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RAIL EFFECTIVENESS IMPACT IN RAIL-SEA CONNECTIVITY FOR PTP CARGO HANDLING PERFORMANCE

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ABSTRACT

The increasing demands of global trade necessitate a robust and efficient maritime logistics network. Seamless hinterland logistics facilitate cargo movement from ports to inland destinations and ensure timely and cost-effective deliveries. Meanwhile, maritime transport enables the efficient movement of goods across vast oceans. The competitiveness of the Port of Tanjung Pelepas (PTP), a key transhipment hub in Southeast Asia relies heavily on effective hinterland logistics. Rail transport has emerged as a particularly important component due to its capacity to handle large cargo volumes and environmentally sustainable advantages over road transport. This study explores the critical role of intermodal transportation in enhancing hinterland logistics, emphasising rail transport at PTP. A qualitative approach was selected as a medium to achieve the main aim of this research. Semi-structured face-to-face interviews have been conducted to gather information on the issues related to rail-sea connectivity. This study examines how rail effectiveness impacts PTP's cargo handling performance and explores ways to improve rail-sea connectivity. It aims to reduce port congestion, enhance cargo movement efficiency and reliability, and ensure seamless connections between the port and inland areas. The findings emphasise the need for strong rail infrastructure and effective intermodal strategies which providing insights and recommendations for improving transport systems and supporting efficient global supply chains.

Introduction

According to Bergqvist (2020), the seamless transportation of goods between seaports and inland destinations depends on the efficiency of hinterland transportation systems. This segment ensures the economical and effective delivery of goods to final markets acting as a critical intermediary between ports and end-users. The quality of hinterland infrastructure profoundly influences the effectiveness of maritime logistics systems. To optimise this system, intermodal transportation—integrating modes such as rail, trucking, and inland waterways—is essential. Rail transport, as highlighted by LaGore (2024), offers significant advantages in intermodal logistics. It handles large volumes of cargo over long distances at lower costs and with reduced environmental impact, making it an indispensable component of modern supply chains. Rail integration accelerates cargo movement, enhances reliability, and reduces costs which contributing to faster and more sustainable logistics. Congestion remains a persistent issue in many ports, increasing transportation costs and hindering trade

growth (Behdani *et al*., 2020). By reducing road congestion, carbon emissions, and overall transportation costs, railways promote sustainable practices and improve supply chain reliability. Recognising these benefits, Malaysia's Tanjung Pelepas Port (PTP), a premier transhipment hub in Southeast Asia has invested in an extensive rail network to enhance hinterland connectivity. PTP dedicated freight rail lines connect the port to major industrial zones and inland logistics hubs, facilitating the efficient transfer of bulk cargo and containers. This reduces dependency on road transport and strengthens the port's logistics performance. In 2021, PTP handled 11.2 million TEUs—a 14% increase from 2020's 9.8 million TEUs (Finn, 2022)—underscoring its growing prominence in global trade.

PTP's rail network is pivotal in linking the port to regional economic zones, ensuring smooth cargo delivery across Malaysia and beyond. This connectivity enhances the port's competitiveness, offering quicker turnaround times for shipping lines, and reliable schedules for cargo owners. However, challenges such as inadequate rail infrastructure, outdated technology, regulatory barriers, and limited investments in modernisation hinder the full potential of rail-sea connectivity (Inbound Logistics, 2023). Addressing these issues is critical to sustain PTP's status as a key player in global supply chains and strengthening its intermodal transportation system. The operation of PTP is affected by several issues with its railway services. Inadequate infrastructure such as insufficient rail capacity and the need for upgrading, makes it difficult to convey goods efficiently (Whelan, 2021). Note that logistical bottlenecks frequently occur when coordinating many transport modes and stakeholders which is still a complex issue. Operational and regulatory barriers such as different standards and procedures, further complicate the integration of rail services into a broader logistics network. PTP must tackle these obstacles to optimise the advantages of rail transportation and maintain its competitive edge.

The PTP is a vital logistics hub in Malaysia, currently operating with a capacity of 13 million TEUs. Plans are underway to expand this capacity by an additional 3.5 million TEUs through investments in automation, equipment upgrades, and infrastructure improvements (Malaysian Reserve, 2023; New Straits Times, 2024).

PTP's railway services are crucial in connecting the port to inland destinations, promoting efficient cargo transfer, and reducing road congestion. However, challenges such as limited rail capacity, ageing infrastructure, and regulatory constraints restrict the potential benefits of rail-sea connectivity. Hence, addressing these issues could enhance port operations, support environmental sustainability, and improve the reliability of supply chains (Inbound Logistics, 2023; Global Railway Review, 2024).

The competitive advantage of maritime ports in the global supply chain depends on the effective operation of hinterland logistics. As a major transhipment hub, PTP in Malaysia is primarily dependent on its rail network to ensure seamless connectivity between the port and its hinterland. Notwithstanding the benefits of rail transportation including low transportation costs, reduced environmental impact, and the ability to handle large cargo volumes, PTP still has to deal with several issues affecting its logistics performance. These issues include capacity constraints, outdated technology, infrastructure limitations, and coordination issues among stakeholders. The efficiency of PTP's rail system is essential for reducing port traffic, improving the reliability and speed of cargo movement, and facilitating connections between the port and the inland destinations. To comprehend their impact on the port's total logistics performance, a thorough evaluation of the state of the rail infrastructure and its operational effectiveness is necessary. Furthermore, optimising hinterland logistics requires identifying and assessing ways to improve the effectiveness of rail-sea connectivity. This study aims to investigate potential approaches to improve the

effectiveness of rail-sea connectivity and assess whether rail transport's efficiency affects PTP's cargo handling performance.

