasing shipping costs (Reuters, 2025; Reuters, 2024; ITF/OECD, 2024; Rodriguez-Diaz, Alcaide & Garcia-Llave, 2024; World Bank, 2024; Wang et al., 2024). Studies of Southeast Asia emphasize the high-risk profile of the region due to the frequency of vessel losses and piracy incidents (Allianz, 2024). Lau et al. (2024) argue that the ability of maritime transport systems to withstand shocks depends on coordinated governance, investment in infrastructure resilience, and adoption of flexible operational strategies.

Recent scholarship extends this view by connecting digitalization, regulation, and safety under the broader umbrella of maritime resilience. Technological tools, such as artificial intelligence, predictive analytics, and digital twins, are transforming vessel operations and emissions management (Grimaldi et al., 2024). However, as noted by the OECD (2024), fragmented regulatory regimes continue to limit the benefits of such innovations. Cyberattacks, data breaches, and misinformation in navigation systems have further heightened operational risks (Raymaker et al., 2025). Therefore, the success of digital transformation depends not only on technology adoption, but also on institutional alignment, standardized data governance, and coordinated safety frameworks.

### 2.3 Defining success in short sea and Ro-Ro shipping

While success is often referenced in maritime and short sea shipping research, it is defined inconsistently, and may refer to sustainability metrics, operational efficiency, or intermodal integration, rather than being limited to cargo throughput or profitability (Batista Santos & Santos, 2024, Zakaria et al., 2022). More recent research has moved toward multidimensional definitions that integrate institutional, environmental, and social dimensions (Lau et al., 2024). In this study, success in international Ro-Ro operations is defined as the sustained ability of a service to operate efficiently, safely, and profitably within a framework of coordinated governance and environmental responsibility. A successful service must, therefore, demonstrate economic feasibility through stable demand, operational efficiency through adequate port and intermodal infrastructure, regulatory alignment through supportive policy and harmonized procedures, and environmental sustainability through adherence to safety and green performance standards. This integrated definition provides the analytical foundation for identifying and ranking success factors in the IMT-GT region.

### 2.4 Identification of key success factors

The classification of success factors for short sea shipping (SSS) was derived through an extensive review of regional and international literature published between 2020 and 2025. The foundational work of Arof and Zakaria (2020) offered a comprehensive ASEAN perspective on the critical success factors influencing SSS development, highlighting the role of infrastructure readiness, institutional coordination, government support, and operational efficiency. This foundational framework was substantiated and further refined by recent empirical and systematic review studies (Abu-Aisha et al., 2024; Izdebski et al., 2024; Su et al., 2024; Kishore et al., 2024; Lin et al., 2025), which collectively emphasize the interrelationship between policy intervention, port performance, multimodal connectivity, digitalization, and safety compliance. Accordingly, the 17 main factors represent the strategic and operational enablers that underpin SSS viability, while the 14 sub-factors delineate specific mechanisms or policy instruments that operationalize these enablers. This classification ensures a holistic understanding of the determinants influencing SSS performance and supports a structured framework for subsequent analytical modeling. Hence, the summaries of main factors and sub-factors have been tabulated in the **Tables 1** and **2** below:

**Table 1** Definitions of key factors and supporting references.

No.	Key Factor	Description	Supporting References
1	Adequate port facilities and equipment	Infrastructure for berthing, cargo handling, storage, parking, passenger terminal, and IT systems.	Arof and Zakaria (2020); Idris and Siswanto (2024); Wahab et al. (2024)
2	Balanced payload/volume	Paid passenger and cargo loads sufficient for viability.	Arof and Zakaria (2020); Izdebski et al. (2024)
3	Coordinated administrative and CIQS formalities	One-stop port centers for Customs, Immigration, Quarantine, and Security clearance.	Arof and Zakaria (2020); Wahab et al. (2024)
4	Good intermodal links	Integration of Ro-Ro with multimodal transport chains.	Arof and Zakaria (2020); Abu-Aisha et al. (2024)
5	Good port access	Unobstructed land and sea connectivity.	Arof and Zakaria (2020); Mthembu and Chasomeris (2023)
6	Initial government assistance	Financial, tax, promotional, and operational subsidies in early years.	Arof and Zakaria (2020)
7	Harmonization of port procedures	Standardized cargo movement processes.	Arof and Zakaria (2020); Su et al. (2024)
8	Large payload/volume	Sufficient demand to ensure profitability even with imbalanced traffic flows.	Arof and Zakaria (2020); Izdebski et al. (2024)
9	Promotion of SSS	Marketing efforts to improve service image.	Arof and Zakaria (2020); Batista Santos and Santos (2024)
10	Port efficiency	Dedicated terminals, quick turnaround, reasonable charges.	Arof and Zakaria (2020); Kishore et al. (2024)
11	Regional agreements	Relaxation of cabotage or other restrictions to reduce costs.	Arof and Zakaria (2020)
12	Service quality	Regular, reliable, and punctual schedules.	Arof and Zakaria (2020); Lin et al. (2025)
13	Suitable ship type	Vessel capacity, range, and speed matched to service needs.	Arof and Zakaria (2020)
14	Weather conditions	Navigational impact of Malacca Straits and Andaman Sea climate.	Arof and Zakaria (2020); Environmental Science and Pollution Research (2023)
15	Vessel safety	Compliance with IMO standards.	Arof and Zakaria (2020); Saputra et al. (2023)
16	Cargo/vehicle safety	Adherence to IMO-equivalent safety norms.	Arof and Zakaria (2020); Wahab et al. (2024)
17	Passenger/seafarer safety	Safety measures aligned with IMO conventions.	Arof and Zakaria (2020)

Source: Authors' work

## 2.5 Research methodologies in short sea shipping studies

Empirical studies of short sea shipping employ diverse methodological approaches. Quantitative methods, such as the Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), and other Multi-Criteria Decision Making (MCDM) techniques, are commonly used to rank performance indicators and evaluate operational efficiency (Çağlayan & Aymelek, 2024; Soltani Motlagh et al., 2023). These models allow for systematic assessment of interdependent factors affecting port and route performance. The Delphi method has emerged as a valuable qualitative tool for capturing expert consensus, especially where empirical data are limited. It has been successfully applied in maritime safety (Laine, 2024), port governance (Valdez-Banda & Goerlandt, 2023), and

logistics foresight studies (Mutambik, 2025). Combining Delphi with AHP or similar frameworks allows for both subjective and objective weighting of success determinants (Laine et al., 2024). Despite these advances, few studies have applied Delphi-based frameworks to developing maritime sub-regions, leaving a gap that this study addresses through expert-driven assessment of IMT-GT Ro-Ro viability.

**Table 2** Definitions of sub-factors and supporting references.

No.	Sub-Factor	Description	Supporting References
1	Application of electronic data interchange	Utilization of EDI and port community systems for documentation and cargo tracking.	Arof and Zakaria (2020); Su et al. (2024); Wahab et al. (2024)
2	Integrated CIQS facilities	Centralized facilities integrating Customs, Immigration, Quarantine, and Security operations.	Arof and Zakaria (2020); Wahab et al. (2024)
3	Inland waterway transport (IWT) network	Development of inland waterways to complement SSS services.	Arof and Zakaria (2020); Orzechowski et al. (2024)
4	Road/highway network	Efficient land transport connectivity to ports.	Arof and Zakaria (2020); Abu-Aisha et al. (2024)
5	Rail network	Seamless linkage of rail infrastructure to maritime terminals.	Arof and Zakaria (2020); Abu-Aisha et al. (2024)
6	Operational subsidy for shipping company (3–5 years)	Temporary government subsidies to ensure viability of new SSS services.	Arof and Zakaria (2020)
7	Start-up funding (soft loan) for Ro-Ro vessel acquisition	Financial incentives or low-interest loans for vessel procurement.	Arof and Zakaria (2020); Wahab et al., (2024)
8	Government support in Ro-Ro terminal upgrading	Assistance in port construction or modernization projects.	Arof and Zakaria (2020); Idris and Siswanto (2024)
9	Standardized procedures for cargo/vehicle clearance	Harmonized cross-border inspection and clearance standards.	Arof and Zakaria (2020)
10	Simplified administrative procedures	Streamlined cargo and passenger documentation processes.	Arof and Zakaria (2020); Su et al. (2024)
11	Relaxation of national cabotage regime	Policy adjustments to permit regional vessel operation flexibility.	Arof and Zakaria (2020), Wahab et al. (2024)
12	Standardization of regulations for near-coastal ships	Common regulatory frameworks for near-shore vessel operations.	Arof and Zakaria (2020), Wahab et al. (2024)
13	Suitable ship size relative to payload	Vessel capacity optimized to demand volume and route profile.	Arof and Zakaria (2020)
14	Suitable vessel speed relative to distance	Appropriate sailing speed aligned with route length and service schedule.	Arof and Zakaria (2020)

Source: Authors' work

## 2.6 Relevance to the IMT-GT sub-region

The IMT-GT sub-region represents a strategic location for expanding Ro-Ro services. Its dispersed geography and growing trade flows make short sea shipping an attractive alternative to road and conventional ferry systems. However, global lessons indicate that the success of Ro-Ro initiatives will depend on overcoming structural challenges, including inadequate port facilities, fragmented administrative procedures, and limited safety and environmental management. Addressing these factors could not only strengthen regional connectivity but also align IMT-GT practices with global developments in sustainable short sea shipping.

