

Article

Driving Collaboration in Rail Freight Services: A Thematic and MICMAC Analysis of Stakeholder Factors in Thailand

Tawinan Simajaruk and Jirapan Liangrokapart *

Department of Industrial Engineering, Faculty of Engineering, Mahidol University,
Nakorn Pathom 73170, Thailand

* Correspondence: jirapan.lia@mahidol.ac.th

Abstract

Background: Strengthening, coordinating, and sustaining rail freight services is one of the most pressing yet neglected challenges for transport planners in developing economies. Focusing on the institutional context of Thai freight transport, we assess, contextualise, and rank the collaboration factors shaping rail freight competitiveness. **Methods:** MICMAC analysis was selected because it does not require a pre-defined hierarchical structure and it is computationally straightforward for small variable sets. A qualitative study comprising semi-structured interviews was conducted with participants from government transport agencies, the State Railway of Thailand (SRT), private logistics operators, and freight customers. **Results:** The analysis extracted six key factors: government policy, finance, infrastructure readiness, technology and innovation, information sharing, and human resource capacity. Government policy alone occupies the driving quadrant, exerting the strongest systemic influence. Finance and infrastructure readiness emerge as linkage factors, simultaneously shaping and being shaped by the wider network, whereas technology, information sharing, and human resources sit in the dependent quadrant and respond to change. **Conclusions:** This classification allows us to derive seven collaboration strategies matched with appropriate policy levers; the three highest-ranked are policy collaboration, economic instruments, and multimodal integration.

Keywords: rail freight; collaboration; thematic analysis; MICMAC; cross-impact matrix; Thailand; stakeholder; transport policy

1. Introduction

Rail freight occupies a distinctive position in sustainable logistics because it is more energy-efficient than road haulage, generates fewer carbon emissions per tonne-kilometre, and can move large volumes over long corridors at a comparatively low marginal cost [1,2]. Policymakers across Europe, China, and Southeast Asia have acted on these advantages by embedding road-to-rail modal-shift programmes in national decarbonisation strategies [3,4]. These gains remain elusive in much of the developing world, where ageing infrastructure, sparse intermodal connections, and fragmented institutional oversight keep the freight share of rail stubbornly low [5,6].

A body of work has probed collaboration across manufacturing, retail, and logistics supply chains [7–9]. Boehm et al. [2] drew a parallel in the European high-speed rail freight context, stressing that modal shift demands coordinated multi-stakeholder action

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rather than piecemeal fixes. More recently, Rosa et al. [10] argued that systematic stakeholder mapping is a necessary first step before road-to-rail collaboration can take hold. Björk et al. [1] assessed whether Sweden's freight modal shift functions as a policy instrument or as an end in itself, whereas Betarelli et al. [11] documented how transport policy restructuring reshaped Brazil's rail freight market, with deregulation generating measurable economic spillovers across multiple sectors. Lin et al. [12] used a cloud model–fuzzy Petri net framework to evaluate the intrinsic safety of railway facilities and rolling stock, illustrating that systematic multi-criteria risk assessment of rail infrastructure is a prerequisite for effective operational coordination among maintenance, regulatory, and service stakeholders.

Thailand has invested considerable resources in dual-track railway expansion and port connectivity; however, rail freight still accounts for approximately 2% of the country's total freight volume, a share that has barely changed in the past two decades. The State Railway of Thailand (SRT), the country's sole rail operator, must coordinate with freight customers, logistics providers, customs authorities, and several government agencies, an effort that remains conspicuously weak [13,14]. Tracing linkages from consignors through logistics providers to rail operators, Buthphorm et al. [6] used structural equation modelling to identify the development factors specific to Thailand's rail freight sector; their analysis established that institutional backing and coherent policies are the primary determinants of modal-shift success.

Frameworks such as the collaboration index of Simatupang and Sridharan and the resilience model of Scholten and Schilder [15,16] centre on relationship-level constructs (trust, commitment, and information sharing); however, these constructs capture only part of the picture in publicly operated rail freight systems. In developing countries, government policy, large-scale infrastructure investment, and multi-stakeholder regulatory arrangements shape outcomes at least as powerfully as inter-firm trust, and the collaboration factors specific to this institutional context have received scant empirical attention.

MICMAC's methodological positioning relative to ISM and DEMATEL merits explicit consideration. ISM relies on a reachability matrix to partition variables into hierarchical levels, an output distinct from the quadrant-based classification this study requires. DEMATEL computes net cause-and-effect centrality through direct and indirect influence matrices, with its $n(n-1)$ pairwise judgments becoming burdensome for large factor sets. Gupta and Gupta [17], applying grey Delphi–DEMATEL to freight logistics barriers in India through a ten-expert panel, demonstrate that structural analysis effectively surfaces causal relationships among system variables; the present study follows analogous logic using MICMAC, whose quadrant output maps more directly onto the policy-sequencing objective and is consistent with its prior application to small variable sets in transport contexts [18,19].

In light of the above, this study was guided by two research questions:

RQ1: *What are the critical factors that affect collaboration in Thailand's rail freight services?*

RQ2: *What collaboration strategies can be developed to improve rail freight performance?*

This study makes three contributions. First, six collaboration factors specific to rail freight emerge from a qualitative analysis of expert interviews, pushing the collaboration literature beyond its customary focus on manufacturing and retail. Second, a MICMAC analysis classifies these factors by driving power and dependence, revealing the structural dynamics, particularly the dominant role of government policy, that should shape intervention priorities. Third, seven actionable strategies, ranked according to the MICMAC classification, provide concrete guidance for policymakers in Thailand and comparable

state-monopoly rail freight contexts in other developing economies grappling with similar constraints.

The remainder of this paper is organised as follows. Section 2 surveys the relevant literature. Section 3 describes the methodology. Section 4 reports the findings, Section 5 discusses their implications, and Section 6 presents policy recommendations and avenues for further enquiry.

2. Literature Review

2.1. Collaboration in Transport and Logistics

Scholten and Schilder [15], who studied eight buyer supplier relationships in the food processing industry, and Chen et al., who reviewed sustainability-oriented collaboration across multiple sectors, found that information sharing increases supply-chain resilience through improved visibility and velocity and that environmental and economic goals dominate the research agenda at the expense of social dimensions [8,20]. In the transport sector, Barratt argued that firms must segment supply-chain partners by customer buying behaviour before deciding when and with whom to collaborate, and Paddeu et al., [21] surveying urban freight stakeholders in Bristol and Cagliari, reported that coordination among operators and intermediaries shapes service quality, with divergent commercial objectives posing the most persistent obstacle [21,22]. From a practitioner's viewpoint, Horvath argued that competition has shifted from individual firms to entire value chains and that collaboration through standardised e-business architectures is the primary mechanism for value creation [23].

Holweg et al. [20] mapped logistics collaboration as a continuum from information sharing and joint planning to resource pooling and co-investment, and Hingley et al., interviewing three suppliers, three logistics providers, and one UK grocery retailer, found that fourth-party logistics management can improve horizontal collaboration, but that lead-firm power dynamics inhibit adoption [7,24]. Horizontal collaboration, in which firms at the same supply-chain tier cooperate for mutual gain, has received sustained attention. Cruijssen et al. [24] catalogued the principal opportunities and impediments in European road haulage, and Basso et al. [25] subsequently surveyed 26 impediments to practical implementation across six countries [25,26].

Vertical collaboration between shippers, carriers, and receivers is equally consequential. Fawcett et al. [27] conducted a multi-method study comprising a cross-functional survey and 51 in-depth case analyses and found that misaligned incentives between supply-chain tiers constitute one of the most persistent barriers to collaboration [27,28]. Soosay et al. [29] extended this spectrum by demonstrating through Australian manufacturing case studies that collaborative relationships generate capabilities for continuous innovation beyond cost reduction. Abideen et al. [30] conceptualised horizontal logistics collaboration as an integrating mechanism between supply-chain planning and transportation logistics planning, positioning freight coordination as a central element of the integration process.

Rail freight presents additional complexities that general logistics collaboration frameworks do not adequately address. The government simultaneously regulates the sector and, in countries like Thailand, owns the infrastructure outright. How this dual role complicates stakeholder coordination was explored early on by Rangarajan et al. [14], who surveyed four stakeholder groups (community members, operators, regulators, and technical experts) across Missouri and found that successful rail planning requires inclusive engagement in which each group perceives its concerns to be adequately represented. Whether governance structure itself matters was taken up by Nakamura and Sakai [31]; their analysis of the Japanese railway system concluded that vertical integration between infrastructure managers and train operators does improve coordination, though the benefits depend on institutional context.

