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INFLUENCE OF INDIAN HINTERLAND TRANSPORTATION ON PORT PERFORMANCE

A CASE STUDY

by

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ABSTRACT

The effect of hinterland transportation on port operational performance is examined in this research. Such research is regarded as being very beneficial because it adds to the body of knowledge and existing research by providing additional quantitative and statistically analyzed evidence and analyses. It also clarifies and expands on the significance of hinterland transportation in the broader context, in particular its effect on port operational performance. By examining the effects of a structured rail system on port operational performance, the goal of this study is to determine the correlation between port operational performance and hinterland transportation.

To explore the hinterland transit and to be used for additional tests and analysis, a case study technique was developed based on the Dedicated Freight Corridor (DFC) by Indian Railways, which regulates the flow of rail between and through the port of JNPT, Mumbai. A time series of the dataset was compiled from the port, DFC, and Indiastats databases for a five-year period, from 2016 to 2021, using a secondary research strategy and quantitative methods. The basic premise, which states that hinterland transit affects port operational performance, was then explained by developing a conceptual framework from which an analytical method was constructed. After the parameters were projected, four assumptions were used to conceptualize the analytical model.

Following a review of the literature on hinterland and port performance, the study used the railways' (Inland Container Depot's rail turnaround time) variable to represent hinterland transport (an independent variable) and four container terminal performance indicators (ship turnaround time, berth occupancy rate, gross berth productivity, and average ship call size) to measure port performance (dependent variables). In order to explain the analytical model, four hypotheses were developed, one for each of the four-performance metrics described above. The rail turnaround served as the independent variable for each hypothesis.

The hypotheses were put to the test using statistical tools, and the outcomes were then examined and debated. As the three hypotheses were significant, the research's findings indicated that better (efficient) hinterland transit (rail turnaround) has an effect on port operating performance. To investigate every port terminal and assess the extent to which hinterland transport affects port operating performance as a whole, more research is necessary.

PREFACE

I want to start by expressing my gratitude to everyone who has directly contributed to my thesis. I am aware of how precious your time is, and I sincerely appreciate all the time you have taken to assist me with this project, whether it was by email, phone, comments on my writing, scheduling a meeting, or a face-to-face meeting. I would especially want to thank Professor Ted Welton. I immediately sensed your strong confidence in my abilities, and when I was having second thoughts, your optimistic attitude encouraged me to go beyond what I had originally intended. I want to say thank you for giving me the time to assist with the model implementation. Your knowledge of the model as well as your viewpoints on other topics that were discussed even during days have been a genuine inspiration.

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LIST OF ABBREVIATIONS

PPI – Port Performance Indicators

UNCTAD – United Nations Conference on Trade and Development

DFC – Dedicated Freight Corridor

JNPT – Jawaharlal Nehru Port Trust

BRICS – Brazil Russia India China and South Africa

GRT - Gross Tonnage

TEU – Twenty Equivalent Unit

UNECE – United Nations Economic Commission for Europe

ICD - Inland Container Depot

OECD – Organisation for Economic Co-operation Development

GPS – Global Positioning System

PSA – Port of Singapore Authority

IR – Indian Railways

RITES – Rail India Technical and Economic Services

PETS – Preliminary Engineering Cum Traffic Survey

MOR – Ministry of Railways

CAGR – Compound Annual Growth Rate

GHG – Green House Gas

DMIC – Delhi Mumbai Industrial Corridor

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Chapter 1. Introduction

This study aims to comprehend how hinterland transportation affects port efficiency. It was hoped that the organization and enhancement of hinterland transportation would have some good effects on ports as a whole. It is remarkable that so limited research papers have actually been undertaken to establish the stated impact, and the relationship between the two is still open for future study given the considerable interest in inland transit and its significance for terminals and supply chains. In this chapter, the researcher will draw the main research question and try to answer it by formulating the objective questions. Further, a research methodology would be suggested to analyze the stated objective and significance of the research followed by the structural framework to be adopted.

1.1. Background

Trade has always made a substantial contribution to the global population's ability to create prosperity. Around 80% of all trade is through seaborne and the impact of freight transportation on global GDP highlights a correlation between global GDP growth and trade volume growth in recent years. The history of urban development reveals that economic development is especially prominent with seaports.

Thus, Ports as major centers of trade and economic activity, are being carefully researched and studied to improve their performance and efficiency. This can be seen through the development of new technologies that would provide efficient services at a low cost. In recent years, ports have been increasingly becoming important as they are involved in the transportation of goods or people (Meersman et al., 2010). This paper looks into the role of ports and their importance in a country's economy by cataloging the significant figures concerning this vital aspect. Ports can achieve these benefits by coordinating and organising hinterland transport, as ports are becoming more and more reliant on inland transport to increase performance. This typically refers to the transportation of merchandise to and from the port by inland vehicles, railroads, and inland waterways. Without a doubt, this extends ports' geographic reach to the fullest.

Congestion and inadequate investment in the transportation infrastructure are straining ports. Despite new growth plans, there are still a lot of ports that are failing. This is because there hasn't been enough investment in transportation networks, which has a negative impact on the logistic services and performance of ports. Ports face difficulties with the hinterland issue because all shipping companies, traders, and logistics service providers heavily consider it when selecting a port.

The modern port system has become more complex and challenging, with the increasing size of the containerships and schedules for cargo shipping, ports are often overwhelmed. To overcome these challenges, a strategic land-based transport network is necessary. As a result, in recent years there has been an increase in the improvement of hinterland system designs that transfer goods from ports to inland depots (Woodburn, 2010)

Deficient hinterland transit, in general, not only causes more port congestion, ship turnover, and disruption at the entrances and within ports, but also drives up transportation costs because ships stay there longer, and getting to and leaving the ports takes longer (World Bank, 2008). As a result, all parties involved patch up the delay by raising prices, which ultimately fall on clients and end users.

In this study, the research will take the JNPT port, Mumbai, and the dedicated freight corridor system, as a case and will try to define the correlation between the port and the hinterland transport system. The following chapters will detail how the efficiency of hinterland transportation has been improved and organized in recent years due to political action, nationalization of public transport corporations, rising budgetary allocations to public transport, as well as digitization of both ports and freight transportation systems.

One of India's principal seaports is the Port of JNPT in Mumbai. Over the past 30 years, it underwent significant development. Cargoes for importing and exporting include containers, general freight, and bulk cargo. Due to its status as one of the key maritime trade gateways and the fact that the majority of India's trade is directed north, the Port of JNPT is crucial to the country's economy. Even though it was plagued by ineffective inland transportation networks that led to lengthy lines, pollution, and blockages at the gates that caused interruptions within the port area as the port underwent numerous stages of expansion and concessions.

The Ministry of Railways and the Ministry of Shipping in India made the decision to address this persistent issue. They implemented a freight transport logistics service with the goal of reducing and eliminating all types of snarl-ups and traffic jams in the city and to/from the port, as well as improving logistics services in general.

This study examines the significance of hinterland transportation, specifically rail transportation, to port performance and the relation between the two in an effort to advance our understanding of the effects of hinterland transportation on port operational performance. This study studies, analyses, and investigates the connection to see if hinterland transit affects port efficiency.

1.2. Research Questions and Objectives

The research will concentrate on **How the effective hinterland transport system will improve the port operational performance** using a dedicated freight corridor and JNPT port, MUMBAI as a case study. The case report will emphasize on the Indian Railways' transportation network, in particular, the project that created a dedicated freight corridor for moving products from the country's western ports to its northern region.

The following objectives are intended to be covered and in-depth explored here, and they sum up the focus of this research.

1. To define and assess the terms hinterland transportation and port efficiency broadly;

2. To describe and illustrate how effective hinterland transportation (railways) impacts ports generally;

3. To define and establish the connection between port performance and hinterland transit;

4. To evaluate and explain how the hinterland transport system (DFC) can help India move to a greener growth path, assist industrial zones along the route, and lower the cost of logistics?

5. To list and explain the benefits and challenges that will come with putting the DFC into practice.

1.3 Importance of the research

Understanding the correlation between inland transportation systems and port effectiveness is the goal of this research effort. It places a strong emphasis on examining the results broadly, not just for one port or city but also for any type of port from around the world.

Since there is a dearth of research addressing this phenomenon, this study will add to the body of literature by attempting to enlarge and define the connection between both hinterland transportation systems and port performance. In order to determine the presumptive relationships and effects, a suggested analytical method that believes there is a connection between the port and the hinterland transport system will be tested.

1.4. Methodology

The goal of this study is to comprehend how to improve port performance in the context of Indian ports interacting with hinterland transportation. It starts with a review of the literature and other research that provide a general foundation for understanding port performance and hinterland transit. The correlation between hinterland transport and port performance is then linked and identified. An approach to quantitative research is utilized to accomplish these goals. Therefore, as part of this research endeavour, case study methodology is used for both qualitative approaches and statistical analyses and findings.

After organizing inland transport, the researcher wants to find out if DFC has a favourable effect on port performance. By doing extensive qualitative and quantitative research, as well as collecting additional data and background material from publications, websites, organizational documents, earlier studies, and brochures. By examining historical data using a time series data analysis, and statistical analysis, the researcher hopes to determine if the absence of DFC has had an effect on the JNPT port performance.

1.5. Structure

The following chapters of the research, which include a case study, attempt to explain the various features and connections between hinterland transport and port performance and analyze the results. The chapters are arranged in the following way:

• Chapter 1 presents the study's introduction and historical context, objectives and research questions, relevance and goal of the inquiry, research methodology, and research structure.

The performance of the port and the hinterland transportation system are explained in Chapter 2 via a literature review. Additionally, it lays out the conceptual framework and emphasizes the connection between hinterland transportation and port performance.

• The research methodology, together with the hypotheses and analytical techniques, are presented in Chapter 3.

• Chapter 4 analyses the theories and provides information about India's ports and transportation infrastructure. Additionally, it describes the case study's main focus, the dedicated freight corridor system.