Research Objectives

The study aims to analyse the rail effectiveness that impacts the PTP's cargo handling performance and analyse the alternative ways to improve efficiency for rail-sea connectivity.

Research Questions

The research questions of this study are (1) does the rail effectiveness have an impact on the PTP's cargo handling performance and (2) what are the alternative ways to improve efficiency for rail-sea connectivity?

Literature Review

Rail Effectiveness Impact on Port's Cargo Handling Performance

Numerous investigations have looked into how cargo handling performance is affected by rail efficiency. Hao Geun (2012) and Yang and Lin (2013) highlight the significance of effective rail systems in enhancing freight handling. The former names identify automatic rail and electric tyre transtainers as optimal equipment. The necessity for effective technical equipment and the possibility of new technologies such as Positive Train Control to increase rail network capacity and reduce delays are further highlighted by Okorokov (2015) and Dessouky (2019). These findings collectively suggest that effective rail systems can significantly enhance cargo handling performance.

Rail Infrastructure Quality

A range of studies have explored evaluating and monitoring rail infrastructure quality. Indicators for evaluating the quality of railway infrastructure, power supply, civil engineering, and signalling were created by Pyrgidis (2003). On the other hand, Pirvan (2019) presented a method that uses algorithms and a train-mounted device to diagnose and monitor rail quality. The significance of rail quality for railway traffic operation was highlighted by Sladojevi (2011), especially in terms of the speed of the frequent and rapid trains. Stojić *et al*. (1970) emphasised the need for suitable and high-quality train services by discussing the various modes of institutional approaches to manage rail infrastructure.Together, these studies highlight the importance of excellent rail infrastructure and the demand for efficient management and evaluation methods.

The quality of rail infrastructure significantly impacts operational effectiveness, economic viability, and safety. Stable track geometry which is crucial for safe and reliable operations depends on the condition of railway tracks. In large-scale transportation projects, poor quality still poses a serious problem since it can result in irregularities and possible threats to asset integrity and public safety (Love *et al*., 2022). In the article, Sestakova *et al*. (2022) said that through better infrastructure and connectivity, regional cooperation in rail transport can improve trade patterns, attract investments, and accelerate economic development. The quality of railway infrastructure is a danger due to mining damage, systematic risk assessments, and management measures to uphold security, and service standards (Jafarova & Aliyeva, 2023). On the other hand, Lukaszczyk and Granieczny (2023) mentioned that track geometry is a crucial feature for guaranteeing operational quality and diagnostic data and quality indicators are important in decision-making procedures for track quality rehabilitation.

Rail Network Coverage

Urban planning must include the creation of rail networks as rail transit is essential to the growth of cities (Weigu, 2010). It has been suggested that RailNet, an information aggregation network improves the spatial relationship between rail feature pixel values, thereby increasing the accuracy of rail segmentation (Li *et al.*, 2020). Urban rail transit networks' structural features have been examined and various networks have been divided into groups according to their structural efficiency and degree of development (Chen *et al.*, 2022). Railroad is a data dissemination

architecture for wireless sensor networks that effectively distributes data using a virtual infrastructure known as rail (Shin *et al.*, 2005).

To guarantee smooth communication and connectivity for high-speed train systems, rail network coverage is essential. Several techniques and technologies have been developed to improve network coverage along rail routes. The research focuses on using ray tracing simulations and machine learning to forecast and enhance high-speed rail scene coverage. To get over networking obstacles and improve connectivity, other advancements include systems with wireless coverage devices in train carriages, switches, and bridge equipment (Huang, 2020). Key technologies such as Doppler frequency offset correction, exclusive network coverage techniques, and multi-frequency network combinations on China's high-speed rail networks have greatly improved wireless communication coverage (Gong *et al*., 2019). Furthermore, wireless communication network architecture improvements have created ground networks for rail transportation systems with stronger coverage and longer transmission ranges (Zhao, 2023). Additionally, to ensure the effective use of resources along high-speed rail routes, efforts have been made to optimise spectrum resource utilisation by dynamically modifying network types based on user proportions (Yang Yan, 2014).

Scheduling and Frequency of Rail Services

Several models and factors have been investigated in research on the frequency and scheduling of rail services. Despite their shortcomings in modelling low-frequency services, Cascetta and Coppola (2016) showed that frequency-based assignment models are more frequently utilised because of their cost and computational efficiency. Kuo *et al*. (2010) created a train slot selection model to minimise operational costs and delays while satisfying frequency specifications for freight services. Meanwhile, Deng (2014) examined how passenger demand and operator strategies were affected by train formation length and service frequency, highlighting the need to strike a balance between the two. Niu and Zhang (2012) suggested a phase-regular scheduling method for intercity train lines to minimise costs and improve service quality. Together, these studies highlight how crucial it is to consider cost and service quality when determining the frequency and schedule of rail services.