Urban freight presents a different dynamic. Paddeu et al. [21] studied multi-stakeholder consolidation schemes in European cities and reported that, although environmental benefits constituted the strongest motive for collaboration, divergent commercial objectives among partners proved the most difficult obstacle to resolve. In the Southeast Asian context, Kasrim et al. [32] reviewing 85 publications on ASEAN logistics governance published between 2015 and 2025, reached a comparable conclusion, finding that government and private sector coordination is indispensable but that fragmented regulations and limited digital literacy make formalising such arrangements a persistent institutional challenge. A broader view of the literature comes from Wang et al. [33], who reviewed promising solutions for railway operations in the face of disruptions ranging from COVID-19 to natural hazards, cataloguing resilience strategies drawn from 93 sources across scheduling, capacity management, and stakeholder coordination that underscore why collaboration mechanisms must be robust enough to withstand external shocks.

One of the few empirical efforts on the rail freight side is the work of Muni et al. [34], who surveyed 209 shippers, freight forwarders, and clearing agents in Bangladesh and built a six-dimensional service quality instrument; tangibility and transport cost emerged as the strongest predictors of customer satisfaction, with transit time and reliability close behind. Barriers to rail collaboration have received comparable scholarly attention. Kumar et al. [35] ranked ten barriers in the Indian rail supply chain through M-TISM and fuzzy MICMAC, placing lack of policy support for strategic contracting and absence of IT-trained field personnel at the apex of the hierarchy. Governance arrangements are equally important. Prokić and Bošković [36] treated railway corridor governance as a cooperative game and showed that equitable benefit-sharing between infrastructure managers and train operators is the key to sustained corridor-level coordination. At the project level, Basra et al. [37] examined joint ventures in rail infrastructure and identified stakeholder alignment and transparent risk allocation as the two most critical success factors. Trust, transparent governance, and a shared understanding of costs and benefits emerge as pre-conditions for freight collaboration across these studies; however, they remain insufficiently examined in the rail freight domain [21].

The principal causes of underperformance (outdated signalling, scarce waggon availability, high freight charges, opaque subsidy mechanisms, and a thin pool of trained personnel) are tightly interlocked, such that tackling any one in isolation seldom produces lasting gains. Figure 1 maps these stakeholder relationships and the overall service flow.

Table 1 summarises the documented causes of underperformance in rail freight system. Coordination failures, infrastructure bottlenecks, cost barriers, and workforce shortages collectively contribute to the observed stagnation, underscoring the need for a structured analytical approach. Pham et al. [38] interviewed logistics managers in Ho Chi Minh City and Hanoi and found that information asymmetry between shippers and forwarders, rather than technology limitations, constituted the primary barrier to freight coordination in Vietnam's freight sector. Heinbach et al. [39] designed a shared freight intelligence platform on mobile telematics in a German corridor and showed that real-time data exchange reduced empty-run rates and coordination delays among participating carriers. Lee and Joo [40] surveyed 207 Korean manufacturing firms and ranked top management commitment as the single strongest predictor of collaborative green supply-chain performance, above information sharing and resource commitment.

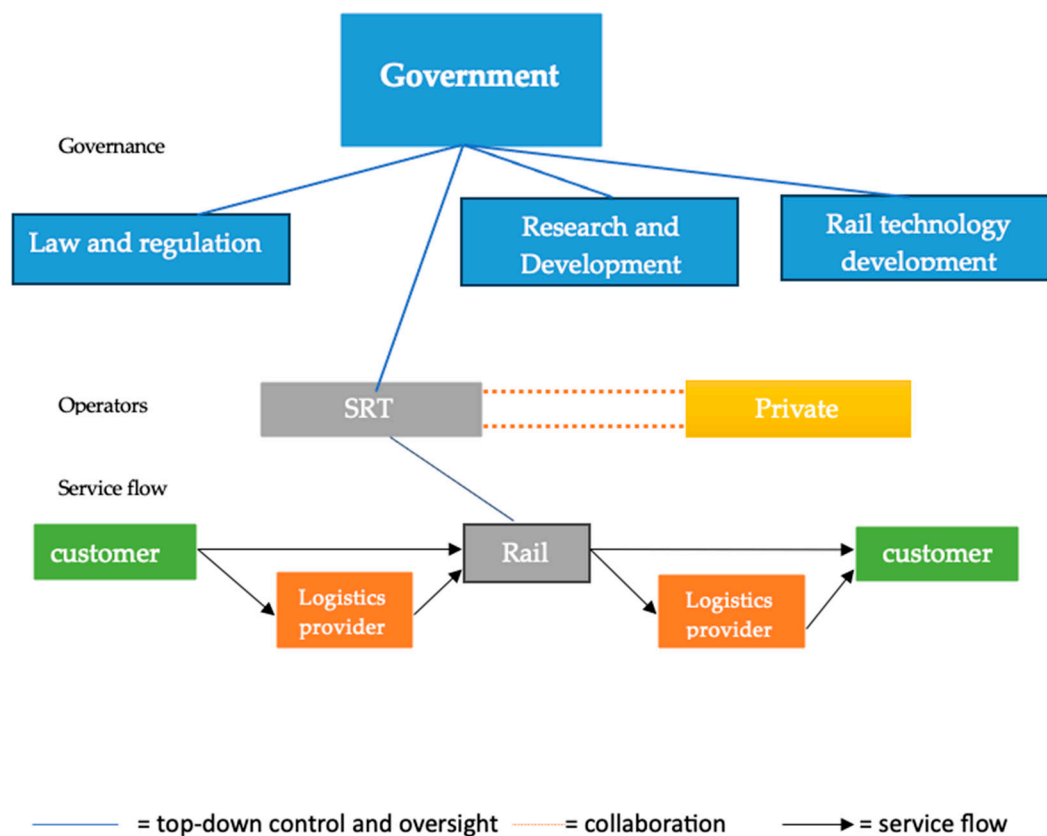


Figure 1. Stakeholder relationships and service flow in Thailand's rail freight system.

Table 1. Documented causes of underperformance in rail freight system.

Cause	References
Lack of coordination among stakeholders	[5,6,13,14]
Old signalling system and technology	[1,2]
High cost of rail transport	[6,21,24]
Shortage of skilled labour	[27,28,41]
Lack of connectivity	[5,21,42,43]
Poor rail infrastructure	[6,14]
Shortage of logistics equipment	[7,26]
Lack of information sharing	[8,15,16]
Unclear government process	[13,32,44]

However, none of these studies systematically examined the collaboration factors that are most consequential in developing-country rail freight, where institutional frameworks remain nascent and infrastructure deficits far exceed those found in liberalised European markets, which dominate the existing literature.

2.2. Factors for Building Stakeholder Collaboration

Drawing on five foundational studies of inter-organisational cooperation, we identified 20 sub-factors that contribute to effective inter-organisational cooperation across supply-chain contexts, including commitment, trust, willingness, information sharing, IT systems, joint decision-making, and government support [9,45–48].

We organised these sub-factors into seven groups. Relationship-level factors cover trust, commitment, and personal relationships. Information communication technology encompasses information sharing, IT systems, and data quality. Joint activities include

joint planning, decision-making, and performance measurement. Resource and investment capture resource sharing, joint investment, and cost alignment. Organisational culture addresses cultural diversity and top management support. Service performance spans quality, reliability, and punctuality. External factors include government support, competitive environment, and customer focus. Table 2 presents the full classification with supporting citations.

Table 2. Classification of collaboration factors from the literature.

Factor Group	Sub-Factors	Key References
1. Relationship Level	Trust, Commitment, Personal relationships	[7,8,27–29]
2. Information Communication Technology	Information sharing, IT systems, Data quality	[16,38,39]
3. Joint Activities	Joint planning, Decision-making, Performance measurement	[15,20,48]
4. Resource and Investment	Resource sharing, Joint investment, Cost alignment	[23,24,26,49,50]
5. Organisational Culture	Cultural diversity, Top management support	[40,45,51,52]
6. Service Performance	Quality, Reliability, Punctuality	[34,46,47]
7. External Factors	Government support, Competitive environment, Customer focus	[21–23,32,44,50]

Manufacturing and retail supply chains have been extensively validated across various sub-factors. However, the unique institutional architecture of state-owned rail freight systems, characterised by government ownership, public monopoly, and legacy passenger-focused regulatory frameworks, remains under-researched. Grounding the present study in the broader digital transformation literature, Gupta and Jamwal [17] identified regulatory gaps, institutional readiness, and high capital investment requirements as primary constraints, with workforce adaptation emerging as a significant barrier. These findings align with the high dependence score of the dependent classification of Human Resource Capacity observed in our MICMAC analysis, confirming that digital integration in state-monopoly freight contexts is contingent upon securing upstream institutional and financial conditions. While the current study delineates the structural hierarchy of these factors, integrating quantitative models to address operational uncertainty, as explored by Varshney et al. [53], represents a crucial next step in logistics management research. Such an approach could provide a more flexible and agile decision-making framework for future rail freight operations in developing countries.

Hofstede's [51] comparative study across 76 countries showed that power distance, uncertainty avoidance, and individualism shape how organisations coordinate, and Kull et al. [52], testing lean practices in 24 nations, corroborated that cultural dimensions moderate whether lean translates into performance gains. Kasrim et al. [32], synthesising 85 publications on ASEAN supply chains, found that government–private sector coordination is fundamental to sustainable logistics but difficult to formalise in countries with fragmented regulations and technological disparities among stakeholders.