• Chapter five gives a synopsis of this research, as well as the conclusions, restrictions, and recommendations for additional research areas.
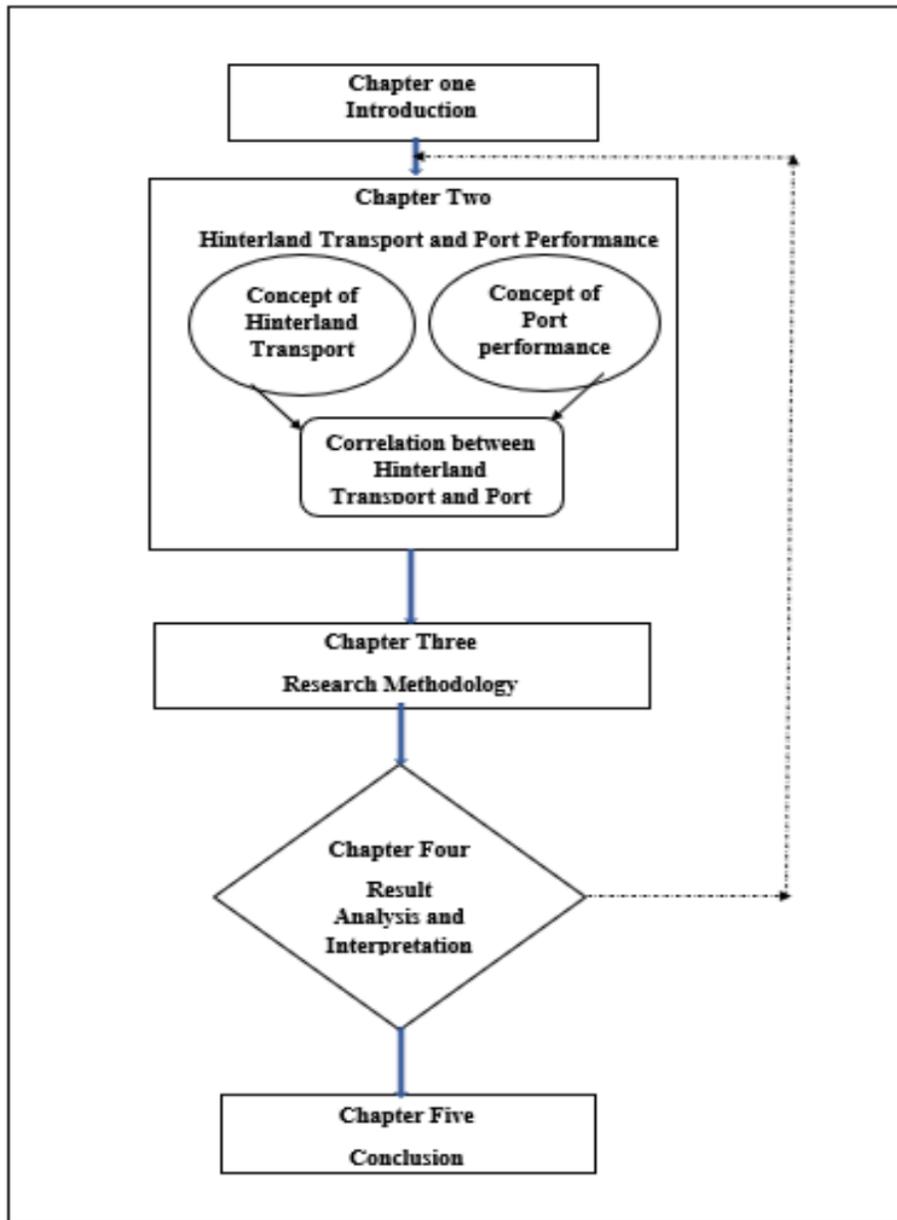
Figure 1: Structural Flowchart

Chapter 2 Hinterland Transport System and Port Performance

Through a variety of literature reviews, the researcher will attempt to conceptualise the Hinterland transport system and Port performance in this chapter. Additionally, we'll aim to narrow down a number of operational indicators, and financial measurements that best reflect the performance of the port and the efficiency of the hinterland transportation system. Additionally, the author will draw several methods and approaches to improve the mentioned metrics and indicators for both port and hinterland system operational performance. The researcher will next determine how the improved and organised hinterland transport will increase the efficiency and productivity of ports and terminals by shortlisting the indicators of the hinterland transport system that will have a direct impact on port performance.

2.1. Principle of Hinterland Transport System

In order to link the local economy with the global economy, hinterland transportation is essential. Regional ports benefit from an increase in competitiveness, particularly when the hinterland system is effective. These locations are crucial for the expansion of both domestic and foreign trade since they cover a wide geographic area. In this essay, various authors have discussed this issue in depth; some have argued that the difficulty of liner shipping has moved from the sea to ports, then to the hinterlands (Guthed, 2005; Notteboom, 2002).

Transport networks in the hinterland are essential to ports since they serve as the major consumer access point. Because the costs of hinterland transport are typically higher than those of ocean transport, it is now crucial to study these systems.

An important consideration in considering the development of container ports is their ability to connect to an efficient logistics network. This provides benefits to both producers and consumers, who will have better access to markets, improved logistics efficiency, and lower costs. For example, manufacturers can ship containers directly from their factory to a hub or export port. Then those containers can be loaded onto ships or rail cars for transport across the ocean or continent. Given that there are often long sea voyages between the hub and final destination, this model results in lower shipping costs per unit transported than transporting goods by train. This approach helps drive up supply chain efficiency through labor savings for importing goods into the cheaper location that wants goods sold locally without wasting resources shipping goods from point A to point B (Acciaro & Mckinnon, 2013).

In order for this model to wor though there needs to be already built out hinterland transportation networks that provide connections between different hubs on the continent.

With the development of bigger container ships, marine container fares have decreased significantly, but hinterland access prices have not. Ports are concentrating on efficiency, market dominance, and economic growth through greater hinterland access as the opportunities for gaining profitability and development through enhanced maritime connectivity are exhausted. The hinterland's definition and level of service, however, have historically been up for debate. For ports looking to enhance demand through reduced transport costs and faster, more dependable access times, objective data on hinterland size, access to ports, and the multimodal split and intermodal connection of that access are becoming more crucial.

2.1.1 Introduction to the Hinterland transport system

The inland region where shipping cargo is gathered is known as the port hinterland. The phrase has been in usage since the early 1980s, but research on the subject did not begin until the mid-to-late 1980s. In order to choose the dynamics of the hinterlands while maximizing the commerce flow in ports, (Ming-Jun and Yan-Ling, 2012) designed a number of optimization methods for a logistics services transport system and financial benefits.

This study's main objective is to examine the functions, characteristics, and benefits of the hinterland. In order to determine if a port offers intrinsic advantages for its hinterland, a methodology for objective evaluation was used in this study. Numerous studies have been done thus far on the function of ports and how they affect the hinterland. A gravity model and a complete assessment model, for instance, were combined by Yang (2002) to describe magnetism and the scope of connection of both a port and its hinterland. Moreover, the World Bank (2008) accurately assessed the reciprocal relationship between the port and the hinterland. On the basis of the force model, a segmentation technique was created. However, few studies have paid attention to the advantages enjoyed by a port over its hinterland.

Regional and national organizations, through their geographical and economic plans, are the primary forces behind the hinterland connection. Government initiatives include the installation of infrastructure improvements, such as establishing industrial and logistical export-oriented facilities and tying infrastructure to current economic growth centers. In order to increase the reach of their port, port authorities engage with and invest in the facilities of those who run interior facilities, logistic support zones, and rail networks. They also actively promote their capabilities outside of their typical hinterland.

2.1.2 Transport Methods and Development in the Hinterland

The size, type, and accessibility of the local infrastructure, as well as the terminal's operation technology, all have a considerable impact on the complexity and intensity of landside activities. Particularly for the large terminals, a combination of locomotive, highway, and, if possible, barge transit is used. However, Zuidwijk and van Asperen state that road transport is still among the main hinterland transport options because of its adaptability and potential reach given that trucks may travel everywhere there are roads. There are three basic types of hinterland transportation as follows:

1. **Inland waterway transport (barges)**

Inland waterway transport is the movement of goods across inland canals, rivers, and lakes on ships, barges, or any other type of watercraft. between harbors and ports. It is regarded as the most ecologically benign form of transportation while being underutilized. Transport across inland waterways is essential for getting goods and people from distant locations to larger or more developed cities. In industrialized nations, it is seen as a very advantageous option to ease traffic congestion and lessen the environmental consequences of vehicle emissions; this fact aids in inland waterways' expansion and development.

Additionally, inland waterway transport has grown significantly in significance due to its affordability and dependability, which has drawn numerous container shippers that have been using barge transportation since the 1980s. Approximately 500 million tons of commodities were moved over inland waterways in Europe in 2007, up 4% from 2006. Additionally, although the volume of commodities moved in the United States in the same year was around 800 million tons, China and the Yangtze River expanded inland canal traffic to 1.3 billion tons. UNCTAD (2008).

2. **Railway transport (Trains)**

Railway transportation has advanced substantially in recent years and is now capable of transporting ordinary goods, containers, and dry and wet bulks. The rise of demographic factors and the globalization of trade led to improvements and developments in railway traffic all over the world, particularly in BRIC nations. (UNCTAD, 2008),

Europe experienced a similarly rapid pace of railway expansion, whether it be within particular countries like Germany, the Netherlands, Belgium, and Sweden, either across countries to serve more expansive hinterlands. Many countries, like Chile, the United States, China, and Russia, are still developing. By doing this, it may be possible to use an alternative mode of transportation to service the hinterland, improving logistical and the distribution network and improving efficiency at the terminals.

Employing rail and barge is highly recommended since they offer considerable economic and environmental benefits. On the contrary side, this kind of development (12) needs the right infrastructure, which entails investment and successful cooperation between numerous commercial and public investors and organizations. As a result, specific policy action is needed for the integration to be effective. Increasing terminal connectivity with multimodal transportation is a desirable strategy, despite the fact that many countries may not invest in railroads.

3. Road transport (trucks)

Road transportation refers to the movement of goods primarily via the use of automobiles with roads as their primary network. It is more widely utilized to transfer containers, freight forwarding, and dry/wet bulk materials to the hinterlands. When the system as a whole lack coordinated component consolidation and/or cross-country outreach, using road transportation can lead to a number of issues, including traffic congestion, infrastructure strain, and issues with safety and the environment.

Despite this, 90% of inter-urban traffic in Europe is still transported by road, indicating that roads continue to be the most popular form of hinterland transportation (UNCTAD,2008). Practically, trucks account for the majority of port hinterland traffic, which is why there is typically so much congestion in and around port districts.

Therefore, a modal shift from vehicles to train or interior waterway transport was included by many ports in their strategic plans; nevertheless, not every port is well interconnected to developed rail networks or has inland waterways. Additionally, in some ports, even if using railroads is an option, the expense can outweigh the benefits. A modal shift is therefore not feasible in many ports, but a range of instruments can be used to decrease the impact of truck utilization in hinterland transportation.