Despite this strategic importance, academic research on IMT-GT maritime transport remains limited. Existing studies primarily describe policy frameworks and infrastructure plans without quantitatively assessing determinants of route viability. Reports such as PwC Indonesia (2024) and Riau Pos (2025) discuss the Dumai–Melaka Ro-Ro project, but stop short of identifying how institutional, infrastructural, and market conditions interact. Comparative analyses from Europe provide valuable insights into governance models and operational integration, but do not account for the regulatory diversity or financial constraints of Southeast Asian ports. Consequently, there is a clear need for an empirically grounded framework that captures the contextual realities of IMT-GT shipping corridors. The present study responds to this gap by employing a Delphi approach to identify, validate, and prioritize success factors for international Ro-Ro development, ultimately supporting the creation of a regional decision-support model.

**Figure 2**, below, illustrates the geographical scope of the Indonesia–Malaysia–Thailand Growth Triangle (IMT-GT), which encompasses Southern Thailand, Peninsular Malaysia, and Sumatra in Indonesia. This area is significant for promoting cross-border cooperation, enhancing connectivity, and supporting maritime transport initiatives such as Ro-Ro short sea shipping to strengthen economic linkages among the three participating countries. **Figure 2** shows the Indonesia–Malaysia–Thailand Growth Triangle (IMT-GT) and highlights how the three countries are connected through major ports and land transport corridors. The black dots represent important ports such as Phuket port, Penang port, Klang port, Belawan port, Dumai port, and Melaka Port, which serve as key maritime gateways in Southern Thailand, Northern/Western Malaysia, and Sumatra, Indonesia. The purple dashed lines indicate the main land transportation routes that link major cities and economic areas across the IMT-GT region. These corridors support cross-border movement of goods, people, and services, creating an integrated logistics network that strengthens regional economic cooperation among the three countries.

## 3. Research methodology

This study employed the Delphi technique to identify and prioritize the key factors that determine the feasibility of Ro-Ro short sea shipping (SSS) in the Indonesia-Malaysia-Thailand Growth Triangle (IMT-GT). The Delphi method was chosen for its ability to achieve consensus among experts on complex, multidisciplinary issues, and has been widely applied in recent maritime transport and logistics studies (Laine et al., 2024).

Additionally, the Delphi method was adopted because the main goal of this research was to identify and prioritize several interrelated determinants within a regional setting that lacks comprehensive data and involves sensitive policy issues. Such a context requires the use of structured expert judgment, rather than depending solely on empirical evidence. When compared with other consensus-building or multi-criteria decision-making approaches, such as the Analytic Hierarchy Process or the Analytic Network Process, the Delphi technique offers distinct advantages. It allows experts to provide feedback through several rounds while maintaining anonymity, reduces the influence of dominant participants, and encourages the discovery of context-specific insights through open-ended expert input (Laine, 2024; Çağlayan & Aymelek, 2024).

However, the Delphi approach also presents certain weaknesses. It depends on the subjective opinions of experts, can be influenced by the composition of the panel, and often requires more time

to complete than a single-round survey. To reduce these limitations, the present study complemented the Delphi-derived weights with a quantitative sensitivity analysis and included several reliability and agreement measures such as Cronbach's alpha, the intraclass correlation coefficient, and Kendall's coefficient of concordance. These additions enhanced the overall validity and robustness of the findings.

Therefore, the Delphi-based weighting procedure is especially appropriate for exploratory and policy-oriented decision studies in situations where data are incomplete or inconsistent. It provides a systematic and credible framework for gathering expert opinions and translating them into meaningful analytical outcomes.



**Figure 2** The IMT-GT growth triangle.

Source: Authors' work

### 3.1 Sampling and data collection

Data collection was conducted between January 2022 and March 2024 through two rounds of Delphi surveys. A purposive sampling approach was adopted to ensure that only individuals with deep expertise in short sea shipping, port operations, and transport infrastructure were included.

Snowball sampling was also applied by requesting identified participants to nominate other qualified experts in the IMT-GT sub-region.

In total, 42 experts were invited to participate, with 34 completing the first round, and 30 completing the second round, resulting in response rates of 81 percent (34/42) and 71 percent (30/34), respectively. The panel consisted of three categories of respondents:

- Academia, defined as professors, associate professors, and senior lecturers with at least five Scopus-indexed publications in maritime, transport, or logistics within Southeast Asia.
- Maritime transport experts, defined as senior decision makers with at least 10 years of experience in shipping companies, port authorities, or government agencies responsible for maritime policy.
- Others, defined as stakeholders supporting maritime operations such as third-party logistics providers, industry consultants, and policy advisors with substantial involvement in IMT-GT maritime connectivity projects.

### 3.2 Expert selection and credibility

The Delphi panel of 30 experts combined academic, operational, and policy expertise in IMT-GT maritime connectivity, providing balanced perspectives for robust consensus. Anonymity and controlled feedback across rounds minimized bias and supported independent judgment. These measures follow established Delphi guidelines, ensuring the reliability and validity of the findings.

This categorization reflects best practices in Delphi research, where diversity of expertise strengthens the validity of findings (Laine, 2024; Mutambik, 2025). Details of questionnaire distribution and respondent breakdown are presented in **Tables 1** and **2**.

**Table 3** Prospective expert respondents for Delphi questionnaire.

Country	Academia		Maritime Transport Experts			Others	Total
	Prof / Associate Prof/Equivalent level	Senior Lecturer	Ship	Port	Government		
Malaysia	2	1	3	4	2	2	14
Indonesia	2	1	3	4	2	2	14
Thailand	2	1	3	4	2	2	14
Total	6	3	9	12	6	6	42

Source: Authors' work.

**Table 4** Round 1 Delphi questionnaire returned.

Country	Academia		Maritime Transport Experts			Others	Total
	Professor / Associate Prof or equivalent	Senior Lecturer	Ship	Port	Government		
Malaysia	2	1	3	4	2	2	14
Indonesia	1	1	2	3	2	1	10
Thailand	1	1	2	2	2	2	10
Total	4	3	7	9	6	5	34

Source: Authors' work.

From **Tables 3** and **4**, from 42 Delphi questionnaires distributed, 34 were returned, giving an 81 % (34/42) response rate, which is considered satisfactory.