2.3. MICMAC Analysis in Transport and Logistics Research

MICMAC (Matrice d'Impacts Croisés Multiplication Appliquée à un Classement) originated in the French school of la prospective and is designed to identify and classify the interrelationships among variables within complex systems [54,55]. Analysts construct a cross-impact matrix recording the direct influence each variable exerts on every other variable, and then sort variables into four quadrants along two axes, namely, driving power (the row sum of influence exerted) and dependence (the column sum of influence received).

Four quadrants emerge. Autonomous variables (Quadrant I) register low driving power and low dependence and sit largely outside the system. Dependent variables (Quadrant II) respond to other factors but exert little influence themselves. Linkage variables (Quadrant III) score high on both dimensions, making them both influential and vulnerable. Driving variables (Quadrant IV) propagate influence through the system while remaining relatively insensitive to feedback.

MICMAC is commonly employed in conjunction with interpretive structural modelling (ISM) in transport and logistics research. Vishwakarma et al. [18] used ISM–MICMAC across 12 barriers identified from Indian apparel and textile firms, classifying regulatory and institutional factors in the driving quadrant. Ghatak [56] identified 13 barriers to omni-channel logistics integration through ISM–fuzzy MICMAC and placed poor IT infrastructure and a weak top management vision in the driving quadrant. Hasan et al. [42] modelled total logistics cost for intermodal freight diversion and showed that terminal handling charges and transit-time penalties, not line-haul rates alone, deter shippers from switching modes. Gohari et al. [43], working with stated-preference data on intermodal freight in Iran, found that cost, transit time, and reliability are the three variables that shippers weight most heavily when choosing a mode. More recently, Yang et al. [57] turned the same toolkit on cross-regional railway infrastructure interconnection in China and again found policy coordination and institutional capacity in the driving quadrant, well above the technical and financial variables. Jain et al. [58] built a logistics-for-growth framework in the Omani context using fuzzy ISM–MICMAC and ranked efficient port operations and quality control as the highest-priority indicators for national competitiveness. Dhulipala and Patil surveyed shippers and freight forwarders in India's dedicated freight corridors and confirmed that institutional readiness and supportive policy sit in the driving quadrant, echoing the pattern in every other MICMAC application reviewed here [19]. Across all these studies, policy and institutional variables consistently occupy the driving quadrant, regardless of the freight context examined [43].

Gupta and Gupta [59], applying grey Delphi–DEMATEL to freight logistics barriers in India through a ten-expert panel, demonstrate that this approach effectively establishes causal relationships among system variables, producing actionable guidance on stakeholder collaboration and logistics investment priorities.

To date, no published study has applied MICMAC to collaboration factors specific to rail freight services. We address this gap by using the technique to classify the six factors that emerged from our thematic analysis and to reveal the structural dynamics, particularly the driving role of government policy, which should inform how collaboration strategies are sequenced and prioritised.

3. Methodology

3.1. Research Design

We opted for a sequential qualitative design that paired thematic analysis with MICMAC structural analysis. The rationale was straightforward. Thematic analysis allows patterns to emerge inductively from expert narratives, whereas MICMAC adds the structural rigour needed to quantify and classify these interactions. Figure 2 illustrates the research framework, which proceeded in three phases. We began by identifying collaboration factors from the existing literature, then explored and confirmed those factors through expert interviews analysed via thematic analysis, and finally subjected the confirmed factors to structural analysis using a cross-impact matrix and MICMAC classification.

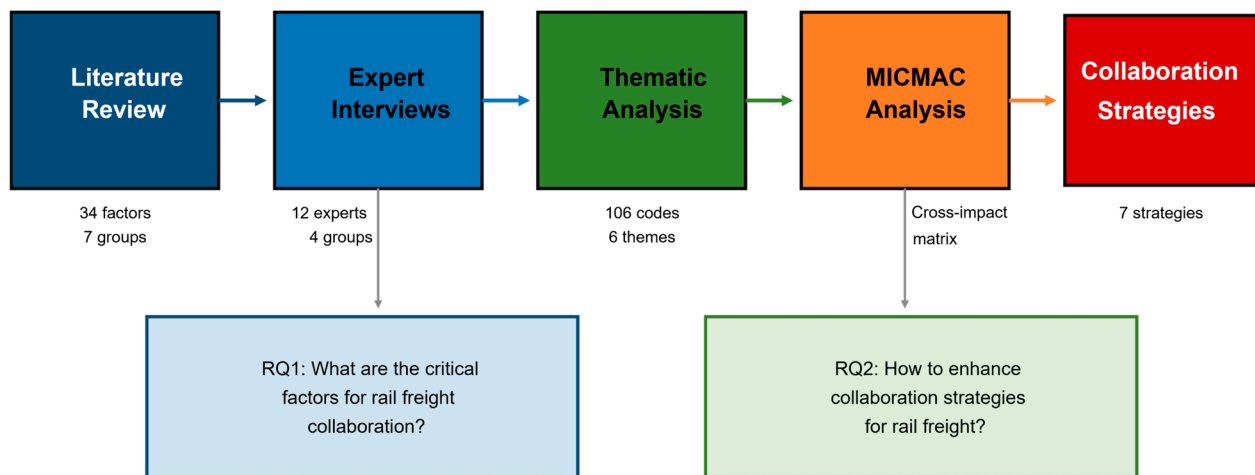


Figure 2. Research framework combining thematic analysis and MICMAC structural analysis.

Thematic analysis excels at allowing patterns to emerge inductively from expert narratives, whereas MICMAC adds structural rigour by quantifying and classifying the interrelationships among those factors and tells us how they interact and which ones should be tackled first. Together, the two methods address both RQ1 (what factors?) and RQ2 (what strategies, and in what order?).

3.2. Semi-Structured Interviews

We conducted semi-structured interviews with experts from the four principal stakeholder groups in Thailand's rail freight sector, namely, the State Railway of Thailand (SRT), freight customers, logistics service providers, and government agencies involved in transport regulation and policy.

We selected participants by purposive sampling to ensure coverage across all four groups. Each participant held a middle or senior management position and had accumulated at least ten years of experience in rail freight or related logistics operations. Twelve experts took part, a number that meets the threshold for data saturation in qualitative interview studies [41,60]. Table 3 profiles the participants.

The purposive composition of the freight customer group warrants clarification. All three freight customers (E2, E4, E8) represent industrial shippers: petrochemical, manufacturing, and third-party logistics, respectively. Agricultural shippers, though an important potential future user segment for Thai rail freight, were not represented because SRT's existing freight traffic is heavily concentrated in industrial commodities, and agricultural customers with meaningful rail freight experience were not available within the sampling frame at the time of data collection. We acknowledge this as a coverage limitation and discuss its implications in Section 5.4. Regarding data saturation, Guest et al. [41] established an empirical benchmark for variable saturation in structured interviews; however, the saturation criterion relevant to qualitative thematic analysis is thematic saturation, as defined by Braun and Clarke [60], which concerns the stability of themes rather than the exhaustion of individual codes. Our six final themes remained stable across the final three interviews, with no new themes emerging beyond E9, which we interpret as evidence of thematic saturation consistent with a sample of this depth and purposive design.

Table 3. Participant profiles.

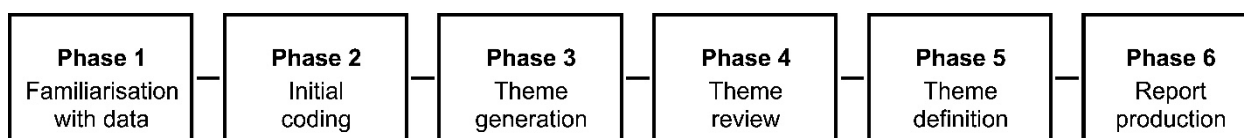
Code	Stakeholder Group	Focus	Management Level	Experience (Years)
E1	Government Agency	Rail technology development	Top	15
E2	Freight Customer	Reuse paper Transport	Top	11
E3	State Railway of Thailand	SRT Regional Operations	Middle	10
E4	Freight Customer	Transport Cement and Construction Materials	Top	27
E5	Government Agency	Law and regulation	Middle	13
E6	Logistics Provider	Cold chain logistics	Middle	13
E7	Logistics Provider	Container export	Middle	15
E8	Freight Customer	Transport Chemical Products and Hazardous Materials	Top	17
E9	Government Agency	Research and Development	Middle	13
E10	Logistics Provider	Bulk product	Middle	10
E11	State Railway of Thailand	SRT Marketing and Development Division	Middle	15
E12	State Railway of Thailand	SRT Train Operations	Middle	16

Each session ran between one and two hours and was face-to-face. We used an open-ended interview guide organised around four thematic areas. The guide covered factors related to creating railway transport cooperation and their necessity and urgency, current rail freight work processes and data sharing among stakeholders, problems and obstacles in building cooperation and data sharing, and recommendations for improving rail freight efficiency for sustainable transport. With participants' consent, all sessions were audio-recorded and transcribed verbatim, and we anonymised respondents as E1 through E12.