In train services, scheduling and frequency optimisation are essential for effectiveness and customer satisfaction. Studies have indicated that future service planning can benefit from using time series models such as utoregressive Integrated Moving Average (ARIMA) to forecast passenger numbers (Borucka & Guzanek, 2022). Trajectory optimisation within high-frequency systems can enhance energy efficiency in rail transportation while considering the best reserve time distribution throughout the line to reduce delays (Simonelli *et al*., 2020). Due to their cost-effectiveness, frequency-based assignment models are frequently employed. However, scheduled-based models could be required for more realistic long-distance service modelling, particularly in cases where demand distributions are not uniform (Cascetta & Coppola, 2016). Li *et al*. (2018) said one can improve overall passenger experience by deliberately modifying service frequency, lowering operational costs, increasing service quality, and encouraging customers to shift from peak to off-peak travel hours. The advantages of rail over road transportation are further demonstrated by the correlation between increased rail service frequency and reductions in road traffic externalities such as severe accidents and pollution.

Relationship between Rail Transport and Cargo Handling

Cargo handling and rail transportation have a complex and multifaceted relationship. Allen *et al*. (2012) emphasises how geographic, spatial, and land use factors affect freight activity in urban areas, with commercial and industrial land use patterns particularly important. According to the analysis of geographical and spatial characteristics by Allen *et al*. (2012), well-planned urban areas with strategically placed commercial and industrial zones are

typically necessary for effective rail freight operations. Kuznetsov *et al.* (2018) suggests that containerisation may enhance bulk cargo transit operations while reducing environmental impact and loss rates. In his support of containerisation, Kuznetsov *et al*. (2018) draws attention to a revolutionary strategy in bulk cargo logistics that, by offering a more efficient and safe way of transportation, may significantly reduce losses and environmental impact.

On the other hand, Yanovsky *et al*. (2019) highlights the significance of clear interaction between all elements in the logistics chain, especially regarding rail transportation. According to Yanovsky *et al*. (2019), synchronised operations and communication play a crucial role in improving the efficiency of rail transport. They also highlight the importance of a seamless interaction between all elements of the logistics chain. Boysen *et al*. (2013) emphasises the need for more effective freight handling in railway yards to attract a higher share of freight traffic to rail. Moreover, Boysen *et al*. (2013) emphasises on the operational aspects of freight handling at railway yards, highlighting the need to enhance yard productivity to increase rail's attractiveness as a freight transportation option, which is necessary to grow its market share.

Thus, combining these diverse elements–geographical concerns, containerisation, and operational enhancement–can result in a more reliable and effective rail cargo handling system.

Alternative Ways to Improve Efficiency for Rail-sea Connectivity

To fulfil the demands of growing global trade, modern logistics and supply chain management must prioritise improving the efficiency of rail-sea connectivity. Streamlining operations, reducing transit times, and lowering costs depend on intermodal transportation which integrates road, rail, and sea transportation. Based on the research findings, several alternative ways can be used to improve the efficiency of rail-sea connectivity. Firstly, to minimise delays and maximise cargo flow, seaports and railway transport must coordinate their action (Svetlana, 2022). This integration requires significant investments in infrastructure development such as improving rail connections to ports and updating terminal facilities. Logistics operations can be optimised by utilising technological innovations such as real-time tracking and automated cargo handling systems. Secondly, the region's connectivity and trade performance can be greatly enhanced by making investments in fundamental infrastructures, expanding logistics connection points, and promoting international trade (Netirith & Ji , 2022).

Better connectivity is made possible by regulatory frameworks and policies that support the government. Coordinated operations depend on effective cooperation amongst all parties involved, including government agencies, rail operators, port authorities, and logistics firms. Enhancing rail-sea connectivity also helps the environment by reducing emissions and relying on road transportation. These strategies can be used to significantly increase the effectiveness of rail-sea connectivity.

Coordination between Rail and Sea Transport

For ports to operate effectively and for the transportation of goods, rail and sea transport must be coordinated. Burkovskis and Palšaitis (2002) and Valkova *et al*. (2022) stress the need for improved communication between seaports and railway transport with Valkova *et al*. emphasises how this coordination affects the effectiveness of port operations. This interaction influences the total throughput of ports and the reliability and promptness of cargo deliveries. Moreover, improved coordination can result in more coordinated schedules between available trains and arriving ships, minimising wait times and enhancing the flow of goods.

This issue is further explored by Li *et al*. (2018) and Fomin (2019) who concentrate on different aspects: Li *et al*. (2018) is concerned with promoting inland waterway transport, while Fomin *et al*. (2019) addresses the safety

of tank containers in combined trains on railway ferries. Both studies emphasise how crucial coordination is to ensure both the effectiveness and reliability of inland waterway transportation and the seamless transhipment of containers. Fomin's emphasis on safety highlight the need for coordinated efforts to maintain high safety standards which is crucial while dealing with hazardous materials and operational efficiency (Fomin *et al.*, 2019). Li's emphasis on inland waterways raises the possibility that strengthening rail and sea connectivity could have a cascade effect that boosts the effectiveness and connectivity of other forms of transportation as well (Li *et al.*, 2018).

These studies show how optimal coordination between sea and rail transportation can result in safer and more reliable overall transit and more successful port operations and freight handling. This coordination requires technological and infrastructure investments, strong regulatory frameworks, and stakeholder cooperation to ensure the smooth operation of various transport modes.

Intermodal Facilities Quality

The quality of intermodal facilities is a key factor influencing the effectiveness and user satisfaction of transportation systems. Studies underscore the importance of addressing insufficient infrastructure, long waiting times, and disruptions to improve service quality and reduce costs (Abramovic, 2012; Moodley & Venter, 2022). These issues have the potential to significantly hinder transportation systems' overall performance, increase operating costs, and lower customer satisfaction. Intermodal freight terminal productivity, infrastructure investment decisions, and overall terminal functionality are all closely related to the level of service provided (Stjepana, 2012). When terminals provide high-quality service, they can efficiently manage larger amounts of freight which attracts more business and justifies further investments in infrastructure improvements.