2.1.3 Performance Evaluation of the Hinterland

Due to the lack of data and consistency issues, the UNECE study (Woodburn, 2010) claims that there is no consistent technique for measuring hinterland connection performance. This makes the comparison challenge. The World Economic Forum presents a global comparison of nations on the foundation for logistics operations, which strives to gauge a country's logistical performance; Without a doubt, this includes the hinterland connections in the index. The hinterland connection performance may be included in three important indexes, According to Woodburn (2010), the indexes are:

- **The Logistics Performance Index (LPI):** The World Bank's Logistics Performance Index (LPI), gauges a nation's logistics performance friendliness The World Bank (2007b) states that there are six main components that make up the LPI. They also assess how trading partners' opinions of the logistics environment compare to their own. Customs, border controls, transportation standards, shipment planning, the local logistics sector, domestic logistics costs, the capacity to trace shipments, the timeliness of shipments arriving at their final destination, and IT infrastructure are all included in this. The index also offers statistics on the real-time cost performance for the nation of operation and the logistics environment in the home country of operation.
- **Trading Across Borders indices:** The World Bank's Trading Across Borders indices, concentrate on the exact steps necessary to export and import products in various nations.
- **The Enabling Trading Index:** The World Economic Forum's Enabling Trading Index examines market access, border management, communication and transportation infrastructure, and the business climate.

At the particular port or corridor level, hinterland connectivity is not routinely examined. Ports can evaluate the performance of the hinterland in terms of connectivity to inland sites by examining the number of interior terminals served, the volume of service, the transmission time, the response times, and the products that terminals or geographical areas get. Environmental performance measurements are also becoming more significant (Woodburn, 2010).

2.1.4 Methods to enhance the hinterland transportation efficiency

Private firms, commercial shipping, terminal operators, logistics providers, clearance brokers, trucking, rail, and barge companies, as well as public organizations including customs authorities, inspection services, and operators, are all involved in hinterland transportation. In order to enhance hinterland transport. (De Langen et al., 2007) analyzed the coordination in that sector and offered numerous methods to boost coordination in regions with larger supply and logistics network constraints.

As a result of free-riding issues, communication discrepancies, and the requirement for contractual obligations that arise from a disparity between the expenses and benefits and a lack of investment zeal, they claimed that the absence of rewards and desire for future collaboration could impede progress. It was recapped that coordination problems are brought on by a number of things, such as poor information sharing, difficulties with investment opportunities, new products necessitate fundamental quantities that may be denied if not met, inadequate making plans on cargo containers, delays with formalities and inspections, and a lack of understanding regarding the clearing customs of containers.

Additional major mechanism frameworks that have been implemented to improve coordination include the establishment of incentives, such as a compensation system, various price points, remuneration, the formation of multi alliances, changes to organisation scope, and the layout of collaborative efforts by port authorities and transport companies. The ports in Europe experienced improvement and solved a number of concerns with the shipping of the hinterland thanks to the organised and categorised one of the aforementioned solutions to every logistical issue.

- **Optimisation of truck and rail transit**

  Numerous studies have explored and looked at ways to improve the effectiveness of hinterland transportation. It was observed about 13% of trucks had incorrect paperwork. Also, one of the primary causes of port gate congestion was thought to be the fact that only 50% of import container truck drivers have the correct documentation. Traffic ahead of the entry gate could be reduced by getting rid of these trailers. Ports have therefore implemented a variety of initiatives to improve truck traffic, reduce congestion, and address other effects of significant reliance on truck systems. The following are the approaches: Notteboom (2008).

1. **Improvement in port entry gate procedures**

   The port gate method was implemented in many ports and port cities to decrease idle vehicles in ports and moderate traffic in order to lessen urban congestion and environmental effects. The port appointment scheduling and system for a simulated container yard are the main policy tools in this regard.

   The **truck/rail appointment system** is a program that provides a platform to arrange vehicles themselves in the appointment system. An effort to reduce traffic on the highways leading to terminals or at terminals. The benefit of this technique is that terminals schedule the arrival of trucks/rails at ports, allowing them to distribute the truck/rail flow more evenly throughout the day. These programs have enhanced terminal output, enhanced efficiency for transport businesses, and improved the flow of trucks/rails. Also, minimizing the turnaround time

   By providing stimulus to encourage the usage of **off-peak hours** that reduce bottleneck at the ports, extended gate-hours attempt to reschedule the times of trucks/rails that arrive at port terminals throughout the day. However, this program has limitations, such as long lines just before the start of the off-peak period.

   The extended gates plan to relocate a component of the port closer to the hinterland by transferring logistics operations, inspections, and other official processes to an internal port. As a result, less traffic is generated at the port's gates and terminals.

2. **Dedicated Freight Corridor**

   Many nations developed the concept of designated freight route lines and corridors to speed up continuous freight transit and enable a very small amount of mixing with the transportation of urban passengers.

3. **Use of Automation & technology**

   Apart from some internal transit at industries or container yards, automated transport continues to be in its development. Nevertheless, automated freight transit is nevertheless extremely infrequently used. Automation is becoming increasingly popular due to its many advantages, including minimized labour costs, 24/7 operations, and improved reliability. The most relevant automated transport technology for shorter-distance container shipping for hinterland transport are

   Automated trains, automated barge handling systems, automated capsule/alternative rail systems, automated trucks and multi-trailer systems, etc.

2.2 Principle of Port Performance

Ports serve as the primary point of contact for interior transportation, goods, and ships that arrive at the port from the sea for transhipments or travel to the heartland. According to UNCTAD (2015), more than 70% of global trade's value and around 80% of its volume are moved by water and processed at ports, making port performance extremely prime. Due to their dependency on terminals, which caters to the majority of their trade, many developing nations see the importance of this situation as being even greater.

Given the limitation, to the total no. of ports around the world, it is essential to have effective terminals that minimize traffic, facilitate commerce, and so raise a port financial system and port competitiveness. Ports may please carriers by providing excellent services for ships docking at their docks. On the other side, ports could not provide enough services for the interests of cargo, such as bad interior transit or poorly treated cargoes, meaning less added value or subpar services.

In the end, this circumstance is what leads to some consumers' dissatisfaction with what they see as inadequate performance. Port efficiency, often known as performance, measures many elements of port operation as an output in relation to input (Song & Cullinane, 1999). On the other hand, due to the desire of all stakeholders to work with an effective port that consistently produces excellent performance, assessment of such performance has grown in importance.

Song (2012) asserts that Performance evaluation is constantly desired for a variety of reasons, including:

1) activity monitoring;

2) performance comparison based on prior performance;

3) performance comparison of the intended results;

4) performance comparison against competitors;

5) target adjustment;

6) business promotion; and

7) evaluation of port efficiency, productivity, and effectiveness.

Because ports vary in size, the quantity and size of ships that call them, and the variety of commodities that pass through, benchmarking performance measurement is quite complex.

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The takeaway from this is that port performance is not evaluated just on the basis of its proximity to the sea. It is a collection of intricate processes and all-encompassing actions taken into account. In reality, ports involve a composite set of activities with a wide variety of sources for input and output, making comparisons between two ports is quite challenging.

 The following elements need to be considered when evaluating port performance:

1) The length of the ship's port stay (ship turnaround);

 2) The efficiency with which cargo is handled;

3) The level of service provided by the inland transport system while they are at the port.

The idea of port efficiency has expanded quickly and begun to be applied broadly. It's now more complex and demanding than it used to be to monitor port performance (De Langen, 2004) However because performance is usually used in conjunction with port efficiency and effectiveness, it also includes the overall throughput, services, and economy of the port. In order to define the necessary steps, we genuinely need to comprehend and identify all port performance measures. Most ports employ key performance indicators and port performance indicators to achieve the above.

The trade for a nation's port services is measured and evaluated using the port operational performance indicators. Thus, if objectives are set for key performance indicators, the port performance indicators may be measured and improved. For the future creation and administration of the implementation of new projects, like the establishment of a new transportation system, the problem of performance assessment and monitoring is of utmost importance (World Bank, 2007b).

2.2.1 Port Performance Indicators (PPIs)

UNCTAD (1976) advised that port performance metrics can be divided into financial indicators and operational indicators, which are depicted in the following Tables. Although it is still a good strategy to set up port performance, this method is regarded as a more conventional one that uses productivity and effectiveness as indicators.

Table 1: Financial Indicators

Finanacial indicators	Units
Tonnage worked	Tons
Berth occupancy revenue per ton of cargo	Monetary units/ton
Cargo handling revenue per ton of cargo	Monetary units/ton
Labor expenditure	Monetary units/ton
Capital equipment expenditure per ton of cargo	Monetary units/ton
Contribution per ton of cargo	Monetary units/ton
Total contribution	Monetary units/ton

Table 2: Operational Indicators

Operational indicators	Units
Arrival date	Ships/day
Waiting time	Hours/ship
Service time	Hours/ship
Turnaround tome	Hours/ship
Tonnage per ship	Ton/ship
Fraction of time berthed ships worked	-
Number of gangs employed per ship per shift	Gangs
Tons per ship-hour in port	Ton/hour
Tons per ship-hour at berth	Ton/hour
Tons per gang hours	Ton/hour-hour
Fraction of time gangs idle	-

Resource: (UNCTAD.1976)

The performance measurement that UNCTAD has suggested includes the conventional PPIs, which are frequently mentioned in the literature and include productivity and effectiveness measurements. The most recent PPIs can mimic the current scenario and the pertinent demands of ports, despite the fact that more PPIs for expanded logistics solutions have been approved and developed. Current indicators suggest that in addition to quantitative assessments, the port performance and efficiency assessments should also contain qualitative ones (Anto et al., 2005).

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2.2.2 Key performance indicators for terminals

Due to the increasing expansion of the container trade, ports are concentrating on measuring and enhancing container terminal performance indicators. In addition, inter-ports in the surrounding areas compete fiercely with one another to draw in more clients and create an example of first-rate service that increases consumer satisfaction overall. Hassan et al. (1993) suggested classifying closely connected port activities into four categories: the management of cargo, stowage, inland transit; and maritime operations.

Koh and Ng (1994) similarly separated terminal operations in container ports into the following categories:

1) Berth operation: Here, the duration a vessel spends in the quay—commonly referred to as vessel turnaround time—is crucial. Vessels are given particular quays, quay-cranes, and other terminal handling systems upon arrival in order to execute the transfer of goods.

2) Ship operation: Here, the goods are exchanged into and off of the vessel using a certain number of cargo handling equipment; in this regard, an excellent strategy to attain high productivity, is measured in TEUs carried out to maximize the output per hour.

3. Yard operation: Of all tasks that include handling containers from truck transport and/or moving them to other yards, this one is said to be the busiest.

4) Gate operation: This refers to the transit of commodities by trucks and railroads to/from the yard or dock. In general, freight forwarders are skilled in this type of transit.

5) Scheduling: This crucial task ensures that various resource pools, including prime movers, yard cranes, gantry cranes, and other handling equipment, are planned and used effectively while taking into consideration constraints and varying needs.