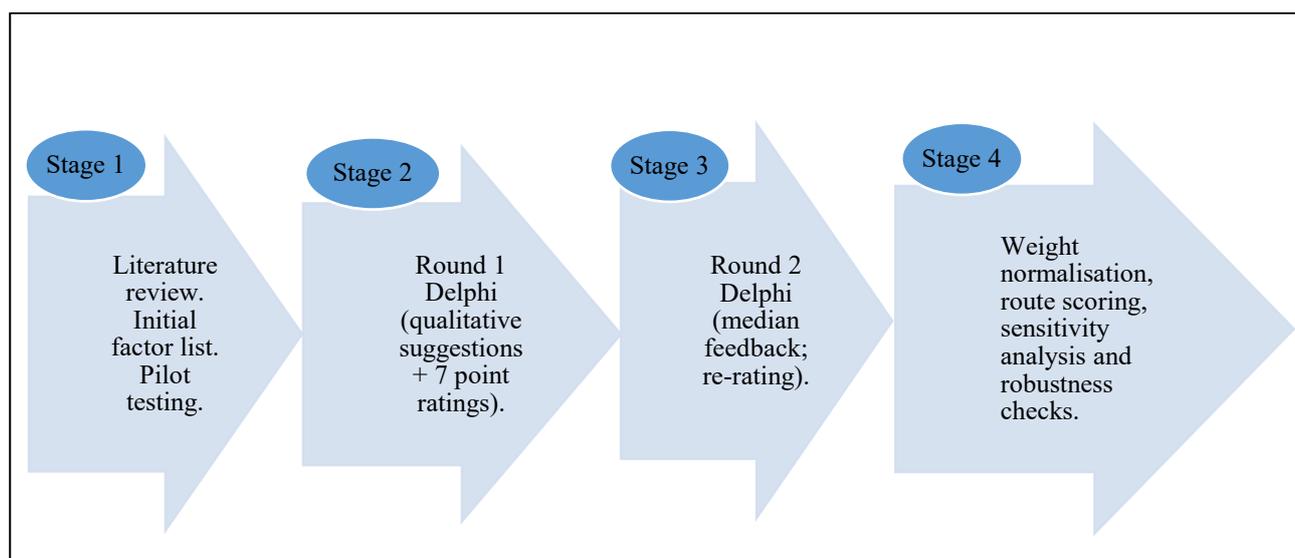
### 3.3 Survey design

The Round 1 survey required respondents to rate 17 factors and 14 sub-factors identified through the literature review on a seven-point Likert scale, where 1 indicated least importance and 7 indicated highest importance. To minimize ambiguity, each factor was clearly defined in the questionnaire, following guidelines from recent transport studies (Weerasinghe & Perera, 2023). Based on Round 1 results, two new factors were added: the availability of investors and funding for human resource development. In Round 2, participants were provided with median values from the first round along with their previous scores to allow reconsideration. Cronbach's alpha and intraclass correlation coefficient (ICC) were calculated for reliability testing. Both exceeded 0.90 in each round, demonstrating high internal consistency.

Furthermore, two additional main factors (availability of investors; funding for human resource development) and two sub-factors (funding for infrastructure; funding for HR development) emerged from the qualitative open item in Round 1. Respondents were asked to list omitted benefits or obstacles; these textual responses were coded by two independent researchers using thematic coding. Items mentioned by at least three independent experts or those judged conceptually distinct by both coders were proposed as candidate factors for Round 2. The consolidated factor list was then returned to participants in Round 2 for re-rating. This procedure follows standard Delphi practice for integrating qualitative signals into the structured instrument.

### 3.4 Data analysis stages

The empirical analysis was conducted in four distinct stages: factor identification and instrument design, Round 1 Delphi (exploratory), Round 2 Delphi (consolidation), and model construction with robustness assessment. These stages, from literature-based factor identification through Delphi consensus and model development, are summarized in the data analysis flowchart in **Figure 3**.



**Figure 3** Data analysis flowchart

Source: Authors' work

### 3.5 Consensus definition and statistical criteria

In this study, consensus was evaluated using several complementary statistical measures consistent with contemporary Delphi research practices (Franc et al., 2023; Laine, 2024). The use of multiple indicators provided a robust and multidimensional assessment of expert agreement. Specifically, the IQR and percentage agreement metrics captured the degree of dispersion and concentration within responses, median stability reflected convergence across Delphi rounds, and the ICC, Cronbach's alpha, and Kendall's Coefficient of Concordance (W) collectively represented internal reliability and ranking consistency (Franc et al., 2023; Laine, 2024). Additionally, Kendall's Coefficient of Concordance (W) was computed to assess the strength of consensus across ranked items, where values  $\geq 0.70$  denote strong agreement (Sun et al., 2024).

### 3.6 Sensitivity analysis and route selection

Short sea shipping is commonly described as maritime transport that takes place over relatively short distances. In the context of this research, the routes examined include Dumai to Melaka, Belawan to Penang, Belawan to Phuket, and Belawan to Port Klang. These routes extend across national boundaries and, therefore, involve a combination of customs, immigration, quarantine, and security procedures, as well as other cross-border regulatory aspects. Such characteristics make them distinct from domestic coastal shipping activities.

Domestic coastal services, including cabotage and national feeder operations, usually function under a different legal and administrative structure. They are generally less affected by cross-border documentation and inspection requirements. Hence, the present study places stronger emphasis on the international perspective of short sea shipping. Several of the findings, particularly those that highlight the need for administrative harmonization and coordination among CIQS agencies, are influenced by the complexities of international procedures, rather than by domestic operational factors.

This difference in scope is recognized as one of the limitations of the current analysis. Future research should aim to compare domestic coastal transport with international short sea shipping within the IMT-GT region. Such comparative work would help to separate policy recommendations that apply specifically to each context and allow for more targeted policy development. The present study acknowledges this limitation to ensure transparency and accuracy in interpreting its conclusions.

To enhance methodological transparency, this study incorporated sensitivity analysis directly into the research design. Four potential international Ro-Ro routes were selected for evaluation: Dumai-Malacca, Belawan-Penang, Belawan-Phuket, and Belawan-Port Klang. The Delphi-derived weights for the identified factors and sub-factors were then applied to assess the relative viability of each route.

The robustness of the decision-making model was examined through three sensitivity scenarios: (1) excluding the most influential determinant, harmonization of administrative procedures, (2) excluding the second most influential determinant, initial government assistance, and (3) increasing the weight assigned to the least influential determinant, balanced payload volume. This structured procedure reflects recent recommendations stressing the importance of incorporating robustness checks in multi-criteria decision models to better accommodate dynamic policy and market conditions (Çağlayan & Aymelek, 2024; Soltani Motlagh et al., 2023).

## 4. Data analysis

### 4.1 Round 1 Delphi survey

The Round 1 (R1) questionnaire, which had been pilot tested by relevant and qualified experts, was divided into a qualitative part, where the respondents were requested to identify the main benefits and obstacles that are expected to be experienced by the Ro-Ro SSS operation, and a quantitative part, where the 17 main factors and 14 sub-factors identified through the literature were rated by the

respondents using a seven-point Likert scale, with 1 representing ‘least important’ and 7 standing for ‘most important’. In order to avoid ambiguities, all the variables identified through literature were explained in the Round 1 survey questionnaire.

To minimize ambiguity, each variable identified from the literature was clearly defined within the questionnaire. All 34 R1 respondents provided complete ratings for all factors, enabling the calculation of reliability using Cronbach’s alpha and the intraclass correlation coefficient (ICC). Both tests produced a value of 0.918, indicating high internal consistency.

The 17 factors, primarily identified from analyses of SSS operations in Europe and North America, were considered important by experts from the IMT-GT sub-region, with mean scores ranging from 5.85 to 6.82. Additionally, two new main factors specific to the IMT-GT sub-region were identified, namely, the availability of investors and funding for future infrastructure and human resource development. Two new sub-factors were also identified, namely, funding for infrastructure and funding for human resource development.

#### 4.2 Round 2 Delphi survey

In Round 2 (R2), all factors from R1, including the newly identified main and sub-factors, were presented to respondents for re-evaluation using the same seven-point Likert scale. Respondents were provided with the median scores from R1 and their initial ratings for reference. Thirty of the original 34 respondents participated in R2, and the reliability of expert responses was confirmed by Cronbach’s alpha values of 0.918 in Round 1, and 0.957 in Round 2, indicating excellent internal consistency. To further assess the strength of agreement among the 30 expert panel members in Round 2, Kendall’s Coefficient of Concordance (W) was calculated, yielding  $W = 0.998$  ( $\chi^2 = 539.05$ ,  $df = 18$ ,  $p < 0.001$ ), which demonstrates exceptionally strong consensus on the nineteen main factors influencing international Ro-Ro short-sea-shipping operations. This level of concordance supports the stability and robustness of the consensus achieved, and aligns with current methodological guidance that emphasizes reporting multiple consensus metrics (Hsu et al., 2023; Keshavarznia & Wallace, 2023)

As a high level of agreement was achieved, additional Delphi rounds were deemed unnecessary. The results of R2 are presented in **Tables 5 - 7**.