Identifying and eliminating transportation bottlenecks enhances service quality, resulting in shorter transport times, more efficient routes, and reasonable service prices (Ballis, 2004; Roso *et al.*, 2015). This entails careful examination and optimisation of all stages of the transportation process from transfer and storage to loading and unloading, to maximise efficiency at each stage. Furthermore, choosing suitable locations is essential to their profitability and functionality. Thus, important aspects to consider during this process include good flows and geographical considerations. The total efficiency and effectiveness of the transportation network are eventually improved by properly located terminals which also enable smoother logistics operations, better connectivity with other transport modes, and enhanced accessibility for users.

Handling Time at the Port

Various aspects of handling time at ports have been the subject of research such as estimating ship handling times (Nishimura *et al.*, 2003), minimising port stays and transfer rates (Ma *et al.*, 2013), and optimising the efficiency of yard and berth planning (Nishimura, 2019). With an emphasis on container handling, this research has suggested models and algorithms to enhance port operations. More precise ship handling time estimation techniques were introduced by Nishimura *et al.* (2003). This facilitates more effective resource planning and allocation, resulting in shorter ship turnaround times and reduced idle time. According to Ma *et al.* (2013), minimising port staying time and transfer rates involves developing plans to expedite the loading and unloading processes will shorten the time that ships spend at ports. This may include the use of more effective equipment for cargo handling, simpler procedures, and better coordination among different port services. Ma's research emphasises the significance of transfer rate optimisation which guarantees the prompt movement of containers from ships to storage areas or other means of transportation (Ma *et al.*, 2013).

Expanding on maximising the efficiency of yard and berth planning, Nishimura (2019) concentrated on arranging ships at berths

and containers in the yard in space and time. Planning the yard and berths well improves container movement and makes the most use of available space which minimises traffic and delays. Advanced algorithms and simulation models are frequently used to predict and optimise these movements and balance the demands of incoming and outgoing traffic. Additionally, managing customer arrivals with time windows has been explored as a potential remedy for terminal gate congestion (Chen & Jiang, 2016). This involves planning truck arrivals, so that demand is distributed equally throughout the day, avoiding peak-hour traffic and enhancing the overall flow of cargo in and out of the port. Time window management also makes it possible to allocate resources more effectively at gates, reducing truck waiting times and improving port operations' overall effectiveness.

These studies contribute to the development of efficient time management strategies at ports. These research projects seek to improve port operations by concentrating on precise estimation, reducing stay and transfer times, improving spatial arrangements, and managing arrivals. By taking a comprehensive strategy, ports can increase their operating efficiency while simultaneously reducing costs and enhancing customer satisfaction levels, which increases their competitiveness in the global logistics network.

Infrastructure Investment

Based on the insights from the research article, several solutions can be implemented to increase the effectiveness of rail-sea connectivity through infrastructure investment. Connectivity and trade performance can be greatly increased by investing in fundamental infrastructures like increasing logistics connection points and improving intermodal connectivity (De Rivera *et al*., 2020). Enabling smoother and quicker cargo movements can involve the development of dedicated freight corridors, logistics hubs, and seamless transfer facilities between rail and sea transport. Besides that, enhancing rail infrastructure can benefit freight distribution, operation management, and service reliability, ultimately reducing seaport dwell time (Netirith & Ji, 2022). Investments in rail infrastructure include expanding the capacity of rail yards, constructing new rail lines, and upgrading existing tracks to accommodate cargo volumes. This would guarantee that items can be transported more efficiently and reliably and reduce port congestion.

Additionally, upgrading network infrastructure can boost the effectiveness of applications in railway transportation systems, resulting in reduced transmission delays and more bandwidth for better performance (Valkova & Notteboom, 2022). This can be achieved by implementing advanced communication systems like Multiprotocol Label Switching-Transport Profile (MPLS-TP) for railway communication. Such technological developments can enhance decision-making and coordination by enabling real-time data exchange between ports and rail operators. By offering comprehensive insights into cargo movements and potential bottlenecks, integrating Internet of Things (IoT) devices, automated tracking systems, and predictive analytics can further optimise logistics operations.

To maximise rail-sea connectivity and increase overall trade competitiveness, it is crucial to coordinate the relationship between seaports and railway transport which ensures institutional integration and effectively manages infrastructure maintenance (Popinchalk & Mark, 2023). This includes creating joint task forces and working groups among stakeholders, standardising regulations and standards, and developing shared planning and communication. Predictive and preventative maintenance are two effective ways of maintaining infrastructure that can assist in minimising downtime and guarantee uninterrupted smooth operation.

According to Michell (2000), efficient infrastructure should be planned with a focus on track capacity, speed, and local infrastructure development to enable train operations that are both economical and efficient. To handle higher

speeds and heavier loads, it involves not only constructing new tracks but also modernising the ones that already exist to boost the rail network's overall capacity and efficiency. Ambrosino and Sciomachen (2017) emphasise the part maritime investments play in boosting modal split and rail capacity while minimising costs and externalities. Reducing the dependency on road transport, lowering greenhouse gas emissions, and improving traffic congestion in port communities can all be achieved by strategically investing in port infrastructure such as expanding rail terminals and installing effective cargo-handling equipment. Furthermore, the utilisation of on-dock rail and rail-focused projects at the Port of Long Beach to improve rail capacity and efficiency is covered in Wanek-Libman (2014). Containers may be loaded straight onto trains at the port thanks to on-dock rail infrastructure, eliminating the need for intermediate handling and storage. This lowers the overall cost of moving freight and expedites the transfer procedure.