Additionally, Thomas and Monie (2000) divided performance metrics into four categories with regard to the aforementioned tasks, as indicated in Table 3. These groups are;

- **Production measurements:** Throughput measures, which indicate the effort required to move that cargo in terms of container movements per unit of time, are also known as traffic measures and are defined as "the amount of goods going to pass through a terminal in time interval. ("Measuring, 2012).
- **Productivity measurements:** Productivity is generally understood to be "the ratio of output to input, measured in terms of the quantity of production (items, tones, units,

etc.) achieved per unit of resource" (per person, per square meter, per piece of equipment) in unit time (day, week, month, etc.). This measure is essential for the terminal operator because it affects the cost of running the terminal.

- **Utilization measurements:** These indicate how intensely terminal resources are used. They are normally computed as a ratio, between a resource's actually used and its maximum permissible usage for a specific time frame ("Measuring, 2012).

- **Service measurements:** It shows the level of facilities provided to the port clients, including vessel operators, cargo traders, receivers, and transportation facilitators. They represent the clients' fulfillment with the facilities provided by the terminal. In addition to trade, traffic, and efficiency, terminal operators must also consider how well the terminal satisfies the needs of customers for a dependable, consistent, and quick response ("Measuring, 2012).

Table 3: Port Performance Measures

Category	Relevant measures	Reflection
Production measurement (traffic throughput per unit of time)	Ship throughput	The number of containers the ship loads or unloads in a specific time frame (a shift, day, month or year).
	Quay transfer throughput	Handling tonnes of containers between the quay and the storage area
	Container yard throughput	Movements sum in the storage areas
	Receipt/delivery throughput	Outbound & inbound containers
Productivity measurement (ratio of the output to the input)	ship productivity	Rate of processing containers from a ship's call to the length of time needed to serve the
	Crane productivity	calculated in gross and net values per crane
	Quay prodcutivity	Relationship between production and quay resources in terms of unit time, working with quay length, or per quay metre
	Terminal area productivity	ratio of total terminal area to terminal production for a given unit of time.
	Equipment productivity	Number of container transfers for a particular handling equipment machine or for the stock of a same type of machine every working
	Labor productivity	Productivity of man-hour over a measured period
	Cost effectiveness	Cost of handling terminal container traffic or throughput over a specified period, month/year

Utilization Measurement (how intensively the production resources are used)	Quay utilization	Amount of time that the birth was occupied out of total time available
	Storage uitlization	Comparison of the percentage of storage spaces utilised vs all the spaces available based on the yard's design capacity
	Gate uitilzation	Processing of entering and departing inland vehicles at the gate efficiently.
	Equipment utilization	Percentage of time it was used throughout a certain time period.
Services Measurement (reliability, regularity and quickness of services)	Ship turnaround time	Total amount of time a ship spends in port during a particular call. the total of waiting time, berthing time, or the amount of time a ship spends at a berth, and sailing delay
	Operational dwell time	Total days that departing containers arrived at the port before the scheduled time and the total number of days that incoming containers stayed in the container yard after they were available for pickup.
	Road vehicle turnaround time	Duration of loading or unloading a container at the terminal
	Rail service measures	Time taken by rail to return to port

Resource: (Thomas & Monie, 2000)

2.2.3 Port Operating and Financial Measures

The standard indicators of port operation and financial performance were specified within a set, as per the World Bank's (2007b), Port regulatory module. To be consistent with the several primary categories of port traffic and vessel types, such as containers, dry bulk, and liquid cargoes, separate values for metrics must often be stated. These indicators make it easier to see success across several areas. These indicators and the methodology of computation are described in Table 4.

Table 4: Standard Performance Indicators

Finanacial Measures	
Operating surplus per ton handled	Net operating income from port operations divided by total tonnage of cargo handled
Charge per TEU	Total charges for container handling divided by total TEUs handled
Collected charges per billed charges	Total collected charges as a present of accounts billed (with 30-day lag)

Operating Measures	
Average ship turnaround time	Total hours vessel stay in port divided by the total number of vessels arrived at the port.
Average ship waiting (idle) time (for berth)	Total hours of vessels waiting for berth divided by total number of vessels berthed
Average vessel time at berth	Total hours alongside berths divided by total number of vessels berthed
Average waiting rate (%)	Total hours vessels wait for a berth divided by total time at berth
Gross berth productivity	Number of container moves or tons of cargo divided by the vessel's total time at berth measured from first line to last line
Berth occupancy rate (%)	Total time of vessels at berth divided by total berth hours available
Berth utilization rate (%)	Total time that ships actually work divided by total time of ships alongside (time that the berth is occupied)
Working time over time at berth	Total time of vessels being serviced at berth divided by total hours at berth. Reasons for non-working time may include labor disagreements and work rules, rain, strikes, equipment failure, port operating schedules, and holidays
Cargo dwell time	Cargo tons times days in port from time of unloading until the cargo exits the port, divided by cargo tons
Ship productivity indicator	Total number of moves (for containers) or tons handled (for breakbulk and bulk cargoes) divided by total hours in port
Tons per gang-hour	Total tonnage handled divided by the total number of gang hours worked
TEUs per crane-hour	Total number of TEUs handled divided by total number of crane-hours worked
Average Tons per ship-day (hour)	Total tonnage of cargo handled divided by total number of vessel days in port
Average vessel call size	The average in tons

Resource: (World Bank, 2007b)

The operational reports created by port or terminal operators often make the input data easily accessible. As an alternative, the berth occupancy indicators for bulk, general cargo, and container ships are determined separately. For instance, the input data for vessel waiting times are typically also available from ports,

The average waiting hours per ship, broken down by commodity type, are used to construct the ship waiting time indicator. Additionally, the average waiting time is frequently contrasted with the average berthing time to produce the ship waiting rate. In this regard, berth occupancy, berth utilization, and waiting times are unmistakable signs of under-capacity, which in turn might point to not just port congestion and poor performance but also a lack of significant competition (World Bank, 2007b).

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2.3. Correlation Between Hinterland Transport system and port performance

It is evident from a survey of scholarly research as well as existing frameworks and policies that port hinterland transport has gained importance since it affects all supply and logistics chain policymakers. Therefore, rather than concentrating on individual legs, policy-makers in the logistics services are likely to take into account the features of the entire network (Woodburn, 2010).

Exists a significant danger that terminals may see a loss of traffic if their hinterland network are ineffective or expensive, as they increasingly prove to be the chain's most vulnerable link. This indicates that one of the elements affecting port performance is the hinterland transport system since it significantly increases port productivity and efficiency. Performance at the port will be better and more efficient the better organized the transport system is.

No matter how strong the port infrastructure is, inadequate or poorly coordinated hinterland transit still degrades port performance as previously described. For instance, merchants and shipping lines could think twice about doing business in that port. As per (Acciaro & Mckinnon, 2013), with the evolvement of the supply chain and hinterland transportation system, shipping companies possibly shift ports of call and only resort to alternative terminals in order to maintain adaptability and secure capability. Due to higher ship turnaround times, these Ineffective terminals become less competitive, which often has a negative impact on the entire supply and logistics chain and higher inventory costs.

Additionally, one of the most crucial aspects of the logistical organization is hinterland transportation. Transport from and to ports is typically thought of as being essential for shippers, carriers, consignors, and consignees. All of them look for routes with cheaper costs, ports with effective hinterland access via dependable forms of transportation, and ports with a minimum ship waiting times. The effectiveness of hinterland transit is what maintains the port's performance; in fact, it is an important aspect of terminal efficiency.

Horst and De Langen 2008 emphasized this point by stating that "Ports and their hinterland transport networks could only draw and handle increased container traffic if the hinterland transport network is handled effectively and successfully." To put it another way, there is evidence that there is a correlation connecting hinterland transit and port effectiveness whenever the terminal utilization grows as a result of efficient hinterland transport (container traffic).

Because of this, ports play a significant role in hinterland transportation. Therefore, a key strategic objective for all ports is to maintain and develop reliable transit opportunities for port clients throughout the logistic system. Decreased cost-effective container flows and potential degradation of transportation quality and stability follow the loss of terminal profitability in geographic hinterlands. Additionally, a seaport's ability to compete depends on how quickly the goods it handles can be transported to its hinterland destination (Notteboom, 2008). As a result, one of the most basic concerns affecting growth globally is recognized as the critical importance of hinterland links.

However, the links between port hinterlands have not progressed at the same rate as ship size economies of scale and the emergence of focal point ports (Merk &2015 (Notteboom). Hence, it is obvious that this has made the bottlenecks in the hinterland worse and consequently lowered the port's effectiveness.

2.3.1. Hinterland and Ports as Logistics Chain

The liberalization of international commerce, globalization, industrialization, and the development of the geographical distribution of commodities have all contributed to a relatively rapid increase in world throughput during the past few decades (OECD/ITF, 2016). Numerous port-related factors, such as the hinterland transport connections, came under a lot of pressure as a result. The associated financial, societal, and environmental challenges, as well as, more significantly, cost and expenditure issues, such as higher inventory costs brought on by ineffective hinterland transit linkages, increased as a result. (Woodburn, 2010).

According to research the performance of the transportation system and the cost of logistics have a direct impact on the shape and determination of trade costs. Additionally, the expense of transportation is still seen as a roadblock to international trade.

The global supply chain urgently needs effective inland and sea transportation infrastructure in such a globalized environment. The role of ports and hinterland linkages has been significantly impacted by the growth of global logistics chains (OECD/ITF, 2016). In the literature, the idea of port hinterland-associated concerns was well addressed and debated. For instance, De Langen (2008) stressed that door-to-door services, in particular, are expensive in the transportation chain, and are larger than the combined costs of sea transport and ports. Additionally, Notteboom (2008) said that as inland transit quality connects their clients and influences door-to-door, carriers are aware of its expanding relevance.

In order to participate in the interior operations supplying ports and hinterlands, shipping companies have gained or strengthened cooperation and arrangements with terminal operators. Additionally, the literature covered the logistics chain and its components generally, providing a broader perspective on the hinterland transportation system and how it influences the terminal and its operations. The majority of participants agreed that a terminal's development and competitive edge relied on a variety of dynamic elements, including its hinterland linkages, in addition to its established infrastructure, high productivity, and performance.

An efficient and dynamic hinterland transportation infrastructure that is tightly connected with the supply chain and logistics is essential. This unquestionably enhances the port's basic functionality. Song and Panayides (2008) identified key factors that enhance the unification of the port's distribution network, which will boost its efficiency and competitiveness, including, among other things, the interaction with inland transport providers.

The container terminals are seen as a key link in the world's logistics network, hence rivalry between ports now focuses on competition across transport chains. Ports are therefore eager to improve the standard of their inland transportation infrastructure.

For instance, in recent years, European ports' ability to reach the hinterland has been viewed as essential to their profitability (De Langen, 2004). Given the central role that port terminals play in the supply chain, greater tracking, extensive container visibility, and a focus on environmental concerns and regulatory compliance are all necessary for terminals to become more productive and reliable. An effective hinterland transportation system that allows for information sharing and easy tracking of the movement of products and containers to and from destinations might meet this requirement.