**Table 5** Influential main factors for international Ro-Ro SSS operations.

No.	Main factors	N	Mean	Std. Deviation
1	Good intermodal links	30	6.5667	0.50401
2	Adequate port facilities and skilled human resources	30	6.5000	0.73108
3	Coordinated administrative and CIQS	30	5.8667	2.01260
4	Good port access	30	6.5000	0.77682
5	Balanced payload or shipment volume	30	5.3333	2.08993
6	Large payload or shipment volume	30	5.2333	2.12835
7	Promotion of SSS	30	6.1000	0.80301
8	Port efficiency	30	6.4000	0.77013
9	SSS service quality	30	6.3000	0.79438
10	Suitable ship’s type in relation to payload, distance and speed	30	5.5667	2.14449
11	Availability of investor	30	6.3000	0.83666
12	Funding for future infrastructure and HR development	30	5.8333	2.22963
13	Government assistance at initial period	30	6.6000	0.62146
14	Harmonization of administrative procedures among ports	30	6.7000	0.59596
15	Regional agreements to relax shipping restriction	30	5.4000	1.37966
16	Weather and meteorological conditions	30	5.9667	1.67091
17	Safety of vessels	30	5.8000	1.66919
18	Safety of cargo and vehicles	30	5.4333	1.50134
19	Safety of passengers and crew	30	5.9333	1.08066

Source: Authors’ work

Based on **Table 5**, the five factors with the highest mean scores are led by “harmonization of administrative procedures among ports”, with a value of 6.7, followed by “government assistance during the initial period”, with a value of 6.6. These are followed by “good intermodal links,” “adequate port facilities and skilled human resources,” and “good port access,” each with a mean value of 6.5. Conversely, “balanced payload or shipment volume,” with a value of 5.33, and “large payload or shipment volume,” with a value of 5.23, are among the lowest-rated factors contributing to the success of Ro-Ro operations in the IMT-GT sub-region. The relatively high standard deviation (SD) values are acceptable, as they fall within the range of one to two SDs. This aligns with empirical work in recent Delphi research demonstrating that, in 7-point Likert-scale Delphi surveys, values of standard deviation are informative about consensus, and that around 75 percent of ratings typically lie within two standard deviations of the mean, and about 89 percent within three standard deviations (Franc et al., 2023).

Although the panel achieved strong overall agreement, several factors show larger standard deviations. In **Table 5**, the items with relatively high SD include factors 3, 5, 6, 10, 12, 15, and 16. High dispersion is not a fatal flaw; it is an analytic finding that points to heterogeneous priorities among expert subgroups. For example, items referring to payload volume and ship type reflect a trade-off between short-term commercial viability and longer-term strategic fit. Operators and commercial respondents tended to prioritize volume and cash-flow considerations, while academics and planners emphasized technical compatibility and network stability. This divergence identifies domains where further empirical study, stakeholder dialogue, or scenario analysis would be valuable. Recent methodological reviews recommend explicitly reporting and discussing such divergence, because it reveals the multi-stakeholder nature of complex policy problems and strengthens theoretical interpretation (Niederberger et al., 2024; Wahid et al., 2023).

**Table 6** Influential sub-factors for successful international Ro-Ro SSS operations.

No.	Main factors	Sub-factors	N	Mean	SD
1	Coordinated administrative and CIQS formalities	1. Application of electronic data interchange	30	6.3000	1.0222
		2. Integrated CIQS facilities	30	5.8333	1.3667
2	Good port access	3. Inland waterway transport (IWT) network	30	6.2333	1.0063
		4. Road/highway network	30	5.4000	1.0034
		5. Rail network	30	5.7000	1.9853
3	Government assistance at initial period	6. Operational subsidy for shipping company for a period of 3-5 years	30	5.6333	1.9561
		7. Start-up funding (soft loan) for acquisition of Ro-Ro vessel	30	6.3000	0.9523
		8. Government support in the construction or upgrading of Ro-Ro terminal	30	6.6333	0.4901
4	Harmonization of administrative procedures among ports	9. Standardized procedures between countries for cargo/vehicle clearance, i.e., to avoid car smuggling	30	6.6667	0.4794
		10. Simplified administrative procedures, especially those involving cargo/vehicle clearance.	30	6.3667	1.2726
5	Regional agreements to relax shipping restriction	11. Relaxation of national cabotage regime	30	6.3667	1.5196
		12. Standardization of regulations for near coastal ships	30	6.0333	1.5643
6	Suitable ship type in relation to payload, distance, and speed	13. Suitable ship size in relations to the expected payload	30	5.7000	2.1838
		14. Suitable speed in relation to the distance, i.e., vessel for a route with longer distance should have higher speed	30	6.4333	0.7279
7	Funding for future infrastructure and HR development	15. Funding for infrastructure	30	6.0667	1.3879
		16. Funding for HR development	30	5.6333	1.6291

Source: Authors' work

**Table 6** shows the overall mean and standard deviation for the sub-factors. The highest-rated is “standardized procedures between countries for cargo or vehicle clearance” (6.67), followed by “government support in the construction or upgrading of Ro-Ro terminals” (6.63), “suitable vessel speed in relation to distance” (6.43), “relaxation of the national cabotage regime” (6.37), and “simplified administrative procedures” (6.37). The lowest rated include “operational subsidy for shipping companies for three to five years” (5.63), “funding for human resource development” (5.63), and “road or highway network” (5.40). As with previous findings, the higher SD values remain acceptable, as they are within one to two SD; this aligns with empirical work in recent Delphi research demonstrating that, in 7-point Likert-scale Delphi surveys, values of standard deviation are informative about consensus, and that around 75 percent of ratings typically lie within two standard deviations of the mean, and about 89 percent within three standard deviations (Franc et al., 2023).

**Table 7** Influential clusters for successful international Ro-Ro SSS operations.

No.	Cluster	N	Mean	Std. Deviation
1	Infrastructure	30	6.5333	0.50742
2	Commercial	30	5.7667	0.72793
3	Regulatory	30	6.5333	0.50742
4	Safety and Environment	30	6.0667	0.78492

Source: Authors’ work

The clusters presented in **Table 7** were developed by merging the qualitative groupings identified in Round 1 with the quantitative validation obtained in Round 2. Factors that shared similar conceptual meanings, and displayed comparable median and interquartile range values, were combined into the same group. Each cluster label represents a common functional domain, namely, infrastructure and operations, administrative and policy integration, financial and institutional support, and safety and environmental preparedness. This mixed-method clustering approach, which applies thematic coding, followed by median and interquartile range verification, has been widely adopted in recent Delphi studies to ensure that the resulting clusters are both conceptually sound and supported by empirical evidence (DELPHISTAR Working Group, Niederberger et al., 2024; Del Grande & Kaczorowski, 2023). Based on **Table 7** above, the highest mean is held by Infrastructure and Regulatory, as both clusters carry the same values, which are 6.533, followed by Safety and Environment, with a value of 6.067, and Commercial, with a value of 5.767.

In term of relevance, the identified clusters show how several determinants interact to enhance IMT-GT performance. The Infrastructure and Operations cluster, for example, combines good intermodal links, adequate port facilities, and effective port access (Arof & Zakaria 2020; Mthembu & Chasomeris, 2023). Improvements in these areas reduce transit times, improve handling efficiency, and raise vessel utilization rates, making short sea routes more attractive for investors and shippers. Evidence from regional research demonstrates that improvements in infrastructure quality are closely linked to higher trade volumes and better logistics performance across Southeast Asia (ITF-OECD, 2022; Netirith & Ji, 2022). These findings confirm that strategic investment in infrastructure is essential for strengthening the competitiveness of IMT-GT maritime corridors.

The Round 2 (R2) Delphi results were unexpected, as the factors “balanced payload or shipment volume” (mean 5.33) and “large payload or shipment volume” (mean 5.23) were not ranked among the Very Important factors, despite their earlier identification as major reasons for the failure of previous formal international SSS in the sub-region. This outcome contrasts with the Round 1 (R1) results, where both factors scored higher means of 6.18 and 6.09, respectively. The inclusion of the Belawan-Port Klang route, and the expansion of main factors from 17 to 19, may have influenced expert judgments.

In this study, the top five factors identified were “harmonization of administrative procedures among ports” (mean 6.70), “government assistance at the initial period” (6.60), “good intermodal links” (6.57), “adequate port facilities and skilled human resources” (6.57), and “good port access” (6.50).

The remaining 14 factors also scored above 5 on the Likert scale, confirming their importance in SSS realization. Notable examples include “coordinated administrative and CIQS procedures”, “vessel and passenger safety”, “weather conditions”, “appropriate vessel”, “funding for infrastructure and human resources”, and “regional agreements to relax shipping restrictions”. Other factors include “promotion of SSS”, “port efficiency”, “service quality”, and “investor availability”. As median values were appropriate, and standard deviations complied with Chebyshev’s theorem, consensus among respondents was achieved (Franc et al., 2023).

The following section presents the decision-making model, and explains the relationships between factors, their cluster weights, and their sub-factor weights.

### 4.3 Decision-making model development based on Delphi

The determination of weightage for all variables is essential in developing the Delphi decision-making model. Mean values from **Tables 3 - 5** were used to establish general weightages for each variable group, as well as weightages within clusters and factors, following the approach of Franc et al. (2023).

#### 4.3.1 Clarification of the weighting procedure

The weighting procedure in this study applied a structured and detailed approach that reflects the relative importance of clusters, main factors, and sub-factors influencing the success of international Ro-Ro short sea shipping within the IMT-GT sub-region. This approach ensures consistency, fairness, and accurate representation across all analytical levels, following established principles in multi criteria decision making research as discussed by Nguyen (2023) and Niederberger et al. (2024).