This study was approved by the Mahidol University Central Institutional Review Board (approval number: MU-CIRB.2024/503.0212). All participants provided informed consent and were informed of their right to withdraw at any time.

3.3. Thematic Analysis

We analysed the transcripts using a six-phase framework [61], illustrated in Figure 3.

**Figure 3.** Six-phase framework for conducting thematic analysis.

In Phase 1 (Familiarisation), the research team read and re-read all twelve transcripts to build an intimate understanding of the data, noting preliminary observations and recurring concepts. Phase 2 (Initial coding) involved the systematic coding of statements relevant to collaboration factors and strategies; 106 initial codes were generated. During Phase 3 (Theme generation), codes were collated into candidate themes based on shared patterns and conceptual coherence. In Phase 4 (Theme review), candidate themes were checked against the coded extracts and the full dataset for internal coherence and clear inter-theme distinction. In Phase 5 (Theme definition), each theme was refined, named,

and defined. Finally, in Phase 6 (Report production), the final themes were integrated into the research narrative and supported by direct participant quotations.

We ensured rigour and trustworthiness through several measures [62]. Two team members coded the transcripts independently, and we resolved discrepancies through iterative deliberation until consensus was reached. Triangulation across the four stakeholder groups further strengthened validity.

3.4. MICMAC Analysis

Once the thematic analysis had confirmed the six factors, we subjected them to MICMAC analysis [54,55]. The method proceeds in four steps.

Step 1: Construction of the cross-impact matrix. We constructed a 6×6 matrix in which cell (i, j) captures the degree to which factor i influences factor j. We derived influence values by systematically coding expert statements that described relational linkages between factors. Each expert independently rated every cell (i, j) using a four-point ordinal scale, 0 = no influence, 1 = weak influence, 2 = moderate influence, 3 = strong influence, and 4 = very strong influence, consistent with the scale commonly employed in ISM–MICMAC applications [18,19]. Where an expert did not provide an explicit rating, a score of 0 was assigned. The final cell values were obtained by summing scores across all twelve expert responses, yielding a maximum possible cell value of 48 (12 experts $\times$ 4). This additive aggregation treats each expert's judgement as equally weighted, consistent with established MICMAC protocols for purposively sampled panels with comparable domain experience [54,55].

Three procedures were implemented to mitigate cognitive bias. Each expert scored the matrix independently, without access to other participants' ratings, to prevent anchoring and social conformity effects. Before scoring, all twelve experts received a structured scoring guide with worked examples for each point of the 0–4 scale, anchored to concrete Thai rail freight scenarios, to ensure consistent scale interpretation. Following aggregation, we calculated the mean absolute deviation (MAD) of individual scores from the group mean for each off-diagonal cell; the average MAD across all 30 cells was 0.61, indicating acceptable inter-expert consensus. Four cells with MAD exceeding 1.0 were discussed with a separate panel of three domain experts during member-checking sessions, who confirmed the final values. The full relational coding evidence supporting each cell is provided as Supplementary Materials.

Step 2: Calculation of driving power and dependence. For each factor, driving power is simply the row sum (total influence exerted on other factors), and dependence is the column sum (total influence received).

Step 3: Quadrant classification. We plotted the factors on a driving-power-versus-dependence plane using mean values of driving power and dependence as threshold lines to divide the plane into four MICMAC quadrants. The resulting classification plot is presented in the Results Section.

Step 4: Interpretation. The quadrant assignments guided the prioritisation of collaboration strategies. Driving factors, those that propagate influence throughout the system while remaining relatively insensitive to feedback from other factors, became the highest-priority intervention targets. This analysis employs first-order (direct influence) MICMAC without applying the iterative indirect matrix multiplication steps of the full Godet procedure. This choice is deliberate: with only six variables, first-order driving power and dependence scores already capture the dominant structural relationships, and the additional variance introduced by higher-order multiplication in small matrices is unlikely to alter quadrant assignments. This approach is consistent with prior applications of MICMAC to small variable sets in transport contexts [58] and is acknowledged explicitly as a boundary condition in Section 5.4.

4. Findings

4.1. Thematic Analysis: Collaboration Factors

Of the 106 initial codes, six overarching themes emerged, each representing a critical collaboration factor. Table 4 presents examples of the coding process and theme development.

Table 4. Examples of the coding process from initial codes to themes.

Representative Keywords/Phrases	Initial Codes	Final Theme
Government policy, policy support, laws, regulations, government initiatives, structural reforms	Government support; Regulatory framework; Policy coordination; Legislative clarity	Government Policy (GP)
Cost, transport cost, expensive, high cost, pricing structure, budget allocation, competitiveness	Cost competitiveness; Financial viability; Pricing reform; Budget allocation	Finance (FI)
Capacity, rail system, track issues, network connectivity, dual-track, station facilities, locomotives	Infrastructure adequacy; Network development; Capacity expansion; Equipment readiness	Infrastructure Readiness (IN)
Digital technology, automation, GPS, freight management software, real-time tracking, IoT, AI	Technology adoption; Innovation capacity; Digital integration; Automation systems	Technology and Innovation (TE)
Platform sharing, data sharing, central database, IT system, information exchange, tracking systems	Information sharing; Digital integration; Data connectivity; Central platform	Information Sharing (IS)
Employees, personnel resources, skilled personnel, training, workforce development, competency	Human resources; Training and development; Workforce capacity; Skill gaps	Human Resource Capacity (HR)

Technology Integration, Multimodal Operations, and Human Resources Development were each raised by four or more experts and are described in Section 5.3 in relation to their MICMAC-derived priority sequencing.

Government Policy (GP). Government policy has surfaced consistently as the foundational element for collaboration. Keywords such as “policy,” “policy support,” “laws,” and “regulations” appeared across interviews with government agency representatives and SRT officials (E1, E2, E4, E5, E6, E7, E9, E12), generating subcodes of “government support” and “regulatory framework.” Expert 1 stated that “domestic collaboration should be primarily driven by government initiative the state is responsible for managing, overseeing, and integrating the operation and services of all components of the rail transport system.” Expert 5 provided concrete details describing the Draft Rail Transport Act currently before the House of Representatives and the 34 rail transport standards under development. Expert 4 highlighted the need for policy support in trialling electric locomotives, whereas Expert 12 stressed that “coordination between agencies of government, private sector, and local organisations must be clear, with information sharing to reduce operational obstacles.”

Finance (FI). Financial considerations featured prominently in statements by logistics providers and freight customers (E2, E4, E6, E8, E10, and E12). “Cost,” “transport cost,” “expensive,” and “high cost” recurred frequently, coded into “cost competitiveness” and “financial viability.” Expert 4 described a persistent pricing problem whereby current freight charges bundle fees and fuel costs; therefore, even when fuel costs fall with battery-powered locomotives, charges remain unchanged, eroding competitiveness against road transport. Expert 10 pointed to one-way pricing in road transport as a structural advantage over rail, which charges both outbound and return trips. Expert 12 emphasised

that “appropriate budget and resource allocation is an important factor in pushing projects to achieve goals successfully.”

Infrastructure Readiness (IN). SRT, logistics provider, and freight customer experts (E1, E3, E4, E5, E6, E8, E10, E11, E12) flagged infrastructure limitations “capacity,” “rail system,” “track issues,” and “network connectivity” which were coded into “infrastructure adequacy” and “network development.” Expert 10 offered detailed examples, noting that the Bua Yai–Map Ta Phut route requires locomotive switching at steep gradients because of the terrain, and if the new Tha Kradon–Map Ta Phut railway line was completed, it would solve problems with both gradient and double-track capacity. Expert 12 identified that “railways, freight transfer centres, and logistics support systems must be developed to standards that facilitate service provision.”

Technology and Innovation (TE). Experts from multiple stakeholder groups (E3, E4, E6, E7, E8, E9) raised digital technology requirements through references to “digital technology,” “automation systems,” “GPS,” “freight management software,” and “real-time tracking,” coded as “technology adoption” and “innovation capacity.” Expert 3 detailed the necessity of adopting GPS, transportation tracking systems, and automated cargo systems to improve speed and accuracy. Expert 10 recommended pragmatic approaches: “use appropriate, effective, and cost-efficient technology communication via LINE application is sufficient for transport status tracking.” Expert 9 listed advanced technology, adaptation, and joint knowledge as critical factors in the rail sector.

Information Sharing (IS). Experts 1, 5, 6, 7, 8, 9, 11, and 12 emphasised the need for centralised data systems and inter-stakeholder information exchange “platform sharing,” “data sharing,” “central database,” “IT system” coded as “information sharing” and “digital integration.” Expert 11 described an ongoing project to develop “a central data system to support data aggregation, communication, and real-time information exchange” encompassing freight station information, train schedules, container status, and other logistics data. Expert 7 stressed that information sharing among stakeholders at Laem Chabang Port was critical for coordinating container transfers. Expert 11 further emphasised that “Data is a vital resource in this era of rapid change, and siloed operations no longer meet user needs.”