2.3.2. Hinterland Transport and Port Performance Relevance

One of the most crucial elements affecting port performance is the congestion problem, which may also affect port subsystems like the hinterland transportation system. However, port congestion is either on the coast or inland. Berth occupancy and ships waiting for berth are the two metrics that translate port congestion in terms of a seaside bottleneck (World Bank, 2007b).

Besides, there is a clear correlation between berth occupancy and ship waiting time. That is, there are typically no or few ships waiting when berth occupancy is low. Contrarily, at a certain occupancy level, ship waiting times start to swiftly grow; as a result, even a modest increase in berth occupancy leads to congestion and lengthy ship wait times.

Specifically, On the quay, cargo is laden and discharged from ships and the stowage yard, respectively if trucks or trains arrive at the port on time. As a result, more room is made, allowing the port to accept more ships and handle them more rapidly. Because of issues with interior transportation, ships do not need to wait at the port for very long, this does certainly improve and boost berth occupancy and waiting rates. Additionally, by doing that, ship turnaround time gets even shorter. As a result, these port performance metrics for congestion at the seaside would reflect hinterland transport performance.

On the other hand, truck/rail transport is thought to be the trigger for landside congestion, which often happens at the gates of terminals or ports. Therefore, transportation plays a critical part in the subject of holistic port performance whether it is organized, or if it is not effectively organized, it increases traffic and gridlock. In essence, this argument is strengthened as referenced in (Acciaro & Mckinnon, 2013) finding that inland transportation, particularly rail, may improve port operations' efficiency.

Additionally, because a terminal's overall efficiency depends on the effectiveness of its many subsystems, terminals are especially concerned about gate delays because they induce congestion and ultimately impair port effectiveness.

Particularly in the case of the truck/rail, it is necessary to monitor the turnaround time from the marshaling yards outside the port in order to identify any difficulties and make additional improvements. Additionally, as it affects the entire truck/rail turnaround time, the waiting time at the gate, which depicts the time taken by the transit system to and from, has to be looked at. One may draw the conclusion from this that perhaps the most noteworthy inland transit operations metric is the truck/rail turnaround time. Because it includes the majority of the

congestion issues and improvements inside it. Factors such as a high truck/rail turnaround time mean trucks/rails are continually running late and take longer to reach the quay at the port, and they also cause difficulties in the port such as either within the terminal or at the gate.

Since most ports oversee the common elements of their operations, statistics on significant port operations have always been quite simple to collect. Because pertinent statistics are crucial for cargo carriers, terminal service providers, and port competitiveness. Port operators are compelled to make them available. The government of Canada has created a transport fluidity index. It is made up of metrics that emphasize hinterland intermodal services and port performance (OECD/ITF, 2016). Utilizing the fluidity index effectively allowed Canada to compete with US port routes by promoting and developing transport services through its gateway ports to US industrial hubs.

The metrics of port operations such as ship turnaround time, ship turnaround per container, the number of vessel calls, vessel sizes distribution, port productivity indicator, and cargo dwell time were the main topics of discussion (see Table 5). The indications distinguished between different types of operations, such as bulk and liner services. In addition, the Canadian government collaborated with transportation operators and 27 firms to use GPS data to identify congestions near or at the port.

Table 5: Indicators of Port Efficiency with respect to transportation

Intermodal indicators (containers)	Units
Vessels turnaround time	Hours
Vessel turnaround time per TEU	Seconds/TEU
Average vessel call size	TEU
Berth Utilization	TEU/m. of workable berth
Import container dwell time	Days
Dwell target - % under 72 hours	%
Vessel on time performance	%
Gross port productivity	TEU/hectare
Gross crane productivity	TEU/gantry crane
Container throughput	TEU/month
Bulk indicators	Units
Vessel turnaround time	Hours
Average vessel call size	Tones
Berth occupancy rate	percent
Gross berth productivity	Tones/hour

Resource: (OECD/ITF, 2016)

Overall, it was evident from the review of port performance indicators that there are several PPIs in use. The port determines the performance metrics to differentiate the port from other

ports and to expand its commerce to be more profitable and effective. However, different ports employ various PPIs. This implies that there is no standard method for calculating indicators.

In conclusion, as discussed in the literature, if we want to examine the connection between hinterland transportation and port performance in detail, we choose the terminal performance measures that would incorporate the congestion variable inside them, such as the berth occupancy and berth productivity, as well as ship turnaround time. Truck/rail/barge turnabout, contrarily, is the indication that typically takes into account the transportation performance and is seen to be a strong element reacting with port performance when it comes to the hinterland transport reaction. It demonstrates if traffic is a result of trucks/ rails standing idle at ports or whether it is controlled and organized.

2.4 Theoretical Framework

It is clear that in order to enhance and strengthen the transport linkages to the hinterland, an administration that oversees ports must utilize its best strategies. It is thought that the right hinterland transportation plan affects port efficiency, port competitiveness, commerce flow, and the nation's economy. As a result, transportation and logistics specialists took this into account and included hinterland links as a crucial link in the logistics services. Without a doubt, inland transportation is a significant problem for port access. If the hinterland network is maintained and governed properly, it draws more consumers, traders, and shipping companies and promotes additional cargo flow.

On other hand, if their hinterland transit links are ineffective or expensive, ports run a significant danger of losing traffic. Therefore, for effective hinterland transport, stronger strategies and greater coordination must be put into place to minimize problematic situations like gate congestion, which eventually damage terminal efficiency and the entire logistics system.

In brief, inland transport is the most crucial port facility and thus plays a very significant and irrefutable role in port performance. In other terms, it is a port subsystem that serves to measure port performance.

Notably, the literature in this chapter emphasizes the value of the inland transport link system to the ports while discussing the significance of both inland transport and logistics services. The research does not, however, seem to agree on a clear metric alignment (numeric) of the link between inland transit and port efficiency. As a result, the researcher wants to look at a

port's performance where the inland transport system has been appropriately upgraded throughout time. It is a railway transport system in this instance. Finding the connection and effect between hinterland transportation and port operational performance is the primary goal.

The performance and efficiency of container terminals, however, can most often be evaluated by four port performance indicators, namely ship turnaround time, berth occupancy rate, gross berth productivity, and average ship call size, as discussed in the earlier literature review. These measurements also indicate intermodal transportation performance just like the Canadian fluidity index does. Additionally, as previously mentioned, some of these indicators include the seaside congestion factor, which is thought to be impacted by a variety of reasons, including the disruption brought on by inefficient hinterland transportation and those indicators are ship turnaround time and berth occupancy rate.

Regarding the other two indications, the first one would be the berth productivity, or gross berth productivity, which would increase in the case of the container terminal if the rail movement was quick and effective. The average ship call size is the last indicator. Over time, if a port is doing effectively, especially after it has very effective hinterland transportation, shipping lines will tend to call at ports with bigger ships. As stated previously in this chapter, the literature on hinterland transport, vehicle turnaround from the marshaling yard, and vehicle waiting time at the gate that is, how long vehicles wait before the gate can all be used to describe the performance of the hinterland transport.

The conceptual framework of the researcher presupposes that port operational performance is influenced by hinterland transit. In other words, as soon as transportation enhances, the terminal efficiency also improves over time. Figure 2 displays the theoretical foundation of the operational effectiveness of the terminal and the hinterland transport link. It displays the basic framework described above in brief and relationships direct or indirect that have been hypothesized.
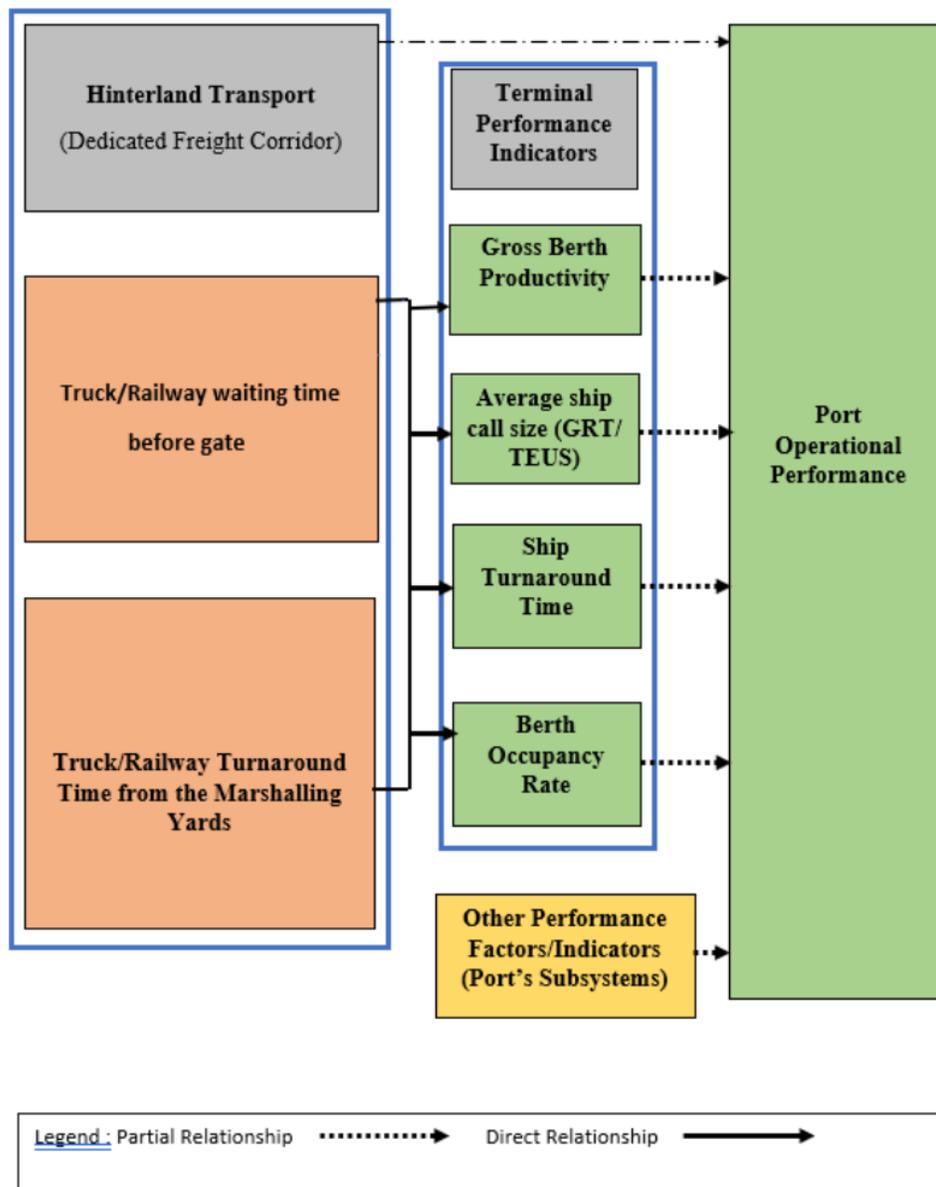
Figure 2: Theoretical Framework

Legend : Partial Relationship ┄┄┄► Direct Relationship ──►

2.5 Conclusion

This section has offered a response to the first two research questions by thoroughly examining the literature on the idea of inland transport and port efficiency. The association between port performance and the increase of hinterland transport efficiency over time might be demonstrated. It follows that once hinterland transportation is effective, port operations are facilitated and enhanced, as seen by increased port performance.