The cumulative findings of this research highlight how crucial infrastructure spending is to raise the effectiveness of rail-sea connectivity. Ports and rail operators can greatly increase their operational efficiency, lower costs, and improve service reliability by concentrating on comprehensive strategies that address multiple infrastructure, technology, coordination, and sustainability-related issues. This will increase their competitiveness in the global trade market.

Research Methodology

This research aims to investigate the rail effectiveness that impacts the PTP's cargo handling and analyse the alternative ways to improve efficiency for rail-sea connectivity. To achieve the research objectives, a quantitative research approach was adopted, utilising a survey method to collect data from participants, as shown in Figure 1. The survey method is particularly appropriate for this study due to its ability to capture data from a diverse group of respondents, encompassing various perspectives, and operational levels within the logistics and port sectors. This broad scope ensures a comprehensive understanding of the challenges and opportunities in rail-sea connectivity at PTP. Additionally, surveys provide quantifiable results, allowing the analysis of trends, relationships, and areas needing improvement.

A quantitative research design was chosen for this study to measure variables and analyse the relationship between them systematically. The survey method is particularly suited for gathering standardised data from a larger sample, enabling statistical analysis.

The survey consisted of 16 multiple-choice questions. The questions were designed on an ordinal scale with response options ranging from "strongly disagree" to "strongly agree". The aim was to survey 100 respondents. Participants were given 10 minutes to complete the survey anonymously and 90 responded. Since not all surveys were fully completed, 90 survey results were used for this research. This format allows for measuring perceptions of rail and sea connectivity.

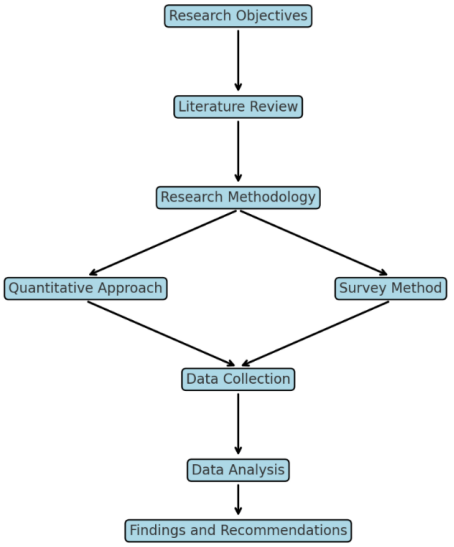

Figure 1: Flowchart of research design

The survey was distributed online to ensure broad reach and convenience for respondents. Participants were invited to complete the survey through email invitations and shared links with a total of 90 respondents completing the survey.

The sampling technique used for this study was non-probability sampling, specifically convenience sampling. This approach was chosen due to the practical constraints of time and resources. Meanwhile, convenience sampling may introduce some bias but it was deemed appropriate for the exploratory nature of this research. Efforts were made to include diverse respondents to enhance the sample's representativeness.

The data collected from the survey were analysed using Statistical Package for the Social Sciences (SPSS) software. The survey data that has been collected through an online questionnaire was analysed using descriptive statistical methods. SPSS software was employed to organise, summarise, and interpret the responses. Descriptive analysis was chosen because it clearly represents participant perspectives by highlighting trends and patterns within the data.

Meanwhile, this study provides valuable insights into rail effectiveness's impact on rail-sea connectivity. Nonetheless, several limitations must be acknowledged. The use of convenience sampling may limit the generalisability of the findings, as the sample may not represent the broader population. Additionally, the reliance on self-reported data can introduce response biases such as social desirability bias, where respondents might answer questions in a manner they perceive as favourable. The relatively small sample size of 90 respondents, though adequate for exploratory analysis may also constrain the statistical power of inferential tests which potentially affecting the conclusions' robustness. Despite these limitations, the study offers a foundational understanding of alternative ways to improve rail-sea connectivity which can inform future research endeavours.

Results

Table 1 presents the frequency of responses to various statements about the quality and efficiency of rail infrastructure and services connected to the port. The variables are used to analyse the rail effectiveness that impacts the PTP's cargo handling performance. For each statement, all 90 respondents provided valid responses, indicating robust and complete data collection with no missing responses.

Table 1: Frequency of responses to various statements related to the quality and efficiency of rail infrastructure and services connected to the port

Statement		*N*	
		Valid	**Missing**
Rail infrastructure quality	The overall quality of the rail infrastructure serving the port is very satisfying	90	0
Rail infrastructure quality	The quality of rail infrastructure impact the efficiency of cargo transport to and/or from the port	90	0
Rail network coverage	The current rail network adequately connects major industrial centres to the port	90	0
Rail network coverage	Do you think by enhancing rail network coverage would attract more cargo traffic to the port?	90	0
Scheduling and frequency of rail services	The increasing of the frequency of rail services would improve the efficiency of cargo transportation at the port	90	0
Scheduling and frequency of rail services	Cost considerations and the frequency of rail services will be prioritised when selecting transportation options for cargo	90	0
Relationship between rail transport and cargo handling	The reliability and punctuality of rail services affect cargo handling schedules and planning	90	0
Relationship between rail transport and cargo handling	The current integration between rail transport and cargo handling operation at the port is very efficient	90	0

Firstly, respondents evaluated the overall quality of the port's rail infrastructure, expressing satisfaction with the infrastructure's condition (Table 2). Similarly, the impact of rail infrastructure quality on the efficiency of cargo transport to and from the port was also fully assessed, highlighting the critical role infrastructure plays in operational efficiency (Table 3).