Human resource capacity (HR). Experts 2, 3, 6, and 12 identified workforce skills and development through references to “employees,” “personnel resources,” “skilled personnel,” and “training,” yielding codes for “human resources” and “training and development.” Expert 2 named human resources as one of the three critical cooperation factors alongside government policy and cost. Expert 3 pointed to a shortage of skilled personnel in rail transport technology and the urgent need to develop highly competent professionals for engineering and railway systems. Expert 12 noted that “internal organisational personnel are still not fully performing their duties from working in various departments to their full capacity.”

Table 5 compares the literature-derived factors with those confirmed through the interviews. Three literature categories (relationship level, organisational culture, and service performance) did not feature prominently in expert statements. This absence is revealing because the dimensions that matter in manufacturing and retail supply chains may be less salient in the institutional context of a publicly operated rail freight system. Three theoretical mechanisms explain this suppression. First, relationship-level constructs such as trust and personal commitment presuppose that collaboration partners have discretion over whether and with whom to cooperate. In Thailand’s rail freight system, the SRT is the sole infrastructure owner and operator; freight customers and logistics providers have no alternative rail partner with whom to build or withhold trust, rendering inter-firm trust a less decisive variable than in competitive markets. Second, organisational culture theory assumes variation across partners. Because the SRT is a state-owned entity

operating under civil service norms, cultural diversity across the dyad is structurally constrained, limiting the salience of Hofstedeian dimensions that drive variation in private sector collaboration outcomes [51,52]. Third, service performance dimensions (quality, reliability, and punctuality) are outcomes of the collaboration system rather than antecedents; they reflect the state of the other factors rather than independently driving collaboration decisions. These distinctions align with Paddeu et al.'s observation that freight collaboration in the public domain involves dimensions absent from private sector models [21]. Government Policy and Finance, by contrast, emerged as factors with no clear equivalent in the traditional collaboration literature, reflecting the sector's dependence on public investment and regulatory frameworks. The confirmed factors are shown in Figure 4.

Table 5. Comparison of literature-derived and interview-confirmed collaboration factors.

Literature Category	Sub-Factors	Interview Status	Notes
1. Relationship Level	Trust, Commitment, Personal relationships	Not confirmed	Not salient in publicly operated rail freight context
2. ICT	Information sharing, IT systems, Data quality	Confirmed as IS	Emphasised by 8 experts (E1, E5, E6, E7, E8, E9, E11, E12)
3. Joint Activities	Joint planning, Decision-making, Performance measurement	Absorbed into GP, IS	Coordination mechanisms subsumed under policy and information sharing
4. Resource and Investment	Resource sharing, Joint investment, Cost alignment	Confirmed as FI, IN	Split into Finance and Infrastructure Readiness
5. Organisational Culture	Cultural diversity, Top management support	Not confirmed	Institutional monopoly context differs from manufacturing/retail
6. Service Performance	Quality, Reliability, Punctuality	Not confirmed	Cited as outcomes, not as collaboration factors
7. External Factors	Government support, Competitive environment, Customer focus	Confirmed as GP	Emerged as dominant driving factor; broadened from literature definition
New factor	Digital technology, automation, IoT, AI	New: TE	Technology and Innovation emerged as distinct factor from 6 experts
New factor	Workforce skills, training, personnel development	New: HR	Human Resource Capacity emerged independently from organisational culture

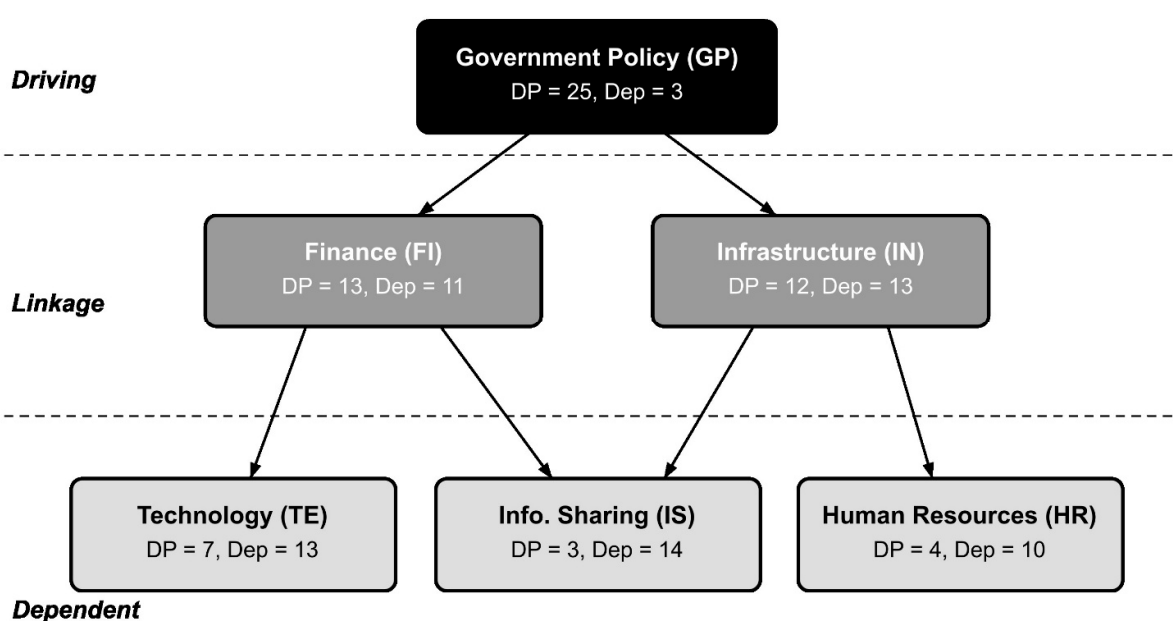


Figure 4. Factors of collaboration identified through thematic analysis.

Figure 5 presents a factor–expert matrix showing which experts contributed to each factor, providing a visual summary of the interview evidence base for each theme.

	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	n
GP	✓	✓		✓	✓	✓	✓		✓			✓	8
FI		✓		✓		✓		✓		✓		✓	6
IN	✓		✓	✓	✓	✓		✓		✓	✓	✓	9
TE			✓	✓		✓	✓	✓	✓				6
IS	✓				✓	✓	✓	✓	✓		✓	✓	8
HR		✓	✓			✓						✓	4

Figure 5. Factor–expert contribution matrix.

4.2. Thematic Analysis: Collaboration Strategies

Seven strategies for enhancing collaboration were identified, along with collaboration factors. Table 6 shows the coding process.

Table 6. Strategy coding: representative keywords, initial codes, and final strategies.

Representative Keywords/Phrases	Initial Codes	Final Strategy
Coherent policy frameworks, coordination mechanisms, strategic direction, Rail Transport Act, dedicated agency	Policy framework; Institutional coordination; Legislative reform	Policy Collaboration
Modal-shift incentives, tax benefits, reduced charges, transport cost subsidies, pricing reform, volume discounts	Cost incentives; Financial instruments; Pricing competitiveness	Economic Instruments
Dual-track conversion, network development, connectivity, station expansion, locomotive procurement	Infrastructure expansion; Network capacity; Equipment modernisation	Infrastructure Investment
Centralised data systems, real-time platforms, cargo tracking, IoT, digital booking, TMS	Digital platforms; Real-time connectivity; Automated systems	Digital Technology Integration
Door-to-door service, intermodal connectivity, terminal coordination, piggyback transport, rail–road–port	Multimodal integration; Seamless connectivity; Intermodal transfer	Multimodal Operations
Upskilling, reskilling, technical competencies, training programmes, education–industry collaboration	Workforce development; Professional training; Skill building	Human Resource Development
Carbon credits, GHG reduction, energy performance, green logistics, ESG alignment, electric locomotives	Environmental sustainability; Carbon reduction; Green technology	Sustainability Development

Policy Collaboration, Economic Instruments, Infrastructure Investment, Digital Technology Integration, Multimodal Operations, and Human Resources Development were each raised by four or more experts and are described in Section 5.3 in relation to their MICMAC derived priority sequencing.

Policy Collaboration. Government agency and SRT experts (E1, E5, E6, E8, E11, E12) called for coherent policy frameworks that promote rail as a preferred freight mode, establish coordination mechanisms, and signal a clear strategic direction to all sectors. Expert 1 stressed that this is a timely opportunity to formulate policies to drive the efficient

development of rail systems. Expert 5 detailed the Draft Rail Transport Act, which would enable the private sector to participate in train operations and promote a modal shift from road. Expert 12 recommended establishing clear cooperation mechanisms, such as joint working committees or logistics coordination centres.