The research demonstrated the significance of inland transport for ports as a component of the port subsystems. The link between hinterland transport and port performance was also aligned in this chapter. Additionally, a conceptual framework explaining this relationship was introduced. This framework will be operationalized by a statistical method in the following chapters to clarify this presumption.

The following chapter will discuss the Indian transport system, Indian ports, and the Dedicated Freight corridor system as the case utilized in this research to provide a thorough overview of both ports and transport systems in India.

Chapter 3. Research Methodology

3.1. Introduction

In chapter two, the connection between hinterland transportation and port efficiency was addressed, and a review of the literature was done to determine the significance of an effective hinterland transportation system. In light of this, it was deemed that hinterland transportation has an impact on the efficiency of the port. That is, after the transportation in the hinterland is improved, there is some improvement in port performance. Consequently, an analytical model will be the conceptual framework and will be operationalized further in this chapter through hypotheses, the base for our quantitative research. Also, time series data for the past five years i.e 2016-2021 will be collected to assess the performance measures for hinterland transport and port efficiency and will form the base for qualitative research.

3.2 Data Collection and Descriptive Analysis

The Ministry of Ports and Shipping (India), Ministry of Railways (India), and Indiastats database, specifically for port performance data and rail turnaround time, were the sources of the data used to test the hypotheses. The main port, more notably the container terminal, was selected. The port data, which includes the terminal gross tonnage, size of the vessel (TEUs), port entry/exit date and time, berth entry/exit date and time, work start time at berth and end time, cargo weight, and the number of berths used, is first gathered from monthly observations over a five-year period between April 2016 and March 2022.

In order to ensure that no data is lost, the data was evaluated by making sure it is in harmony and in compliance with the dates given. Additionally, duplicate information was removed and all ship calls were included. The values of the four performance indicators that in this study explain the performance of container ports were then determined using data. The data was then prepared for use in additional testing and analysis after being averaged and combined into monthly observations. The rail turnaround time was generated using monthly observations from the Indiastats database. On the other hand, bivariate data makes an effort to link two variables together by looking for correlation and covariance. Where covariance is positive when both data elements move in the same direction while it is negative when data points move in opposite directions. The relationship between the two forms of data is studied after they have both been acquired. The generated data, which is based on 72 observations, represents the following variables in monthly observations in figures below represent the spread of data and are utilized in the model:

Average Ship turnaround time: The number of hours on average that ships spend in port, or buoy to buoy time, divided by the total number of ships that have called at the port, is the average ship turnaround time. The data for this variable are displayed in a scatter plot and trend line in Figure 3. The ship turnaround time trend appears to have gotten shorter over time.
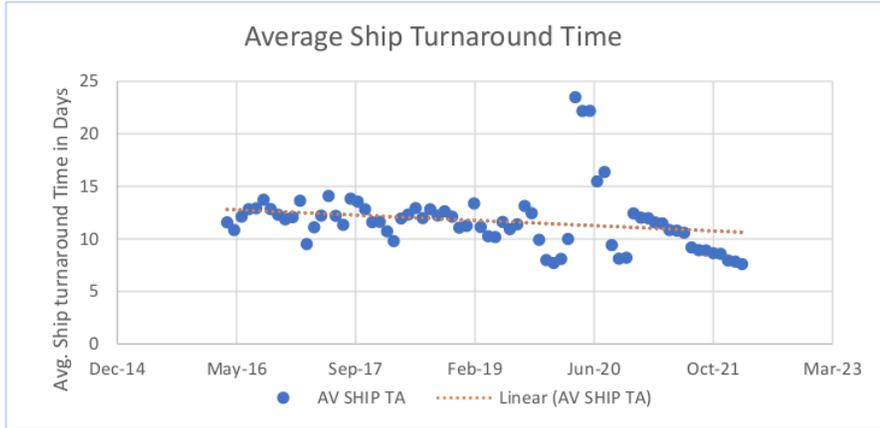
Figure 3: Average Ship Turnaround Time

1. **Average gross berth productivity:** Average gross berth productivity, expressed in teus per day, is calculated by dividing the volume of cargo handled by the container terminal by the length of time the vessel was berthed. The data for this variable are displayed in a scatter plot and trend line in Figure 4. It appears that the cargo flow at the terminals is increasing, as shown by an upward trend.
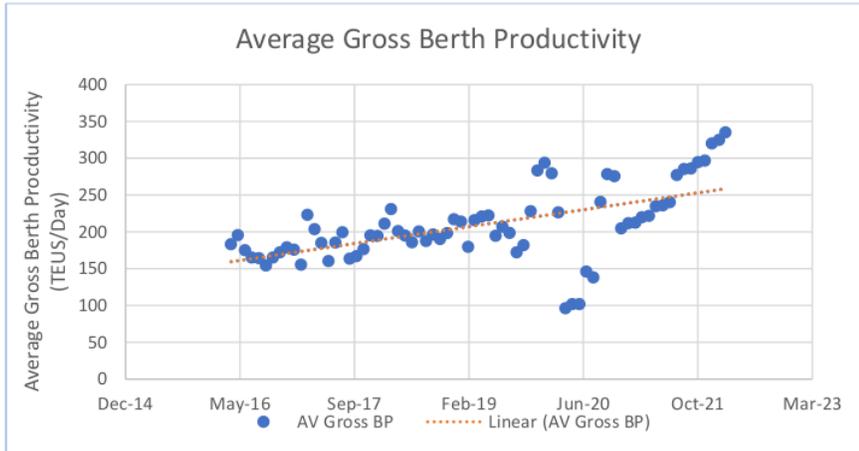
Figure 4: Average Gross Berth Productivity

2. **Average berth occupancy rate:** It is calculated by dividing the total number of available berth hours by the average time that vessels spend berthed. This variable's

data is presented in Figure 5 as a scatter plot with a trend line that also shows a downward trend.
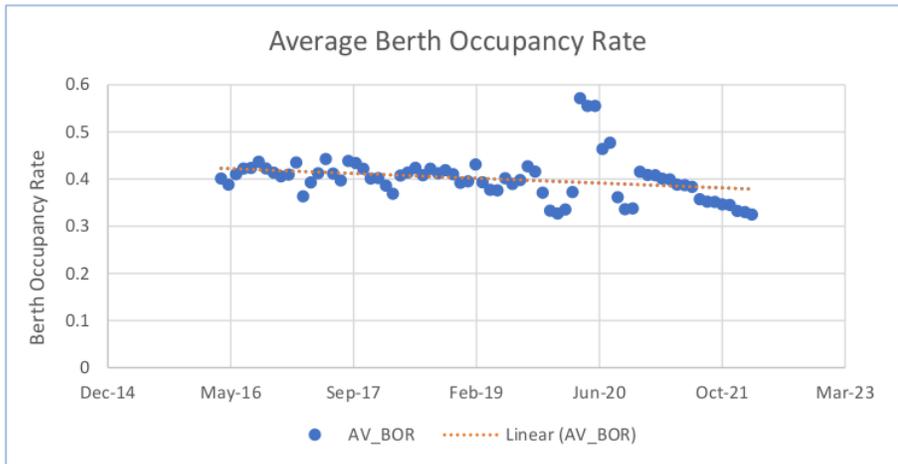
Figure5: Average Berth Occupancy Rate

3. **Average ship call size:** It is calculated by dividing the total registered gross tonnage of all the ships by the total number of ships. Figure 6 displays this variable's data as a scatter plot and trend line, demonstrating how the average gross tonnage increased over time.
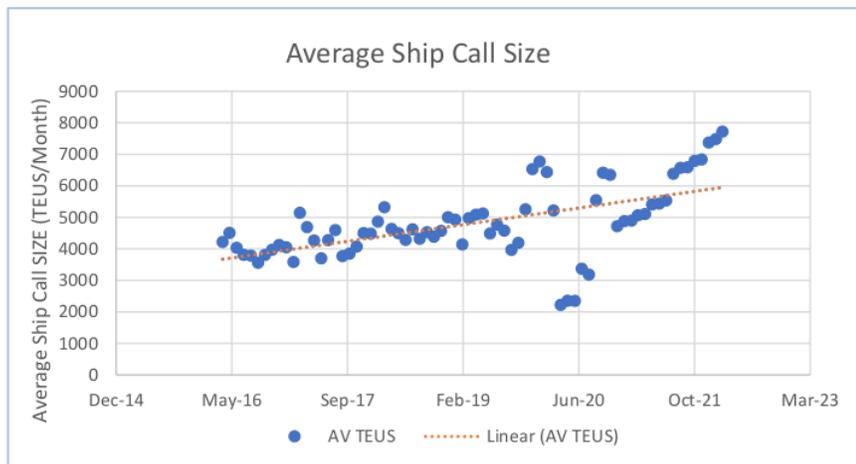
Figure 6: Average Ship Call Size (TEUS)

4. **Average rail turnaround time:** The resource provided this data as a monthly average, which had already been computed. The data for this variable are displayed in

a scatter plot and trend line in Figure 7. It's significant to note that the trend line lowered over time, indicating that the turnaround time was decreasing.
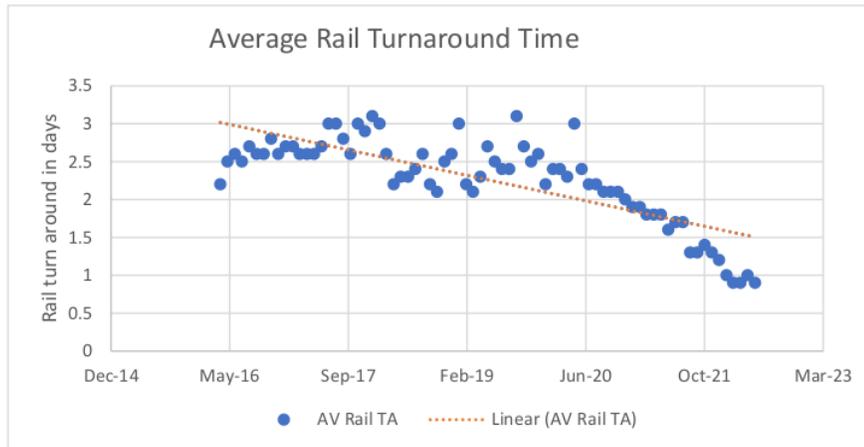
Figure 7: Average Rail Turnaround Time

3.3 Analytical framework

In order to determine the trend and the relationship between the two variables, transport system as the independent variable (X) and port performance as the dependent variable (Y)—we must test and analyze the model that it contains. There are four criteria that could explain port performance in the terminal, among other port performance indicators which are impacted by the hinterland transport system. These four variables are considered to be the average ship call size, berth occupancy rate, gross berth productivity, and ship turnaround time.