Table 2: Rail infrastructure quality – The overall quality of the rail infrastructure serving the port is very satisfying

	Response	**Frequency**	**Percentage (%)**	**Valid Percentage (%)**	**Cumulative Percentage (%)**
Valid	Agree	39	43.3	43.3	43.3
	Disagree	10	11.1	11.1	54.4
	Neutral	35	38.9	38.9	93.3
	Strongly agree	6	6.7	6.7	100
	Total	**90**	**100**	**100**	

Table 3: Rail infrastructure quality – The quality of rail infrastructure impact the efficiency of cargo transport to and/or from the port

	Response	Frequency	Percentage (%)	Valid Percentage (%)	Cumulative Percentage (%)
Valid		1	1.1	1.1	1.1
	Agree	51	56.7	56.7	57.8
	Neutral	21	23.3	23.3	81.1
	Strongly agree	16	17.8	17.8	98.9
	Strongly disagree	1	1.1	1.1	100
	Total	**90**	**100**	**100**	

The adequacy of the current rail network in connecting major industrial centres to the port received unanimous feedback, underlining the network's importance in facilitating industrial connectivity (Table 4). Additionally, the potential benefits of enhancing rail network coverage to attract more cargo traffic to the port were explored, with all participants providing their perspectives, indicating a strong interest in network expansion (Table 5).

Table 4: Rail network coverage – The current rail network adequately connects major industrial centres to the port

	Response	Frequency	Percentage (%)	Valid Percentage (%)	Cumulative Percentage (%)
Valid	Agree	37	41.1	41.1	41.1
	Disagree	18	20	20	61.1
	Neutral	27	30	30	91.1
	Strongly agree	7	7.8	7.8	98.9
	Strongly disagree	1	1.1	1.1	100
	Total	**90**	**100**	**100**	

Table 5: Rail network coverage – Do you think by enhancing rail network coverage would attract more cargo traffic to the port?

	Response	Frequency	Percentage (%)	Valid Percentage (%)	Cumulative Percentage (%)
Valid		1	1.1	1.1	1.1
	Agree	49	54.4	54.4	55.6
	Neutral	1	1.1	1.1	56.7
	Strongly agree	16	17.8	17.8	74.4
	Strongly disagree	23	25.6	25.6	100
	Total	**90**	**100**	**100**	

Regarding the scheduling and frequency of rail services, respondents unanimously agreed that increasing the frequency could improve cargo transportation efficiency at the port

(Table 6). This reflects a shared recognition of the positive impact that more frequent services could have. Furthermore, cost considerations and service frequency were highlighted as critical factors when selecting transportation options for cargo with full engagement from all respondents (Table 7).

Table 6: Scheduling and frequency of rail services – The increasing of the frequency of rail services would improve the efficiency of cargo transportation at the port

	Response	Frequency	Percentage (%)	Valid Percentage (%)	Cumulative Percentage (%)
Valid	Agree	57	63.3	63.3	63.6
	Neutral	15	16.7	16.7	80
	Strongly agree	18	20	20	100
	Total	**90**	**100**	**100**	

Table 7: Scheduling and frequency of rail services – Cost considerations and the frequency of rail services will be prioritise when selecting transportation option for cargo

	Response	Frequency	Percentage (%)	Valid Percentage (%)	Cumulative Percentage (%)
Valid		1	1.1	1.1	1.1
	Agree	49	54.4	54.4	55.6
	Neutral	1	1.1	1.1	56.7
	Strongly agree	16	17.8	17.8	74.4
	Strongly disagree	23	25.6	25.6	100
	Total	**90**	**100**	**100**	

The relationship between rail transport and cargo handling was also examined, particularly focusing on the reliability and punctuality of rail services (Table 8). Respondents agreed that these factors significantly affect cargo handling schedules and planning. Finally, the efficiency of the current integration between rail transport and cargo handling operations at the port was affirmed by all participants, indicating general satisfaction with the current systems in place (Table 9).

Table 8: Relationship between rail transport and cargo handling – The reliability and punctuality of rail services affect cargo handling schedules and planning

	Response	Frequency	Percentage (%)	Valid Percentage (%)	Cumulative Percentage (%)
Valid		1	1.1	1.1	1.1
	Agree	43	47.8	47.8	48.9
	Neutral	16	17.8	17.8	66.7
	Strongly agree	30	33.3	33.3	100
	Total	**90**	**100**	**100**	

Table 9: Relationship between rail transport and cargo handling – The current integration between rail transport and cargo handling operation at the port is very efficient

	Response	Frequency	Percentage (%)	Valid Percentage (%)	Cumulative Percentage (%)
Valid		1	1.1	1.1	1.1
	Agree	34	37.8	37.8	38.9
	Disagree	7	7.8	7.8	46.7
	Neutral	41	45.6	45.6	92.2
	Strongly agree	6	6.7	6.7	98.9
	Strongly disagree	1	1.1	1.1	100
	Total	**90**	**100**	**100**	

Discussions

Evaluating the adequacy of the current rail network in connecting major industrial centres to the port is crucial for understanding its effectiveness in facilitating cargo movement. The data clearly indicates whether the existing network meets the connectivity needs. Adequate network coverage ensures that cargo can be transported seamlessly from production sites to the port, minimising transit times, and reducing logistics costs. If the evaluation reveals gaps in the network, it underscores the need for strategic expansions to enhance connectivity. Therefore, expansion projects connecting more industrial hubs to the port could increase cargo volumes, boosting the port's economic viability and competitiveness. This information is vital for long-term strategic planning and ensuring the rail network evolves to meet growing demands.