Economic Instruments. Financial measures, including modal-shift incentives, tax benefits, reduced usage charges, and transport cost subsidies, were identified as essential for cost competitiveness (E2, E4, E5, E7, E10, E12). Expert 10 proposed government discounts or volume incentives for high-volume users and support for private sector investment in locomotives. Expert 12 recommended providing tax benefits, supporting partial transport costs, and creating public-relations campaigns to encourage rail use.

Infrastructure Investment. Dual-track conversion, network development, connectivity improvements, and higher train speeds were seen as foundational to better service (E1, E3, E4, E5, E6, E8, E10, E11, and E12). Expert 10 specifically identified the Tha Kradon–Map Ta Phut line and the need to expand freight transfer stations to suitable locations. Expert 1 emphasised dual-track railway construction across all regions as the key long-term solution.

Digital technology integration. Centralised data systems, real-time connectivity platforms, and information exchange mechanisms were considered critical for stakeholder coordination (E3, E4, E5, E7, E8, E10, E11, E12). Expert 11 described the ongoing development of a central data system for real-time information exchange. Expert 10 recommended practical solutions, such as communication via the LINE application and developing cargo tracking through IoT and AI.

Multimodal Operations. Experts 5, 7, 8, 10, and 11 emphasised seamless door-to-door services, encompassing intermodal connectivity, coordinated terminal operations, and end-to-end tracking. Expert 10 proposed piggyback transport systems that load trucks onto trains and develop rails alongside roads to create efficient comprehensive transport systems. Expert 5 described the national seamless multimodal transport project, including its connection to industrial estates.

Human Resources Development. Upskilling and reskilling of the rail workforce, encompassing technical and non-technical competencies, were deemed necessary for modernisation (E3, E7, E9, E12). Expert 3 identified the urgent need to develop highly competent professionals for engineering and railway systems. Experts 12 called for promoting personnel development through logistics knowledge training and new technology. Expert 9 recommended that the education, research, and industry sectors should collaborate to define the supply chain direction.

Sustainability Development. Experts 4, 6, and 10 mentioned environmental initiatives, including carbon credit schemes, greenhouse gas reduction targets, energy performance improvements, and green logistics practices. Expert 10 highlighted that many customers have carbon credit policies and are ready to invest in rail services if supported by the government. Expert 4 is actively developing battery-powered locomotives to replace diesels, with the potential for a national electric rail rollout aligned with ESG goals.

While many countries have integrated ESG criteria into their transport strategies, Thailand's rail freight sector remains in its infancy, where operational efficiency continues to be the primary strategic priority. This aligns with Liu and Jia [4], who utilised evolutionary game theory to model freight transport behaviour in China, demonstrating that government subsidies are a crucial mechanism for incentivizing environmental compliance among transporters. In this context, this study suggests that for rail freight systems in developing countries, sustainability-focused strategies may not be effectively implemented without robust financial and policy frameworks. Therefore, the identification of such tools within the 'driver' quadrant of the MICMAC analysis highlights that Thailand's transition to ESG in rail freight requires more than just environmental aspirations; it

necessitates concrete incentive mechanisms to render sustainability practices practically feasible.

Figure 6 illustrates the linkages between the factors and strategies. A separate panel of three experts endorsed the coherence of the factor–strategy framework. Values represent the influence level (0–8) determined by expert consensus. Shading intensity corresponds to the influence magnitude, with darker cells indicating higher influence.

	GP	FI	IN	TE	IS	HR
GP	—	6	8	5	5	1
FI	1	—	3	4	2	3
IN	1	2	—	4	2	3
TE	0	1	0	—	4	2
IS	1	1	0	0	—	1
HR	0	1	2	0	1	—

Figure 6. Cross-impact linkages between collaboration factors and strategies.

4.3. MICMAC Analysis Results

Table 7 presents the cross-impact matrix. Each cell value represents the cumulative influence strength of the row factor on the column factor, aggregated from the relational statements of 12 experts. Table 8 summarises the driving power and dependence scores.

Table 7. Cross-impact matrix of collaboration factors (aggregated influence scores).

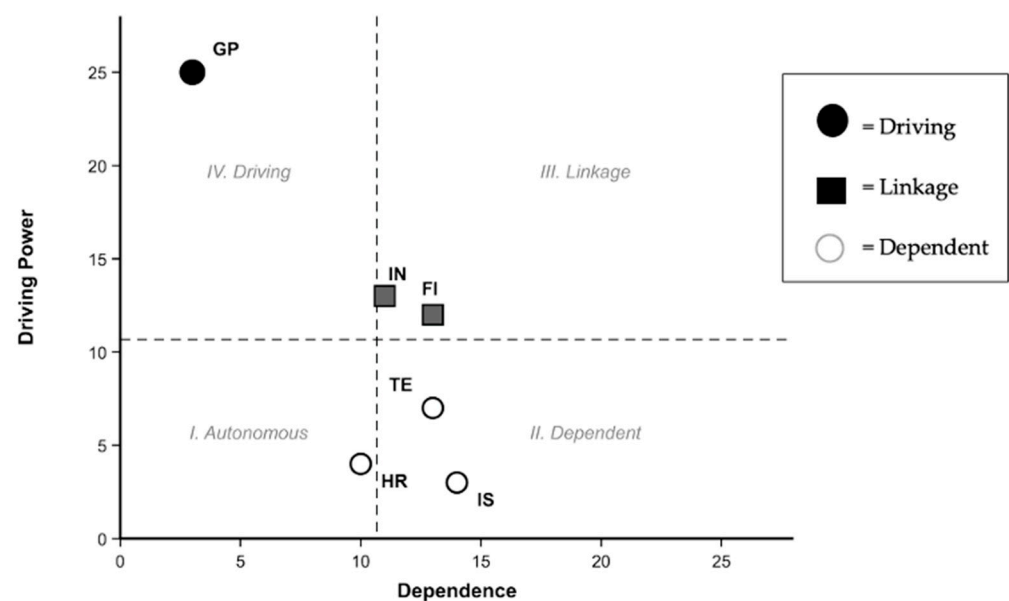
Factor	GP	FI	IN	TE	IS	HR	Driving Power
Government Policy (GP)	-	6	8	5	5	1	25
Finance (FI)	1	-	3	4	2	3	13
Infrastructure Readiness (IN)	1	2	-	4	2	3	12
Technology and Innovation (TE)	0	1	0	-	4	2	7
Information Sharing (IS)	1	1	0	0	-	1	3
Human Resource Capacity (HR)	0	1	2	0	1	-	4
Dependence	3	11	13	13	14	10	64

Note: Cell values represent aggregated influence scores derived from systematic coding of expert interview statements. Row sums represent driving power, and column sums represent dependence.

Table 8. Driving power and dependence scores with MICMAC quadrant classification.

Factor	Abbreviation	Driving Power	Dependence	Classification
Government Policy	GP	25	3	Driving
Finance	FI	13	11	Linkage
Infrastructure Readiness	IN	12	13	Linkage
Technology & Innovation	TE	7	13	Dependent
Information Sharing	IS	3	14	Dependent
Human Resource Capacity	HR	4	10	Dependent

The MICMAC quadrant classification (Figure 7) revealed these structural roles.

**Figure 7.** MICMAC quadrant classification of collaboration factors.

Driving factor: Government policy. GP recorded the highest driving power (25) and the lowest dependence (3), with the widest gap of any factor. GP is firmly in the driving quadrant. In concrete terms, government policy shapes every other element of the collaboration system while remaining largely unaffected by them. Clearer regulations, dedicated collaboration frameworks, and credible investment commitments would propagate benefits across all five remaining factors.

Linkage factors: Finance and infrastructure readiness. FI (13, 11) and IN (12, 13) both exceeded the mean thresholds for driving power and dependence, placing them in the linkage quadrant. These factors transmit the effects of government policies to the operational level. Policy decisions shape subsidy availability and the pace of dual-track construction. These changes, in turn, determine whether technology adoption and information sharing become feasible. As linkage factors are both influential and vulnerable, they require sustained attention because a setback in either finance or infrastructure reverberates throughout the system.

Dependent factors: Technology and innovation, human resource capacity, and information sharing. TE (7, 13), HR (4, 10), and IS (3, 14) exhibit low driving power but moderate to high dependence. They are outcomes rather than originators of system change, improving when policy creates the right environment, financial resources flow, and infrastructure is in place. Information sharing, which has the highest dependence on all six factors (14), is especially sensitive to the state of the rest of the system. Intervening in these areas without first securing driving and linkage conditions would yield limited and fragile

results. Figure 7 illustrates the diagram categorizes factors into four quadrants Autonomous, Dependent, Linkage, and Driving using squares for strategic administrative factors and circles for operational support factors, with the size and position of GP highlighting its role as the primary driving force in the system.

No factor fell into the autonomous quadrant, confirming that all six factors were connected within the collaboration system. Human resource capacity, however, recorded a dependence score of 10, close to the classification threshold, and sat near the dependent/autonomous border. Its position reflects the degree of independence relative to the other dependent factors.