The analysis began by determining the mean score for each cluster, represented as  $W_{main(i)}$ , which was obtained from Round 2 of the Delphi assessment. These mean values indicate the collective view of experts on the importance of each factor. The weight of each cluster, denoted as  $W_{main(i)}$ , was then calculated using the following equation:

$$W_{main(i)} = \frac{M_{main(i)}}{\Sigma(M_{main})} = 1$$

This step ensured that the total of all cluster weights equals one, which maintains balance across the entire framework. The calculated weights were then grouped according to their respective 19 factors. The sum of factor weights within each cluster is equal to the total cluster weight.

At the cluster level, the Infrastructure and Regulatory clusters recorded the highest values of 0.262, reflecting their major contribution to both operational and policy aspects of the Ro-Ro network. The Safety and Environment cluster followed with 0.244, emphasizing its role in maintaining operational security and environmental care, while the Commercial cluster, with a weightage of 0.232, highlights the importance of service efficiency and economic stability.

For clusters that contain sub-factors, a proportional weighting process was applied to maintain the relationship between each sub-factor and its parent factor. The share of each sub-factor, represented as  $S_{sub(i,j)}$ , was determined by the following formula:

$$S_{sub(i,j)} = \frac{M_{sub(i,j)}}{\Sigma(M_{sub(i,j)})} = 1 \text{ to ki } M_{sub(i,j)}$$

where  $k_i$  is the number of sub-factors under the related main factor. This formula indicates how much each sub-factor contributes to the total influence of its main factor.

The total weight of each sub-factor, represented as  $M_{sub(i,j)}$ , was obtained by multiplying the weight of the main factor by the proportional share of the sub-factor, as expressed below:

$$W_{sub(i,j)} = W_{main(i)} \times S_{sub(i,j)}$$

This calculation guarantees that all sub-factor weights under a specific main factor sum up to the total weight of that factor. When necessary, normalization was performed so that the sum of all sub-factor weights equaled one, ensuring consistency across all factors and clusters.

The results shown in **Table 8**, below, present a clear hierarchy that connects clusters, main factors, and sub-factors. In the Regulatory cluster, the most significant factors are “harmonization of administrative procedures among ports”, with a weightage of 0.094, and “government assistance during the initial period”, with a weightage of 0.092. Their sub-factors, “standardized administrative procedures”, with 0.048, and “simplified administrative procedures”, with 0.046, reveal the need for harmonized systems and uniform documentation among ports. Within the Infrastructure cluster, “good intermodal links”, “adequate port facilities”, and “good port access” each recorded a weightage of 0.067. Their sub-factors, such as “application of electronic data interchange”, with 0.031, “integrated CIQS facilities” with 0.030, and “inland waterway, road, and rail networks”, with 0.024, 0.021, and 0.022 respectively, illustrate the importance of connectivity and technological coordination in port operations.

In the Commercial cluster, the main factors include “port efficiency”, “SSS service quality”, and “suitable ship type”, with sub-factors such as “suitable ship size”, with 0.013, “suitable speed”, with 0.014, and “funding for infrastructure and human resource development”, with 0.015 and 0.014, respectively. These reflect the close relationship between operational performance, vessel design, and long term investment.

The Safety and Environment cluster contributes to the overall system stability, with “weather and meteorological conditions” at 0.063, and “safety of vessels” at 0.061. These factors show the significance of environmental monitoring and proactive safety measures in maritime operations. Hence, the weighting procedure successfully integrates expert opinions into a measurable framework that combines operational, policy, economic, and environmental perspectives. This approach offers a balanced analytical basis for evaluating policy initiatives, prioritizing strategic actions, and promoting sustainable development of the Ro-Ro short sea shipping system within the IMT-GT region. The summarized weightages for clusters, factors and sub-factors are presented in **Table 8**.

Eventually, the decision-making model for the success of the international Ro-Ro SSS in the IMT-GT sub-region was developed by utilizing the values based on **Table 8**. Thus, the Delphi decision-making model is tabulated in **Figure 4** below:

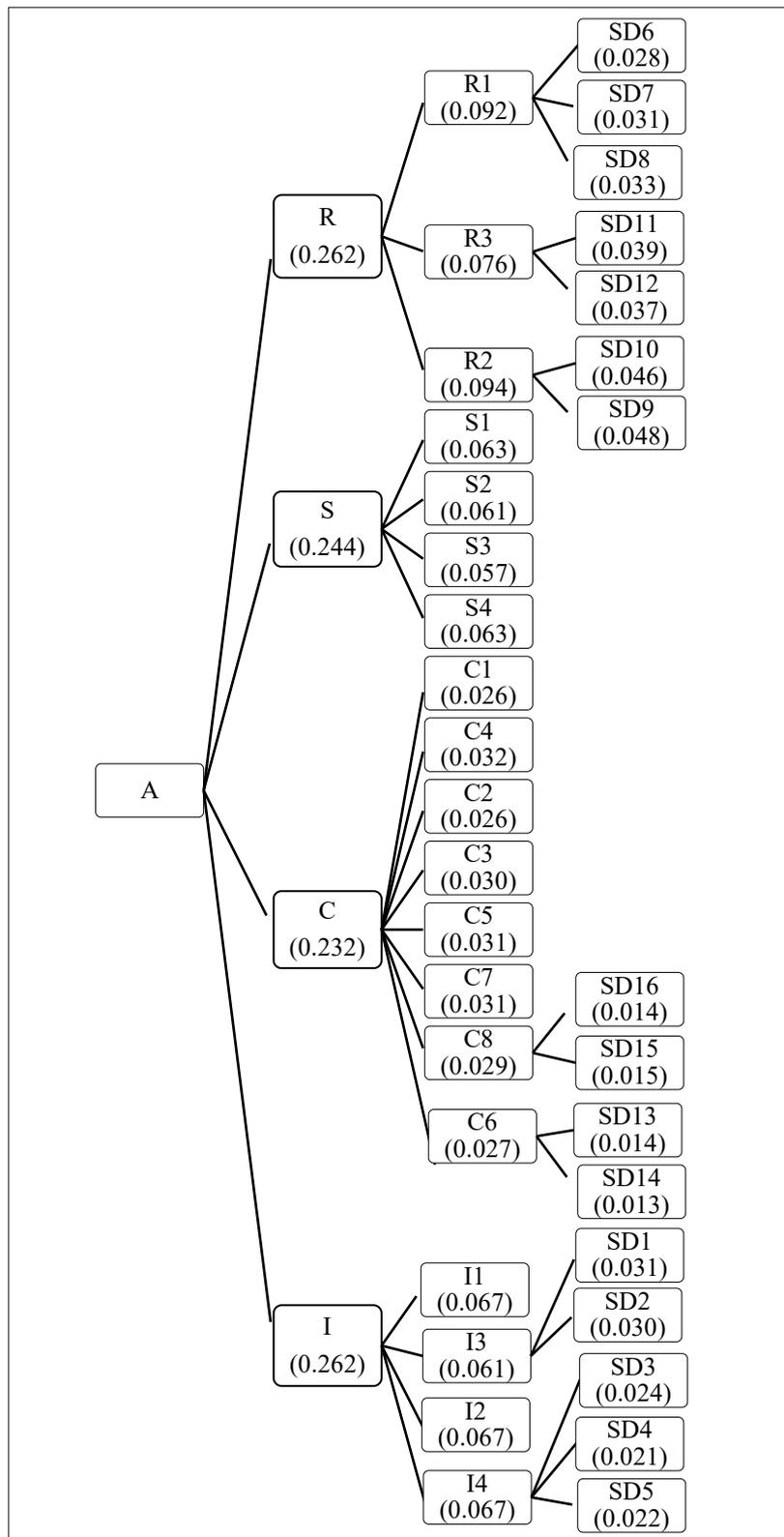
**Figure 4** illustrates expert assessments for developing the decision-making model across four clusters, nineteen main factors, and sixteen sub-factors. The Regulatory and Infrastructure clusters share the highest weightage of 0.262 each. Addressing the seven main factors within these clusters could contribute more than fifty-two percent toward the success of the Ro-Ro SSS initiative. The top main factor is “harmonization of administrative procedures among ports”, with a weightage of 0.094, while the top sub-factor is “standardized administrative procedures for cargo or vehicle clearance”, with a weightage of 0.048.