Because the port that was selected calculates the rail turnaround time from the Inland container depot' gate-in time to the Inland container depot gate-out time, which would capture the overall rail movement time, it is assumed that the independent variable, hinterland transport, can be explained solely by rail turnaround time. Additionally, the majority of rail traffic is planned and managed in advance. As a result, railways enter gates without difficulty and don't wait outside the port for extended periods of time, therefore this indicator is not recorded at the port gates or in the DFC database. Therefore, in accordance with the conceptual framework's explanation of these variables in chapter two, the other rail performance indicator (rail waiting time before the gate) was disregarded.

3.4 Hypotheses

Four hypotheses, listed in Table 6, have been proposed to explain the relationship between the hinterland transport and port terminal operational performance in the analytical model that was previously presented.

Table 6: Model Hypotheses Variables

Hypotheses	Dependent Variables (Y)	Independent Variable (X)
Hypotheses 1	Ship Turnaround Time (Y1)	Rail Turnaround Time (X)
Hypotheses 2	Gross Berth Productivity (Y3)	Rail Turnaround Time (X)
Hypotheses 3	Berth Occupancy Rate (Y2)	Rail Turnaround Time (X)
Hypotheses 4	Average Ship Call Size (Y4)	Rail Turnaround Time (X)

1. **Hypothesis one:** There is a link between them, as evidenced by the fact that rail turnaround time affects ship turnaround time. The independent variable (X) is rail turnaround time, and ship turnaround time is the dependent variable (Y).

2. **Hypotheses two:** Gross berth productivity is influenced by rail turnaround time, indicating that there is a correlation between the two. Gross berth productivity is the dependent variable (Y), and rail turnaround time is the independent variable (X).

3. **Hypotheses three:** Berth occupancy rate is impacted by rail turnaround time. This implies that they are related to one another. The dependent variable (X) is the berth occupancy rate, and the independent variable (X) is the rail turnaround time (Y).

4. **Hypotheses four:** The vessel's call size is influenced by the rail turnaround time. In other words, there is a correlation between them. The dependent variable (V) is the size of the vessel call, while the independent variable (X) is the truck turnaround time (Y).

The figure illustrates the proposed association with the expected relationship in signs, plus for a positive relationship and negative for an inverse relationship, as can be shown in the analytical model (the rail turnaround time affects the port operating performance). Straight arrows signify a direct relationship, which is how the relationship is expressed.
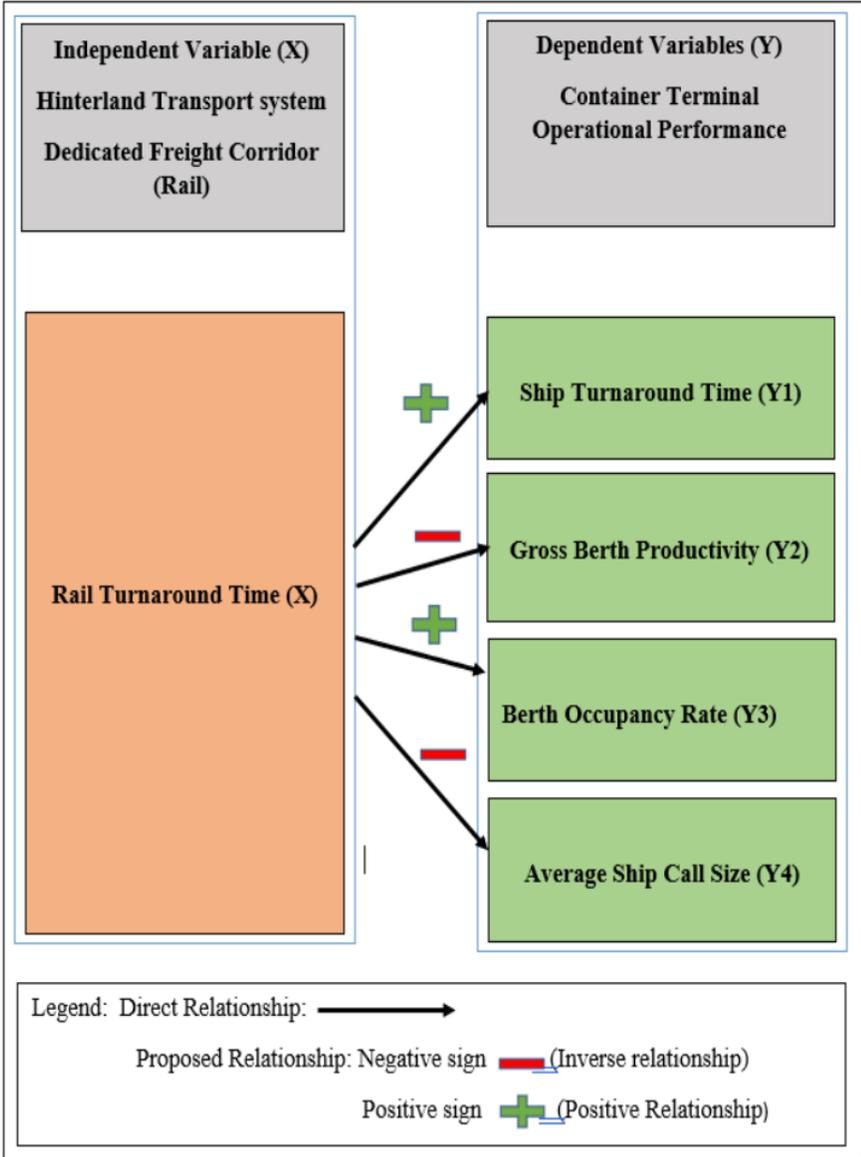
Figure8: Analytical Model

3.5. Testing and Analysis of data

In order to test the hypotheses a variety of tests, including the correlation test, T-test, unit root test, simple regression, and group statistics, were carried out to accurately and dependable test the model's hypotheses.

3.5.1. Correlation

If two variables are interrelated, it indicates that both variables are treated symmetrically and their linear connection is measured, which involves measuring how closely they are linearly related. As a result, it cannot be assumed that altering x will also alter y or the other way around. All that is demonstrated is that the two variables have a linear connection. However, in regression, the dependent variable, y, and the independent variable(s), xs, are viewed in a different way; the y variable is believed to be somewhat random (stochastic), that is, to obtain a probability distribution. In contrast, it is presupposed that the x variables in repeated samples have constant values (non-stochastic).

The purpose of this investigation is to evaluate the correlation coefficient, a number between -1 and 1 that expresses how strongly two variables are related linearly. A significant positive connection is indicated when the correlation coefficient is close to 1. There is no association when the value is 0. A strong negative (inverse) relationship between the two variables is shown by values that are close to -1.

3.5.2. T-test

The T-test compares the means of two groups' scores in order to determine how much the two groups' scores varied or spread apart from one another. This test is intended to test a single hypothesis and can be run either directly on Excel or the T-table. A 95% confidence level, or 5% significance level, defines the critical value. If the t-statistic ratio exceeds the critical value, the null hypothesis of statistical insignificance is rejected, and the alternative hypothesis of significance is adopted.

3.5.3 Regression

Regression analysis is a technique used to describe and assess the correlation between a specific variable, known as the dependent variable, and one or more additional variables, known as the independent variables. It is an attempt to explain changes in one or more variables by changes in other variables. We require a tool for that function in order to verify the aforementioned

hypotheses, analyse the relationship, and identify trends. Microsoft Excel's data analysis function would be used to apply the straightforward linear regression algorithm known as Ordinary Least Squares. After this, we can determine the slope and independent variable coefficients α&β respectively. The coefficient would indicate whether a relationship was positive or negative and how much an independent variable affected the dependent variable (inverse).

Microsoft Excel will be used to run the 72 observations made up of the sample of variables. The hypotheses are outlined in Table 7 with equations, variable names, and abbreviations.

Table 7: Regression's Equations and Variables

No.	Equation	Variables	Abbreviation
1	$y1 = \alpha1 + \beta X + u1$	y1= Average Ship Turnaround Time	AV SHP TA
		X= Average Rail turnaround time	AV Rail TA
2	$y2 = \alpha2 + \beta X + u2$	y2 = Average Gross Berth Productivity	AV Gross BP
		X= Average Rail turnaround time	AV Rail TA
3	$y3 = \alpha3 + \beta X + u3$	y3 = Average Berth Occupancy Rate	AV BOR
		X= Average Rail turnaround time	AV Rail TA
4	$y4 = \alpha4 + \beta X + u4$	y4 = Average Ship Call Size	AV TEUs
		X= Average Rail turnaround time	AV Rail TA

The following are examined to further validate the hypothesis tested throughout the regression study, after doing the t-test.

- **P-value**

The significance level for the t-ratio is denoted by the p-value, which must be less than 5%. This means that the result must be more than 95% with 95% confidence. If the p-value exceeds 5% in the significance threshold, the null hypothesis of statistical insignificance is rejected, which means that we reject the initial hypothesis we tested in the regression because the association is not statistically significant. On the other hand, if the p-value is less than 5% in the significance level, we accept the alternative hypothesis of significance, which means we accept the initial hypothesis that we test in the regression.

- **R-squared**

The statistical indicator of how closely the data resemble the fitted regression line is called R-squared.

Using the degree of fit between the regression line and the data is often referred to as the coefficient of determination. The better the model fits the data, the more often, the higher the value is. We may evaluate the quality of the regression result by examining this indicator.

3.6 Qualitative Analysis

Through a collection of time data series since the inception of the DFC i.e 2018-2021, the researcher will try to assess the operational and financial performance of both hinterland transport and port performance. Here, the analysis will be carried out for traffic projection, overall improvement in the logistic cost, and increase in the total cargo handling over the years. The review of the performance would be based upon various articles, documents, etc published on the related topic and data produced on the DFCCIL web portal.

3.7 Conclusion

The approach for verifying the analytical model's hypotheses that explain how effective hinterland transportation affects port efficiency was established in this chapter. The correlation, t-test, and simple regression will be used to examine four hypotheses (OLS). Due to the limitation of the available data on the port performance indicators the researcher limits the quantitative analysis to the four mentioned variables. Also, these variables constitute the performance of other variables like ship waiting time, vessel working time at berth, ship productivity indicator, and berth utilization rate. Hence, this research was restricted to the above four hypotheses while financial and other related metrics like traffic projection, dwell time, etc will be assessed through qualitative analysis.