The cross-impact matrix values are presented in Table 7, the factor–strategy linkages are shown in Figure 6, and the factor interaction network is illustrated in Figure 8. The numbers on the arrows represent the influence values (0–8) between factors, derived from expert consensus, while the thickness of the arrows correlates with the strength of these influences

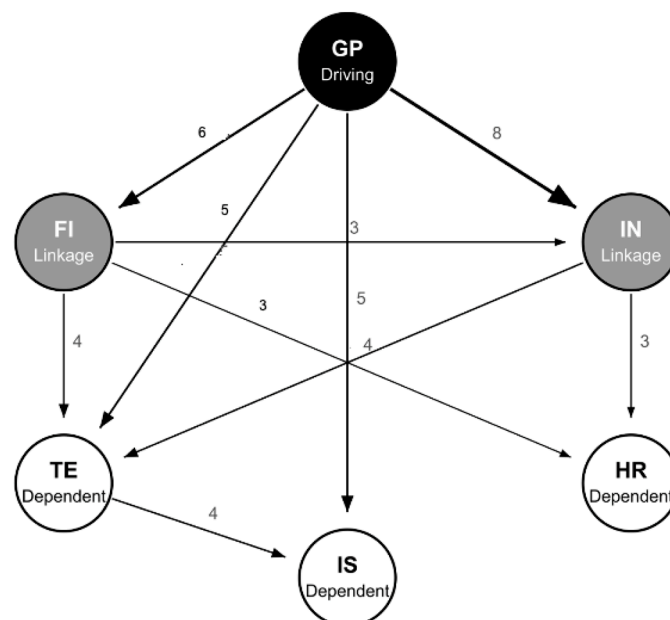


Figure 8. Factor interaction network.

5. Discussion

5.1. Principal Findings

Government policy dominates the MICMAC classification. With a driving power of 25 and a dependence of only 3, it is the only factor in the driving quadrant, and by a wide margin. This asymmetry carries a practical implication that is difficult to overstate, namely that without coherent government policy encompassing legislative frameworks, regulatory clarity, investment commitments, and institutional coordination, efforts to improve collaboration through financial instruments, infrastructure expansion, or technology adoption are structurally unlikely to succeed. Policy is the foundation of the entire system, and weakening it leaves the remaining factors without mutual support.

Finance and infrastructure readiness, classified as linkage factors, occupy positions of both influence and vulnerability. They channel policy intent into operational reality. Government decisions on subsidies (finance) and dual-track construction timelines (infrastructure) determine whether downstream improvements in technology, information sharing, and workforce capacity become feasible. However, because these factors are also sensitive to one another and external shocks, such as fiscal constraints or construction

delays, they demand ongoing management rather than one-off interventions. Mizutani, analysing 536 observations from 29 OECD countries over 1995–2013 with fixed-effects panel data, found that regulatory and policy variables are the primary determinants of rail infrastructure investment, reinforcing the linkage status we observe here [63]. Nakamura and Sakai, examining the Japanese railway system where operators are both privately owned and vertically integrated, found that this structural arrangement facilitates coordination between infrastructure management and train operations, a finding consistent with our classification of infrastructure readiness as a linkage factor [31].

Information Sharing's dependence score of 14, the highest in the system, warrants particular examination in the Thai institutional context. SRT currently operates separate, non-interoperable IT systems for freight management, train scheduling, and billing functions. No standardised data protocol exists between SRT, the Department of Rail Transport (DRT), and private logistics operators, which means that even straightforward cargo status enquiries require manual communication rather than platform-level data access. Expert 6 described the current state as semi-automated processes involving multiple document formats that sometimes lack real-time data connectivity, and Expert 7 confirmed that each organisation's IT systems cannot connect in real time, causing delayed communication or mismatched data. In a state-monopoly supply chain, the structural constraint is more than technical: mandating data sharing between SRT and private operators requires a legislative basis that does not yet exist under the current rail regulatory framework. The Draft Rail Transport Act under consideration (Expert 5) would provide that basis, which explains why IS dependence is so high. Until GP reform creates the legal mandate, and until FI and IN provide the platform infrastructure, IS improvements remain structurally blocked. This pattern is consistent with Gupta and Jamwal's [17] finding that regulatory gaps and institutional readiness are causally upstream of digital adoption constraints in developing economies, a structural parallel to IS's blocked position in the present MICMAC classification.

The clustering of technology, information sharing, and human resource capacity in the dependent quadrant carries a clear message for practitioners. These factors improve as a consequence of a supportive policy and investment environment, not in advance of it. Information sharing's dependence score of 14, the highest in the system, illustrates just how reliant digital coordination is on every other factor being in place. The broader innovation systems literature supports this pattern. Shirkoochi and Mohiuddin, in a PRISMA-guided systematic review of 59 articles on global value chain sustainability published between 2014 and 2024, found that technology diffusion in developing economies depends critically on institutional governance and multi-stakeholder financial commitments, consistent with the dependent status of technology in our MICMAC classification [64].

5.2. Comparison with Existing Literature

The central role we find for government policy echoes recent modal-shift research. Zhang and Zhou [3] showed that policy interventions were the decisive factor in China's "road-to-rail" freight shift. Liu and Jia [4], using evolutionary game theory, demonstrated that government subsidies substantially shape modal-shift behaviour among shippers and railway enterprises. Rosa et al. [10] mapping stakeholders involved in road-to-rail freight modal shift, concluded that government occupies a central coordinating role that private operators cannot substitute [4].

Our six-factor framework extends the study of Paddeu et al. [21], who observed that freight collaboration in the public domain involves dimensions absent from private sector models, including regulation, public investment, and environmental mandates. Our findings align with Buthphorm et al. [6], whose SEM survey of 200 Thai stakeholders explained 98.3% of the variance in rail freight development and ranked government support

and infrastructure as the strongest predictors of modal-shift success. Muni et al. [34], surveying 209 shippers, freight forwarders, and clearing agents in Bangladesh and constructing a six-dimensional service quality instrument, corroborated the importance of service quality dimensions, particularly tangibility and transport cost, that our information-sharing and technology factors partially capture. Lin et al. [12] applying a cloud model–fuzzy Petri net framework to railway safety evaluation, underscored that systematic multi-criteria assessment is essential for infrastructure reliability, a concern echoed by our interviewees, who flagged infrastructure readiness as a precondition for collaboration. Simatupang and Sridharan [15] surveying companies in New Zealand, developed a collaboration index covering information sharing, decision synchronisation, and incentive alignment, and found it positively associated with operational performance. Our six-factor framework extends this by adding government policy and finance as external institutional enablers.

A recognisable pattern runs through recent ISM–MICMAC work. Vishwakarma et al. [18] found regulatory and institutional factors in the driving quadrant when analysing sustainable supply-chain barriers in apparel and textiles, whereas operational and technological factors clustered in the dependent quadrant. Finance and infrastructure occupy the linkage quadrant because they mediate between policy intentions and actual operations [43]. Yang et al. [57], applying a fuzzy DEMATEL–ISM–MICMAC framework to railway infrastructure interconnection, similarly found that policy coordination occupied the driving quadrant, lending cross-national support to our finding that government policy is the most influential variable. Jain et al. [58], working in the Omani logistics-for-growth context with fuzzy ISM–MICMAC, reached a comparable conclusion, ranking governance and regulatory quality as the most influential indicators for national competitiveness.

Why does government policy show such extreme asymmetry here (driving power of 25 against a dependence of just 3) compared with findings in liberalised rail markets? The Thai institutional context provides an answer. In Europe, rail freight reform has proceeded through vertical separation and open-access competition, distributing decision-making authority across multiple actors and reducing reliance on any single institutional driver [35]. An analogous pattern was found in Indian rail freight, where regulatory fragmentation and infrastructure deficits occupied the highest structural positions in their M-TISM hierarchy, confirming that the driving role of institutional factors is not unique to Thailand but extends across South and Southeast Asian rail systems. Prokić and Bošković [36], modelling European railway corridor governance, demonstrated that even in liberalised markets, cooperative mechanisms are needed to align infrastructure managers and operators, a challenge amplified in monopoly settings such as Thailand. Basra et al. [37] identified risk allocation and stakeholder alignment as critical success factors for rail infrastructure joint ventures, a lens through which Thailand might design future public–private partnerships for rail freight expansion. Such institutional concentration amplifies government policy’s driving power far beyond what Nakamura and Sakai observed in Japan’s deregulated, vertically integrated railway market [31]. Thailand’s rail freight system remains a state-operated monopoly under the SRT, where investment approvals, pricing structures, concession terms, and operational mandates all flow from the government. The ongoing dual-track expansion and the proposed Eastern Economic Corridor rail links are government-led mega-projects, and private sector participation hinges entirely on concession legislation that is still before the House of Representatives. In a more liberalised market, policy influence would be distributed across multiple actors, but in Thailand’s monopoly setting, it concentrates into a single driving force. A comparable spatial concentration of freight demand was documented in Turkey [65], and Hasan et al. pinpointed cost-based barriers to intermodal freight diversion that help explain why price-

sensitive shippers in Thailand's agricultural and manufacturing sectors may resist switching to rail unless the cost gap with road haulage narrows [42].