Focusing limited resources on these high impact factors, such as “harmonization of administrative procedures”, “initial government assistance”, “regional agreements to relax shipping restrictions”, “good intermodal links”, “adequate port facilities with skilled human resources”, and “good port access”, would enhance the likelihood of long term sustainability. Consistent Ro-Ro services could then stimulate demand among shippers.

**Table 8** Weightage of clusters, factors and sub-factors.

Cluster	Cluster Weightage	Main Factors	Factor Weightage	Sub-Factors	Sub-Factor Weightage	
1. Infrastructure	0.262	Good intermodal links	0.067			
		Adequate port facilities and equipment	0.067	–	–	
		Coordinated administrative and CIQS formalities	0.061		Application of electronic data interchange	0.031
					Integrated CIQS facilities	0.030
		Good port access	0.067		Inland waterway transport (IWT) network	0.024
					Road/highway network	0.021
					Rail network	0.022
2. Commercial	0.232	Balanced payload or shipment volume	0.026	–	–	
		Large payload or shipment volume	0.026	–	–	
		Promotion of SSS	0.030	–	–	
		Port efficiency	0.032	–	–	
		SSS service quality	0.031	–	–	
		Suitable ship type for payload, distance, and speed	0.027		Suitable ship size for payload	0.013
					Suitable speed for distance	0.014
		Availability of investor Funding for future infrastructure and HR development	0.031	0.029	–	–
			Funding for future infrastructure	0.015		
			Funding for HR development	0.014		
3. Regulatory	0.262	Harmonization of administrative procedures among ports	0.094	Standardized administrative procedures (cargo/vehicle clearance)	0.048	
				Simplified administrative procedures (cargo/vehicle clearance)	0.046	
		Government assistance at initial period	0.092	Operational subsidy for shipping companies (3–5 years)	0.028	
				Start-up funding for Ro-Ro vessel acquisition	0.031	
				Government support in constructing/upgrading Ro-Ro terminals	0.033	
4. Safety and Environment	0.244	Regional agreements to relax shipping restrictions	0.076	Relaxation of national cabotage regime	0.039	
		Weather and meteorological conditions	0.063	–	–	
		Safety of vessels	0.061	–	–	
		Safety of cargo and vehicles	0.057	–	–	
		Safety of passengers and crew	0.063	–	–	

Source: Author’s work



**Figure 4** Delphi decision-making model for the success of international Ro-Ro SSS in the IMT-GT sub-region.

Source: Authors' work

Legend:

A Determinants of Ro-Ro in IMT-GT

R Regulatory

S Safety

- C Commercial
- I Infrastructure
- I1 Good intermodal links
- I2 Adequate port facilities, equipment
- I3 Coordinated administrative and CIQS
- I4 Good port access
- C1 Balanced payload or shipment volume
- C2 Large payload or shipment volume
- C3 Promotion of SSS
- C4 Port efficiency
- C5 SSS service quality
- C6 Suitable ships type
- C7 Availability of investor
- C8 Funding for future infrastructure, HR
- R1 Government assistance
- R2 Harmonization of administrative
- R3 Regional agreements
- S1 Weather, meteorological conditions
- S2 Safety of vessels
- S3 Safety of cargo and vehicles
- S4 Safety of passengers and crew
- SD1 Application of electronic data
- SD2 Integrated CIQS facilities
- SD3 Inland waterway transport
- SD4 Road or highway network
- SD5 Rail network
- SD6 Operational subsidy
- SD7 Start-up funding
- SD8 Government support
- SD9 Standardized administrative
- SD10 Simplified administrative
- SD11 Relaxation of national cabotage
- SD12 Standardization of regulations
- SD13 Suitable ships size
- SD14 Suitable speed
- SD15 Funding for future infrastructure
- SD16 Funding for HR development

Interestingly, the Commercial cluster ranked lowest, despite including two important determinants, “port efficiency” and “SSS service quality”, and despite having more factors than other clusters. This is largely due to “balanced payload or shipment volume” and “large payload or shipment volume” having the lowest mean values. This indicates that, while relevant, they are less critical compared to other criteria, which is consistent with the literature.

#### 4.4 Sensitivity analysis

To ensure the reliability of the Delphi-based decision-making framework developed in this research, a sensitivity analysis was undertaken on the alternative short sea shipping (SSS) routes linking Indonesia, Malaysia, and Thailand. The routes under consideration comprise: Route 1 (Dumai-Malacca), Route 2 (Belawan-Penang), Route 3 (Belawan-Phuket), and Route 4 (Belawan-Port Klang). These routes were previously assessed through expert judgements, and their priority

ranking was established according to the aggregated evaluation of the selected determinants. The principal aim of this analysis is to test whether minor adjustments in the weighting of determinants would lead to noticeable changes in the final ranking of the alternatives. Such an assessment is vital, as decision-making within the maritime transport sector is often influenced by dynamic policy and operational and market conditions. By simulating incremental increases and decreases in determinant values, the stability of the ranking outcomes can be observed, thereby providing evidence of the model’s robustness and suitability for practical decision-making applications.

Basically, the mean values in **Table 4** were multiplied by the weightage of each determinant as listed in the second row of **Table 8**. The results of the multiplication as stipulated in **Table 10** for each route were used to perform a further simulation stage in sensitivity analysis.

**Table 10** Results of multiplication.

Route	Determinant									
	I1	I2	I3	I4	C1	C2	C3	C4	C5	C6
1	0.067	0.067	0.060	0.067	0.026	0.026	0.030	0.032	0.031	0.027
2	0.375	0.308	0.336	0.308	0.099	0.099	0.138	0.144	0.164	0.105
3	0.369	0.302	0.330	0.302	0.104	0.104	0.141	0.138	0.158	0.111
4	0.362	0.295	0.330	0.302	0.099	0.101	0.132	0.141	0.155	0.105
4	0.375	0.268	0.336	0.308	0.101	0.101	0.126	0.141	0.161	0.108

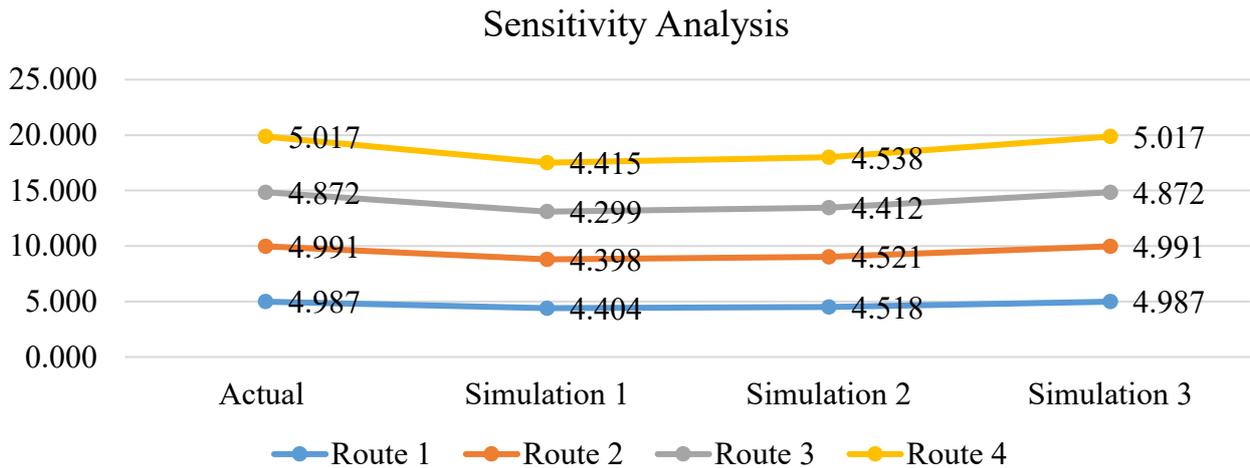
Route	Determinant									TOTAL
	C7	C8	R1	R2	R3	S1	S2	S3	S4	
1	0.031	0.029	0.092	0.094	0.076	0.063	0.061	0.057	0.063	4.987
2	0.140	0.116	0.469	0.583	0.464	0.258	0.268	0.285	0.328	4.991
3	0.140	0.116	0.469	0.592	0.471	0.265	0.268	0.285	0.328	4.872
4	0.136	0.110	0.460	0.573	0.456	0.252	0.262	0.279	0.321	4.872
4	0.143	0.119	0.478	0.602	0.479	0.271	0.275	0.291	0.334	5.017

Source: Authors’ work

For this purpose, three simulations were performed. The first simulation eliminated determinant R2, “harmonization of administrative procedures among ports,” which had the highest weight in the Delphi decision-making model, by assigning it a zero value (0.094). The second simulation similarly assigned a zero value to the second-highest determinant, R1, “government assistance at initial period” (0.092). Finally, the third simulation involved upgrading the determinant with the lowest weight, C1, “balanced payload or shipment volume,” from 0.026 to 0.126.