The efficiency of integration between rail transport and cargo handling operations at the port is a vital aspect explored in the table. Effective integration ensures that cargo transitions smoothly between rail and port operations, minimising handling times, and reducing the risk of damage or loss. It provides insights into views on the current state of the integration, highlighting areas where improvements might be needed. Evaluating integration efficiency can help to identify best practices and operational bottlenecks.

Table 10 provides a comprehensive summary of survey responses concerning coordination, intermodal facilities quality, handling time at ports, and infrastructure investments in the context of rail and sea transport. The variables are to analyse the alternative ways to improve efficiency for rail-sea connectivity. It reflects the opinions and evaluations of 90 respondents on multiple statements.

Table 10: The summary of survey responses

Statement		*N*	
		Valid	**Missing**
Coordination between rail and sea transport	The current level of coordination between rail and sea transport services for handling cargo shipments is very effective	90	0
Coordination between rail and sea transport	Real-time communication between rail and sea transport operators has led to delays or inefficiencies in cargo handling processes	90	0

Intermodal facilities quality	The quality of intermodal facilities significantly impacts the efficiency of rail-sea connectivity	90	0
Intermodal facilities quality	The condition of intermodal facilities impacts the overall competitiveness of rail-sea transportation compared to other modes of transport	90	0
Handling time at port	Inefficient operations contribute most to delays in cargo handling at port	90	0
Handling time at port	Reduction of handling time at port could improve overall supply chain efficiency	90	0
Infrastructure investments	Public-private partnerships are an effective way to finance infrastructure projects at port and railway	90	0
Infrastructure investments	Port terminals are areas of infrastructure investments that require the most urgent attention	90	0

Firstly, Table 11 addresses the effectiveness of the current level of coordination between rail and sea transport services in handling cargo shipments. It assesses whether the respondents believe that the coordination between these two modes of transport is effective. Additionally, it explores the impact of real-time communication between rail and sea transport operators on the efficiency of cargo handling processes, particularly focusing on whether such communication has led to delays or inefficiencies (Table 12).

Table 11: Coordination between rail and sea transport – The current level of coordination between rail and sea transport services for handling cargo shipments is very effective

	Response	Frequency	Percentage (%)	Valid Percentage (%)	Cumulative Percentage (%)
Valid	Agree	31	34.4	34.4	34.4
	Disagree	11	12.2	12.2	46.7
	Neutral	41	45.6	45.6	92.2
	Strongly agree	5	5.6	5.6	97.8
	Strongly disagree	2	2.2	2.2	100
	Total	**90**	**100**	**100**	

Table 12: Coordination between rail and sea transport – Real-time communication between rail and sea transport operators have led to delays or inefficiencies in cargo handling processes

	Response	Frequency	Percentage (%)	Valid Percentage (%)	Cumulative Percentage (%)
Valid	Agree	45	50	50	50
	Disagree	8	8.9	8.9	58.9
	Neutral	29	32.2	32.2	91.1
	Strongly agree	8	8.9	8.9	100
	Total	**90**	**100**	**100**	

Next, the quality of intermodal facilities is evaluated in two significant aspects. One aspect considers how this quality influences the efficiency of rail-sea connectivity (Table 13). The other aspect examines the broader impact of intermodal facility conditions on the overall competitiveness of rail-sea transportation compared to other modes of transport (Table 14). Correspondingly, these evaluations help understand the critical role of infrastructure quality in facilitating efficient transport operations.

Table 13: Intermodal facilities quality – The quality of intermodal facilities significantly impacts on the efficiency of rail-sea connectivity

	Response	Frequency	Percentage (%)	Valid Percentage (%)	Cumulative Percentage (%)
Valid	Agree	48	53.3	53.3	53.3
	Disagree	1	1.1	1.1	54.4
	Neutral	27	30	30	84.4
	Strongly agree	14	15.6	15.6	100
	Total	**90**	**100**	**100**	

Table 14: Intermodal facilities quality – The condition of intermodal facilities impact the overall competitiveness of rail-sea transportation compared to other modes of transport

	Response	Frequency	Percentage (%)	Valid Percentage (%)	Cumulative Percentage (%)
Valid	Agree	50	55.6	55.6	55.6
	Disagree	1	1.1	1.1	56.7
	Neutral	28	31.1	31.1	87.8
	Strongly agree	11	12.2	12.2	100
	Total	**90**	**100**	**100**	

Handling time at ports is another crucial area explored in the survey. The respondents provided insights into whether inefficient operations at ports contribute the most delays in cargo handling (Table 15). Furthermore, the survey investigates whether reducing the handling time at ports could enhance the overall efficiency of the supply chain, indicating the importance of operational improvements in port activities (Table 16).