5.3. Implications for Strategy Prioritisation

Our MICMAC results point to a clear sequencing logic for the seven collaboration strategies. Because government policy alone occupies the driving quadrant, policy collaboration should be the first priority, namely, establishing a dedicated rail freight collaboration framework, clarifying the Railway Transport Act, and institutionalising multi-stakeholder coordination mechanisms. Without this foundational work, the legislative and institutional conditions for everything that follows simply do not exist.

We then turn to economic instruments and infrastructure investments. The linkage status of finance and infrastructure means that these strategies amplify policy intentions and enable downstream gains. Without competitive pricing and adequate physical capacity, the benefits of policy reform cannot reach an operational level. Banister and Thurstain-Goodwin [65] proposed a three-level framework for quantifying non-transport benefits of rail investment, identifying macroeconomic output and productivity gains, meso-level agglomeration and labour market effects, and micro-level land and property value uplift as returns extending well beyond the transport sector

Digital technology integration, multimodal operations, and human resources development are best positioned once the enabling conditions are in place. A dependent status does not imply a lack of importance. It means that investment in these areas yields stronger returns when preceded by policy reform and sustained resource allocation. We observed this pattern in Thailand, where digital platforms stalled without regulatory clarity to mandate data sharing, and workforce training programmes could not attract funding until the policy framework signalled long-term commitment to rail. Bigi et al. demonstrated the value of long-term fleet management planning for freight trains [66], whereas Huang and Xing [67] and Fang [68] proposed optimisation strategies for rail–sea intermodal container transport in China. These studies confirm that multimodal and infrastructure strategies produce the greatest returns when the enabling policy and financial conditions are in place.

5.4. Limitations

Several limitations warrant acknowledgement. The sample of twelve experts meets the threshold for qualitative thematic saturation; nevertheless, it inevitably constrains how far the findings can be generalised to other developing-country rail freight systems, particularly those operating under governance structures that differ substantially from Thailand's state-monopoly arrangement. The twelve participants collectively bring 175 years of direct experience in rail freight and logistics, lending the qualitative data a depth that partially compensates for the modest headcount.

Two sampling characteristics require explicit acknowledgement. The freight customer group (E2, E4, E8) comprised industrial shippers exclusively; agricultural customers, who represent an important potential future user segment for Thai rail freight, were not included because the SRT's established freight base is concentrated in industrial commodities and no agricultural shippers with meaningful rail freight experience were available within the sampling frame. Future studies should deliberately oversample agricultural shippers to test whether sustainability and cost factors take on different structural weights in agricultural freight contexts, where road transport cost advantages are less pronounced. Regarding data saturation, the present study applies the criterion of thematic saturation as specified by Braun and Clarke [60] rather than the variable saturation threshold of Guest et al. [41]; the six themes remained stable across the final three interviews,

providing evidence consistent with thematic saturation for a 12-expert purposive panel of this depth.

Because the cross-impact matrix is based on qualitative expert judgements rather than quantitative measurement, a degree of subjectivity is inherent in any MICMAC application. We capture a snapshot of the institutional environment as it currently stands. The ongoing dual-track expansion and the proposed Eastern Economic Corridor rail links will alter factor weights as Thailand's rail infrastructure matures.

The potential migration of factor classifications across MICMAC quadrants as Thailand's rail network develops warrants specific acknowledgement. As the EEC rail links and the China–Thailand rail corridor progress, Technology and Information Sharing may migrate from the dependent to the linkage quadrant: at higher infrastructure maturity, data standardisation and technology adoption become preconditions for multimodal integration rather than outcomes of policy reform. A longitudinal MICMAC re-survey at a later infrastructure maturity stage would capture this structural shift and provide a natural extension of the present study. Such a trajectory would align with the broader pattern documented by Shirkoohi and Mohiuddin [69], who found that technology's structural position in developing-economy supply chains shifts from dependent to driving as institutional governance capacity matures.

Finally, we confined the analysis to direct influences and did not apply indirect influence matrix multiplication, consistent with the first-order direct MICMAC approach described in Section 3.4. A follow-up study that incorporates second- and higher-order effects might reveal longer-range cascading dynamics that this classification misses.

5.5. Policy Implications

Three practical recommendations are offered below. First, Thailand should establish a dedicated rail freight collaboration body, a permanent multi-stakeholder working group comprising the SRT, the Ministry of Transport, logistics industry representatives, and freight customer associations, with clear roles, responsibilities, and accountability. Such a body would operationalise the driving role of government policy by providing continuous coordination and monitoring. Sørensen and Longva evaluated the coordination mechanisms available in public transport and concluded that formalised collaboration structures outperform ad hoc arrangements [13]. Second, infrastructure investments and economic incentives should follow a phased roadmap aligned with policy priorities. For instance, modal-shift subsidies should be tied to measurable service improvements (transit time, reliability, and on-time delivery) rather than volume targets alone. Linking incentives to outcomes prevents misallocation and signals policy commitment to all stakeholders. Third, digital platforms, information-sharing protocols, and workforce training should be designed as components of the overarching collaboration framework and not as standalone initiatives. Embedding technology and capacity building within the policy architecture ensures coherence and durability. Dhondt et al. in a European-level assessment of workforce needs across railway staff categories, identified emerging skills gaps particularly in digitalisation and data management [68]. Rikala et al. [70] proposed approaches to measuring Industry 4.0 skill gaps, providing a measurement framework directly applicable to rail freight workforce planning. Nowell et al. provided detailed guidelines for ensuring trustworthiness in thematic analysis, including the maintenance of an auditable decision trail [62].

A fourth recommendation addresses the strategies available to private logistics providers and freight customers navigating the current government-driven operating environment. Although systemic change awaits the legislative and infrastructure reforms described above, private operators can take three concrete steps within existing constraints. Informal data-sharing arrangements through accessible tools, Expert 7 already described

communication via application for container status coordination at Laem Chabang Port as a practical current-state solution, can reduce coordination delays without waiting for the centralised IS platform. Freight customer consortia can aggregate cargo volumes to negotiate structured volume discounts under the existing pricing framework, improving rail competitiveness against road transport at the transaction level. Active participation in the public consultation process for the Draft Rail Transport Act, allows logistics providers and freight customers to shape concession terms, pricing structures, and data-sharing mandates before legislation is finalised, a lower-cost intervention than post-enactment advocacy.

6. Conclusions

This study identifies key collaborative factors for Thailand's rail freight sector and establishes a comprehensive framework to prioritise improvement strategies. By employing a hierarchical approach that integrates Braun & Clarke's thematic analysis and the Cross-Impact Multiplication Matrix (MICMAC), the research unveils the complex institutional dynamics between state-monopoly operators, private logistics providers, and freight customers.

The MICMAC analysis identifies government policy as the primary 'driver,' possessing systemic importance that dictates the behaviour of all other variables. This is consistent with Liu and Jia [4], who applied evolutionary game theory to demonstrate that government subsidies and robust policy frameworks are essential mechanisms for incentivizing environmental compliance. Crucially, this study finds that while the transition to ESG in Thailand's rail freight sector is a strategic necessity, it cannot be achieved through infrastructure expansion alone; it requires concrete 'incentive mechanisms' to render sustainability practices practically feasible. Within this framework, financial and infrastructure readiness serve as critical linking factors possessing both influence and vulnerability while technology, information sharing, and human resource capabilities act as layers dependent on high-level policy. Information sharing, with the highest dependence score of 14, reflects its extreme sensitivity to both legislative constraints and the broader policy environment. This research provides a clear blueprint for practical implementation. The seven identified cooperation strategies follow a logical sequence: policy collaboration must first establish the necessary legislative architecture, followed by economic instruments and infrastructure investment. Finally, digital integration, multimodal operations, and sustainability strategies will yield the greatest returns once these enabling conditions are secured.

To address the limitations of the current cross-sectional data, future research should utilise longitudinal tracking designs to examine the evolution of these factors as Thailand's rail expansion projects and the Eastern Economic Corridor (EEC) reach maturity. Furthermore, extending this MICMAC framework to comparative studies in other developing countries, such as Vietnam or Laos, would test the transferability of these findings and help establish a scalable green logistics blueprint for emerging market economies worldwide.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/logistics10070145/s1>, Table S1: Factor identification by experts; Table S2: Strategy recommendations by experts. Figure S1: Code tree.

Author Contributions: Conceptualization, T.S.; Methodology, T.S.; Validation, J.L.; Investigation, J.L.; Writing—original draft, T.S.; Writing—review & editing, J.L.; Visualization, J.L.; Supervision, J.L. All authors contributed to the conception and design of the study. Data collection and analysis

were performed by the first author. All authors have read and agreed to the published version of the manuscript.

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