In this simulation, the total value of each route did not differ from the actual outcome, with Route 4 remaining on top. Similarly, Route 2 remained in second place, Route 1 remained in third place, and Route 3 remained at the bottom, with a score slightly lower than the others. The outcomes of the three simulation tests reveal consistent yet distinct patterns. In Simulation 1, the recorded values were 4.404, 4.398, 4.299, and 4.415, showing stable results within a close range. Simulation 2 produced slightly higher values of 4.518, 4.521, 4.412, and 4.538, suggesting a moderate increase compared to the first set. The highest figures were obtained in Simulation 3, with results of 4.987, 4.991, 4.872, and 5.017, indicating a marked improvement and greater reliability across the outcomes.

Next, the comparisons between the total score in the actual judgement and the simulated scenario are underlined in **Figure 5**, as below:



**Figure 5** Sensitivity analysis of short sea shipping (SSS) routes.  
 Source: Authors' work

Based on **Figure 5**, the above sensitivity analysis has proven the robustness of the Delphi decision-making model, as the ranks of the alternative routes remain stable in all three cases when the values of the key determinants are increased and decreased. This indicates that the proposed model is stable, robust, and appropriate for decision-making purposes.

## 5. Discussion

This study provides new insights into the determinants of successful international Ro-Ro short sea shipping (SSS) in the IMT-GT region, addressing both policy and operational dimensions. The findings highlight the relative weight of regulatory, infrastructural, and institutional factors, compared with traditional emphasis on market demand and cargo volume. By situating these results within the context of recent literature from 2022 to 2025, the discussion contributes to advancing knowledge on sustainable and feasible maritime connectivity in Southeast Asia and beyond.

While the Delphi technique helped the panel reach a broad agreement, several variables showed noticeably wider differences in the scores provided by the experts. These include coordinated CIQS procedures, balanced and large payload volume, suitability of ship type, service quality, regional agreements, and weather conditions. The diversity in these judgements reflects differences in professional backgrounds, operational experiences, and national contexts among the respondents, rather than weaknesses in the method itself. Experts differed in their views on payload related variables because the IMT-GT sub-region does not share a uniform market profile. Respondents from Malaysia and southern Thailand, where passenger and vehicle flows are more stable, tended to believe that Ro-Ro operations can begin even with modest cargo levels, as long as institutional support is strong. Indonesian respondents were more cautious because their earlier attempts at interstate Ro-Ro services suffered from low cargo fill rates and high imbalance between directions. These contrasting experiences influenced how strongly each group perceived the role of balanced or large volumes.

Disagreement was also visible in the ratings related to coordinated administrative and CIQS procedures. Some experts who had direct involvement in cross border projects believed that CIQS integration is making progress and, therefore, did not see it as an overwhelming barrier. Others, particularly those familiar with ground level implementation, felt that variations in staffing, inspection routines, and documentation systems between the three countries remain a major obstacle. These different day to day realities naturally influenced the scoring. The suitability of ship type generated another spread of opinions. Respondents with commercial shipping experience gave higher importance to vessel characteristics because of their direct influence on operating costs and route

economics. Experts with policy or academic backgrounds placed more emphasis on administrative and infrastructural readiness, assuming that vessel choice can be adapted after other constraints are resolved. This difference in perspective explains why the consensus on this factor was not as tight. There were also contrasting views on the weight of service quality. Some experts associated service quality primarily with frequency and punctuality, while others linked it more to passenger amenities and price. These different interpretations led to a wider distribution of scores, even though all respondents agreed that service reliability matters for long term success.

Regional agreements, such as cabotage relaxation, produced mixed ratings, because the three participating countries hold different positions on regulatory reform. Respondents who are familiar with national level policy processes understood the political sensitivities and, thus, believed that these agreements would take time to mature. Others working at the operational level viewed such agreements as essential and urgent, particularly for lowering barriers to entry. Weather and meteorological conditions also drew varied ratings. Experts who focus on the Malacca Strait generally considered weather risks manageable, because the area is relatively sheltered. Those with experience in the Andaman Sea or northern Sumatra emphasized seasonal monsoon effects more strongly, which naturally raised the importance they attached to this factor. Therefore, the disagreements observed in these variables reflect the diverse environments in which the experts operate. Their different national responsibilities, exposure to past Ro-Ro initiatives, and distinct interpretations of each variable shaped the range of scores. Rather than weakening the study, this variation helps present a more realistic picture of the conditions influencing Ro-Ro development in the IMT-GT region.

## **5.1 Comparison with recent literature**

### ***5.1.1 Infrastructure, intermodal connectivity, and port access***

The results confirm that intermodal links, adequate port facilities, and efficient port access are decisive factors for the viability of international Ro-Ro routes. Recent research similarly emphasizes the importance of hinterland and intermodal connectivity. For instance, Saha et al. (2024) and Mthembu and Chasomeris (2023) demonstrated that integration of inland rail, road, and river terminals at Chattogram Port significantly improved efficiency and reduced disruptions in container logistics. Such findings align with this study's conclusion that physical access and multimodal readiness are not peripheral, but central, to Ro-Ro success. The Indonesian government's current initiatives to improve road and port entrance infrastructure under national strategic projects also reinforce this conclusion. The alignment between these practical policy efforts and the findings suggests that IMT-GT stakeholders are responding to the same priorities identified through expert consensus (PwC Indonesia, 2024).

### ***5.1.2 Regulatory and institutional determinants***

The Delphi results place "harmonization of administrative procedures" and "initial government assistance" at the top of the determinant ranking. These findings are strongly supported by recent developments in maritime connectivity. For example, regulatory reforms and government-driven projects in Indonesia have been identified as critical levers for strengthening ASEAN shipping integration (PwC Indonesia, 2024). In addition, current geopolitical and logistical disruptions underline the importance of government intervention. For instance, Asian shippers in South Korea and Vietnam benefited from direct state support to offset disruptions caused by Red Sea diversions, demonstrating how public policy remains a stabilizing force for maritime operations (S&P Global, 2024). These cases highlight that government assistance and harmonized regulatory frameworks are not merely supportive, but essential, enablers of sustainable Ro-Ro services.

### ***5.1.3 Payload and cargo volume***

Interestingly, "balanced payload volume" received relatively low weighting in this study. While earlier studies emphasized volume as a prerequisite for route sustainability, recent scholarship

points to a more nuanced picture. Batista Santos and Santos (2024) argue that, even where cargo demand is modest, regulatory, technological, and environmental enablers can compensate and create viable operational models. This suggests a shifting paradigm, in which the quality of institutional support and infrastructural preparedness outweighs the sheer scale of traffic, consistent with the findings presented here.

#### **5.1.4 Safety, environmental, and technological factors**

“Safety of vessels, cargo, and passengers”, as well as “weather-related considerations”, emerged as important though secondary determinants (Saputra et al., 2023). These findings align with Batista Santos and Santos (2024), who emphasize that environmental regulations, safety compliance, and the adoption of digital technologies are increasingly integral to short sea shipping. The inclusion of these dimensions reflects the growing recognition that operational sustainability extends beyond cost and efficiency, encompassing environmental resilience and risk management.

### **5.2 Contributions and implications**

The findings contribute to the literature by offering a structured prioritization of determinants for Ro-Ro operations in emerging maritime regions, which carries several important implications. First, the weighted determinants provide a quantified prioritization of interventions, allowing governments and investors to allocate resources more strategically, with administrative harmonization and infrastructure readiness taking precedence. Second, the results of the sensitivity analysis demonstrate robustness under uncertainty, as route viability remained stable even when key determinants were varied, thereby giving confidence to policymakers and planners in long-term decision-making. Third, the study highlights the role of policy levers over market size, showing that higher weightings for “government assistance” and “administrative streamlining” compared to “balanced payload” indicate that effective policies can mitigate the challenges of lower demand. Finally, by integrating safety, weather, and environmental considerations, the model reflects global sustainability expectations and ensures greater applicability across different contexts.

### **5.3 Practical recommendations**

The recommendations presented in this section are arranged according to the empirical findings of the Delphi study, ensuring that every suggestion corresponds directly to the highest-weighted sub-factors identified in Round 2. The purpose is to provide a sequence of policy and operational actions that reflect the experts’ collective judgment regarding what is most critical for the success of international Ro-Ro short sea shipping operations in the IMT-GT region.