Table 15: Handling time at port – Inefficient operations contribute most to delays in cargo handling at port

	Response	Frequency	Percentage (%)	Valid Percentage (%)	Cumulative Percentage (%)
Valid		1	1.1	1.1	1.1
	Agree	48	53.3	53.3	54.4
	Disagree	3	3.3	3.3	57.8
	Neutral	20	22.2	22.2	80
	Strongly agree	18	20	20	100
	Total	**90**	**100**	**100**	

Table 16: Handling time at port – Reduction of handling time at port could improve overall supply chain efficiency

	Response	Frequency	Percentage (%)	Valid Percentage (%)	Cumulative Percentage (%)
Valid	Agree	44	48.9	48.9	48.9
	Disagree	3	3.3	3.3	52.2
	Neutral	25	27.8	27.8	80
	Strongly agree	18	20	20	100
	Total	**90**	**100**	**100**	

Lastly, Tables 17 and 18 addresses infrastructure investments, focusing on two key statements. The first examines whether public-private partnerships are effective for financing infrastructure projects at ports and railways (Table 17). The second identifies port terminals as areas of infrastructure that require the most urgent investment and attention (Table 18). Consequently, these responses highlight the importance of strategic investments in infrastructure to support and enhance transport efficiency.

Table 17: Infrastructure investments – Public-private partnership are an effective way to finance infrastructure projects at port and railway

	Response	Frequency	Percentage (%)	Valid Percentage (%)	Cumulative Percentage (%)
Valid	Agree	38	42.2	42.2	42.2
	Disagree	1	1.1	1.1	43.3
	Neutral	30	33.3	33.3	76.7
	Strongly agree	20	22.2	22.2	98.9
	Strongly disagree	1	1.1	1.1	100
	Total	**90**	**100**	**100**	

Table 18: Infrastructure investments – Port terminals are areas of infrastructure investments that require the most urgent attention

	Response	Frequency	Percentage (%)	Valid Percentage (%)	Cumulative Percentage (%)
Valid	Agree	39	43.3	43.3	43.3
	Disagree	1	1.1	1.1	44.4
	Neutral	33	36.7	36.7	81.1
	Strongly agree	17	18.9	18.9	100
	Total	**90**	**100**	**100**	

A significant number of respondents have evaluated the coordination between rail and sea transport services for handling cargo shipments, highlighting its crucial role in logistics. The effectiveness of this coordination is fundamental to ensure smooth cargo transitions between these two transport modes. Furthermore, real-time communication

between rail and sea transport operators has been identified as critical. All respondents emphasised that delays or inefficiencies in this communication can lead to significant disruptions in cargo handling processes. This underscores the necessity for seamless and efficient communication channels to maintain the flow of goods.

All respondents recognised public-private partnerships as an effective way to finance infrastructure projects at ports and railways. Such collaborative funding approaches could strategically enhance infrastructure, ensuring necessary improvements are made to support efficient logistics operations. Additionally, the respondents underscored the urgency of investments in port terminals. Port terminals were identified as infrastructure areas requiring immediate attention and investments, highlighting the need for focused funding and improvements to maintain and enhance port operations.

The analysis reveals that effective coordination between different transport modes, the quality and condition of intermodal facilities and the efficiency of port operations are critical factors in the logistics and transportation industry. Strategic investments, particularly through public-private partnerships could significantly improve efficiency and competitiveness, addressing the immediate needs identified by the respondents.

Conclusions

In conclusion, this study highlights the critical elements that impact the efficiency and competitiveness of rail-sea cargo transportation. The coordination between rail and sea transport services, real-time communication between operators, and the quality and condition of intermodal facilities are pivotal factors influencing the effectiveness of the logistics chain. Inefficiencies in port operations were identified as significant contributors to delays in cargo handling, underscoring the need for operational improvements to enhance overall supply chain efficiency. Additionally, strategic infrastructure investments, particularly through public-private partnerships were emphasised to finance necessary enhancements and address urgent infrastructure needs especially at port terminals.

The findings of this study have several important implications for the logistics and transportation industry. Policymakers and industry stakeholders should prioritise in improving the coordination and communication between rail and sea transport operators. Therefore, developing integrated communication systems can reduce delays and inefficiencies in cargo handling processes. This improvement will enhance the overall efficiency of logistics operations and ensure timely delivery of goods, which is critical for maintaining competitive advantage in the market.

Investment in the quality and condition of intermodal facilities is essential for improving rail-sea connectivity. Enhancing these facilities will lead to better integration of transport modes, resulting in smoother transitions and reduced bottlenecks. Thus, stakeholders should consider allocating resources to maintain and upgrade these facilities regularly. This strategic investment will bolster the infrastructure, making it more resilient and capable of handling increased cargo volumes, thereby supporting economic growth.

Port authorities and operators need to address inefficiencies in port operations. Implementing best practices and innovative technologies can streamline cargo handling processes, reducing delays, and improving supply chain efficiency. Optimising port operations can enhance the throughput capacity and reduce turnaround times for vessels , which can significantly boost the overall performance of the logistics chain. This study has significantly contributed to understand rail-sea connectivity and intermodal transport efficiency, specifically within the PTP context. It highlights the critical role of coordination between rail and sea transport services, real-time communication, and the quality of intermodal facilities in optimising logistics operations.

The research also underscores the importance of addressing inefficiencies in port operations to improve overall supply chain performance.

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Conflict of Interest Statement

The authors have no conflict of interest.

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