The analysis shows that the most important intervention involves the improvement and standardization of cargo and vehicle clearance procedures across participating countries. The sub-factor “standardized procedures between countries for cargo or vehicle clearance” received the highest mean value of 6.67, while “application of electronic data interchange” scored 6.30. These results demonstrate that experts see the integration and simplification of CIQS processes as the single most important enabler of short sea shipping efficiency. Harmonized clearance rules, coupled with the digitalization of customs and inspection documentation, would substantially shorten turnaround time, lower administrative costs, and enhance service reliability. It is therefore recommended that the IMT-GT secretariat, together with the national customs and port authorities, develop a unified electronic clearance platform that allows information exchange among the three participating nations. Pilot projects, involving two ports with compatible ICT infrastructure, would provide valuable insight into the technical and procedural adjustments required for regional implementation.

The second recommendation concerns investment in terminal upgrading and capacity enhancement. The sub-factor “government support in the construction or upgrading of Ro-Ro terminals” recorded a mean of 6.63, confirming that adequate terminal facilities are essential to sustain operational efficiency. Upgraded terminals with sufficient ramp space, berthing capacity, and

skilled personnel can accommodate higher vessel frequencies and minimize waiting times. Governments are therefore encouraged to prioritize terminal modernization projects through public-private partnerships, and to link financial assistance with measurable performance indicators, such as reduced vessel turnaround time and improved cargo throughput.

Another priority area involves the provision of financial support mechanisms that can reduce the commercial risks associated with new Ro-Ro operations. The sub-factor “start-up funding for acquisition of Ro-Ro vessels” scored 6.30, while “operational subsidy for shipping companies for a period of three to five years” obtained a mean of 5.63. These values indicate that experts recognize the importance of temporary financial assistance to attract private participation during the early stages of market development. Soft loans or concessional credit lines could be provided for fleet acquisition, while limited performance-based subsidies could help operators maintain service consistency until the market reaches a sustainable volume.

The fourth recommendation focuses on the suitability of vessel characteristics for specific routes. The sub-factor “suitable vessel speed in relation to distance” scored 6.43, reflecting strong agreement that technical compatibility between ship design and route conditions determines service efficiency and cost effectiveness. Port authorities and maritime regulators should therefore encourage the use of vessels whose capacity, speed, and fuel efficiency match the cargo profile and route length. Technical guidelines for vessel selection and fleet planning should be developed to help operators choose ships that are both operationally and economically appropriate.

The next recommendation concerns the harmonization of national cabotage and near-coastal shipping regulations. The sub-factor “relaxation of national cabotage regime” scored 6.37, while “standardization of regulations for near-coastal ships” scored 6.03. These results suggest that experts see regional regulatory convergence as essential for reducing operational and legal barriers to international short sea shipping. Policymakers should therefore initiate discussions to harmonize documentation and certification procedures, and to introduce gradual, transparent liberalization where appropriate. These steps would encourage fair competition, attract foreign investment, and increase the number of service providers in the region.

Another significant recommendation relates to improving multimodal connectivity between ports and their hinterlands. The sub-factor “inland waterway transport network” achieved a mean value of 6.23, showing that efficient inland connections play a crucial role in ensuring smooth cargo movement to and from ports. Governments should focus on upgrading the connecting road and rail systems and on developing multimodal logistics corridors that integrate maritime and inland transport. Improved connectivity would enlarge the ports’ catchment areas and strengthen the overall reliability of the logistics chain.

The findings also indicate that implementation should be sequenced in a logical order, beginning with reforms that yield quick, visible results. Administrative and procedural reforms such as CIQS integration can be implemented relatively quickly and will create immediate gains in service efficiency. These gains can then justify and attract larger investments in infrastructure and fleet modernization. Each recommendation should also include a monitoring plan that uses the same indicators as the sub-factors identified in **Table 5**, so that progress can be evaluated using consistent measures over time.

Thus, the recommendations derived from the Delphi analysis emphasize that the integration of customs and clearance procedures, terminal modernization, and targeted financial incentives should be given first priority. Once these are in place, vessel suitability, regulatory harmonization, and multimodal connectivity should follow as complementary actions. This structured order of implementation ensures that policy measures are data driven, practical, and consistent with the consensus reached by the expert panel. It also provides a clear roadmap for strengthening the efficiency and competitiveness of international short sea shipping operations within the IMT-GT region.

#### 5.4 Limitations and future research

Although the Delphi approach provided valuable consensus, the study is limited by its reliance on expert judgment, rather than operational performance data. Future research should incorporate real-world route data as pilot projects progress. In addition, the integration of environmental performance indicators and digitalization enablers into decision models remains an important research frontier. Recent literature highlights both emissions regulations and technological advancements as reshaping factors in shipping viability (Batista Santos & Santos, 2024). Expanding the expert panel to include shippers, investors, and environmental groups would also enrich the analysis.

Environmental performance has become an unavoidable element of maritime policy, yet most studies, including this one, treat it as a qualitative condition. Future analyses should incorporate measurable indicators such as fuel consumption per trip, emission levels across different sea conditions, lifecycle environmental costs of vessel types, and the financial implications of complying with carbon pricing frameworks. Quantifying these elements would help researchers understand the true tradeoffs between cost, sustainability, and long term operational reliability. This would also allow policy makers to evaluate the environmental consequences of new routes or vessels, rather than relying on general assumptions.

Digitalization represents another area that demands a more precise methodological approach. Concepts such as electronic data interchange, digital twins and port community systems are often discussed as desirable innovations, yet their benefits are rarely expressed in numerical terms. Future research should explore how digital systems reduce clearance time, shorten vessel turnaround, improve safety performance, or influence operational costs. These impacts can be translated into measurable variables such as minutes saved per transaction, percentage increase in schedule reliability, or cost reductions linked to automated processes. Once such metrics are established, they can be incorporated into multi criteria decision models to produce more realistic assessments of technology driven improvements.

An additional research direction concerns the validation of the Delphi model. The present framework reflects expert judgement, which is suitable for early stage planning, but future work should test the predictive accuracy of the model using real operational data. This may involve comparing expected route viability with actual figures on load factors, service frequency, transit time performance, and economic outcomes once IMT-GT Ro-Ro services begin operating. Such comparisons would help refine the weightings assigned to the determinants and reveal whether the expert based assumptions hold true in practice.

Another important avenue concerns the financial dimension of Ro-Ro development. Future investigations should explore realistic funding structures for interstate routes, including various public and private financing models. These studies may examine how investment risks can be allocated fairly, and how government incentives might be designed to encourage private participation while ensuring long term sustainability. A more rigorous exploration of financing options would help bridge the gap between conceptual planning and actual implementation.

Overall, future research must move towards approaches that are measurable, data driven, and grounded in real operational experience. By quantifying environmental and digitalization factors, and testing the model against observed outcomes, researchers can strengthen the evidence base for policy makers and create more reliable tools for developing sustainable Ro-Ro connectivity in the IMT-GT region.

#### 6. Conclusions

This study successfully fulfils its aim of determining the most influential factors that shape the performance of international Ro-Ro short sea shipping services in the IMT-GT corridor. By applying a rigorous two-round Delphi process, and achieving exceptionally high reliability scores, the research establishes a solid and credible basis for understanding what truly drives operational

success. The findings make it clear that administrative harmonization and the seamless integration of customs, immigration, quarantine, and security procedures stand at the core of effective regional maritime operations. Standardized clearance processes, supported by upgraded port terminals and stronger intermodal links, emerge as the most critical priorities that demand immediate attention from policymakers and port authorities.

The evidence points toward three strategic directions that can significantly elevate regional maritime connectivity. The establishment of a unified electronic clearance platform has the potential to remove long-standing procedural bottlenecks and unlock real time coordination across IMT-GT economies. Investments that focus on modernizing terminals and improving the flow between ports and inland logistics routes can create measurable and sustained gains in efficiency. Targeted financial instruments that assist new operators in managing early investment pressures can help build a more competitive and resilient market environment.

The outcomes of the study not only validate the relevance of these factors but also translate them into practical and achievable policy actions. Future research that models the influence of environmental and digitalization related variables will further strengthen the evidence base. Overall, this study provides a decisive framework that can enhance regional maritime performance, stimulate trade growth, and support long term economic sustainability across the IMT-GT region.

### CRediT author statement

**Amayrol Zakaria:** Conceptualization; Methodology; Formal analysis; Investigation; Data curation; Writing – Original Draft; Visualization; Project administration. Funding acquisition. **Ruth Banomyong:** Conceptualization; Resources; Supervision; Writing – Review & Editing. **Aminuddin Md Arof:** Methodology; Validation; Formal analysis; Investigation; Writing – Review & Editing; Visualization. Funding acquisition.

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