They will serve as a foundation for the analysis and interpretation in chapter four. The discussion and analysis of the tests of the hypotheses are covered in the following chapter

Chapter 4: Analyses and Interpretation based on results

In this chapter, the analytical model's hypotheses that attempt to explain the presumption that hinterland transit affects port operational performance were put to the test. All four hypotheses were valid after being put through some tests using the regression tool, much like the initial assumption of each. The relationship between the variables in each hypothesis was clarified using regression. Furthermore, qualitative research was done by using time series data for five years from 2016-2021 on hinterland transport and port performance to validate the stated impact. Also, the benefits and challenges to be faced by the implementation of DFC are discussed.

4.1 Hypotheses One

Hypothesis one contends that ship turnaround time is influenced by rail turnaround time. Several statistical tests and analyses were conducted to examine this hypothesis, as previously mentioned. Their results are compiled in Table 8. Additionally, the data was imported into Excel and run through a basic regression using OLS; see Figure 9.

Table 8: Tests Result

Variables	**Dependent variable (Y1)** AV SHP TA	**Independent Variable (X)** AV RAIL TA
Correlation	0.3863	
T-test	T-statistic (3.50)	
p-value	0%	
R-squared	14.92%	
Independent variable coefficient(β)	2.22	

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.386386
R Square	0.149294
Adjusted R Squ	0.137141
Standard Erro	2.742008
Observations	72

ANOVA

	df	SS	MS	F	gnificance F
Regression	1	92.36317	92.36317	12.28461	0.000801
Residual	70	526.3026	7.518608		
Total	71	618.6657			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0	pper 95.0%
Intercept	6.57294	1.505182	4.366872	4.27E-05	3.570948	9.574931	3.570948	9.574931
(Rail TA time)	2.220134	0.63343	3.504941	0.000801	0.956798	3.483469	0.956798	3.483469

Figure 9: Simple Regression output

The basic regression result is shown in Table 8 above, and it demonstrates a positive correlation between the two variables. The correlation coefficient, which is 38.63%, is regarded as fairly correlated. Additionally, because the t-statistic is higher than the critical value, the T-test rejected the null hypothesis of insignificance, according to which the independent variable is not significant. The null hypothesis—that the independent variable is insignificant—was rejected because the p-value was less than 5% at the significance threshold or zero percent. The R-squared is 14.90%, which is a relatively low number. The regression line fairly fits the data, as indicated by this percentage.

The independent variable is statistically significant as a result. In other words, it has a fair effect on the dependent variable. According to the independent variable coefficient (β), which stands at 2.22, a unit decrease in the independent variable, rail turnaround time, would result in 2.22 days decrease in the dependent variable, average ship turnaround time. In conclusion, hypothesis one was not rejected and there is a significant correlation between the independent and dependent variables. Consequently, the average ship turnaround time is influenced by rail turnaround time.

4.2 Hypotheses Two

Hypothesis two contends that gross berth productivity is influenced by rail turnaround time. Several statistical tests and analyses were conducted to examine this hypothesis, as previously mentioned. Their results are compiled in Table 9. Additionally, the data was imported into Excel and run through a basic regression using OLS; see Figure 10.

Table 9: Tests Result

Variables	Dependent variable (Y1) AV Gross BP	Independent Variable (X) AV RAIL TA
Correlation	0.674	
T-test	T-statistic (7.63)	
p-value	0%	
R-squared	45.43%	
Independent variable coefficient(β)	-66.2	

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.674072							
R Square	0.454374							
Adjusted R Sq	0.446579							
Standard Erro	37.59847							
Observations	72							
ANOVA								
	df	SS	MS	F	gnificance F			
Regression	1	82405.46	82405.46	58.2929	8.58E-11			
Residual	70	98955.15	1413.645					
Total	71	181360.6						
	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	362.9297	20.63909	17.58457	2.18E-27	321.7663	404.093	321.7663	404.093
Rail TA Time	-66.3144	8.685601	-7.63498	8.58E-11	-83.6373	-48.9915	-83.6373	-48.9915

Figure 10: Simple Regression Output

As shown in Table 9 above, demonstrates an inverse correlation between the two variables. The correlation coefficient, which is 0.674, is regarded as moderately correlated. Additionally, because the t-statistic is higher than the critical value, the T-test rejected the null hypothesis of insignificance, according to which the independent variable is not significant. The null hypothesis—that the independent variable is insignificant—was rejected because the p-value was less than 5% at the significance threshold or zero percent. The R-squared is 45.43%, which is a relatively moderate number. The regression line adequately fits the data, as indicated by this percentage.

The independent variable is statistically significant as a result. In other words, it has a moderate effect on the dependent variable. According to the independent variable coefficient (β), which stands at -66.2, an increase in a unit of the independent variable, rail turnaround time, would result in a 66.2 TEU decrease in the dependent variable, Gross berth Productivity of the terminal. In conclusion, hypothesis two was not rejected and there is a significant correlation between the independent and dependent variables. Consequently, the Gross berth productivity is influenced by rail turnaround time.

4.3 Hypotheses three

Hypothesis three contends that the Berth Occupancy rate is influenced by rail turnaround time. Several statistical tests and analyses were conducted to examine this hypothesis, as previously mentioned. Their results are compiled in Table 10. Additionally, the data was imported into Excel and run through a basic regression using OLS; see Figure 11.

Table 10: Tests Result

Variables	Dependent variable (Y1) BOR	Independent Variable (X) AV RAIL TA
Correlation	0.4273	
T-test	T-statistic (3.95)	
p-value	0%	
R-squared	18.26%	
Independent variable coefficient(β)	0.039	

SUMMARY OUTPUT

Regression Statistics					
Multiple R	0.427324				
R Square	0.182606				
Adjusted R Sq	0.170929				
Standard Err	0.043027				
Observations	72				

ANOVA

	df	SS	MS	F	gnificance F
Regression	1	0.028952	0.028952	15.63797	0.000181
Residual	70	0.129596	0.001851		
Total	71	0.158547			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	0.30959	0.023619	13.10752	1.61E-20	0.262483	0.356697	0.262483	0.356697
Rail TA Time	0.039307	0.00994	3.954488	0.000181	0.019482	0.059131	0.019482	0.059131

Figure 11: Simple Regression Output

The basic regression result is shown in Table 10 above, and it demonstrates a positive correlation between the two variables. The correlation coefficient, which is 0.427, is regarded as fairly correlated. Additionally, because the t-statistic is higher than the critical value, the T-test rejected the null hypothesis of insignificance, according to which the independent variable is not significant. The null hypothesis—that the independent variable is insignificant—was rejected because the p-value was less than 5% at the significance threshold or zero percent. The R-squared is 18.26%, which is a relatively low number. The regression line fairly fits the data, as indicated by this percentage.

The independent variable is statistically significant as a result. In other words, it has an effect on the dependent variable. According to the independent variable coefficient (β), which stands at 0.039, a unit increase in the independent variable, rail turnaround time, would result in a 0.039 rate increase in the dependent variable, average ship turnaround time. In conclusion, hypothesis three was not rejected and there is a significant correlation between the independent and dependent variables. Consequently, the Berth occupancy rate is influenced by rail turnaround time.

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4.4 Hypotheses Four

Hypothesis Four contends that the Average ship call size is influenced by rail turnaround time. Several statistical tests and analyses were conducted to examine this hypothesis, as previously mentioned. Their results are compiled in Table 11. Additionally, the data was imported into Excel and run through a basic regression using OLS; see Figure 12.

Table 11: Tests Result

Variables	Dependent variable (Y1) AV call size	Independent Variable (X) AV RAIL TA
Correlation	0.674	
T-test	T-statistic (7.55)	
p-value	0%	
R-squared	45.26%	
Independent variable coefficient(β)	-1524.03	

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.674072
R Square	0.454374
Adjusted R Sc	0.446579
Standard Err	865.5481
Observations	72

ANOVA

	df	SS	MS	F	gnificance F
Regression	1	43671498	43671498	58.2929	8.58E-11
Residual	70	52442149	749173.6		
Total	71	96113647			

	Coefficients	andard Err	t Stat	P-value	Lower 95%	Upper 95%	ower 95.0%	pper 95.0%
Intercept	8354.943	475.1291	17.58457	2.18E-27	7407.328	9302.559	7407.328	9302.559
Rail TA Time	-1526.61	199.9498	-7.63498	8.58E-11	-1925.4	-1127.82	-1925.4	-1127.82

Figure 12: Simple Regression Output

The basic regression result is shown in Table 11 above, and it demonstrates an inverse correlation between the two variables. The correlation coefficient, which is 0.674, is regarded as moderately correlated. Additionally, because the t-statistic is higher than the critical value, the T-test rejected the null hypothesis of insignificance, according to which the independent variable is not significant. The null hypothesis—that the independent variable is insignificant—was rejected because the p-value was less than 5% at the significance threshold or zero percent.

The R-squared is 45.43%, which is a relatively low number. The regression line adequately fits the data, as indicated by this percentage.

The independent variable is statistically significant as a result. In other words, it has a significant effect on the dependent variable. According to the independent variable coefficient (β), which stands at -1524.03, a unit increase in the independent variable, rail turnaround time, would result in a 1524.03 TEU decrease in the dependent variable, Average ship call size. In conclusion, hypothesis four was not rejected and there is a significant correlation between the independent and dependent variables. Consequently, the average ship call size is influenced by rail turnaround time.

4.5 Discussion

As previously mentioned, four performance indicators—ship turnaround time, berth occupancy rate, gross berth productivity, and ship call size—were responsible for the port's operational improvement at the JNPT container terminal. With respect to, the rail turnaround time from the inland container depot near the capital city of New Delhi in terms of hinterland transport.

Due to the fact that port performance is made up of numerous subsystems that influence the performance, one of which is hinterland transport, it is a challenge to identify and explain the impact of this subsystem on port performance.

Except for the commercial partnership to operate the container terminal by a global terminal operator by PSA (SINGAPORE) and DP World, which primarily runs the terminal operations, there were no significant modifications or reforms in the ports in the JNPT port case. Over the sample period, the port's superstructure and infrastructure were essentially unchanged. For instance, there was no upgrading or swap of the cranes or other handling equipment.

The development and organization of the Indian Railways' dedicated freight corridor, which began operations in 2017–18, was the most significant improvement in this regard. The situation was thus appropriate for looking at the effect of hinterland transport on port performance because the other key dominant and prevailing determinants on port performance were not significantly impacting during that time as they remain unchanged. The conclusions and findings of the hypotheses are explained in the sections that follow.

4.5.1 Hypotheses One

After the tests were run, hypothesis one's claim that rail turnaround time and ship turnaround time are related was found to be true. The results revealed a moderate correlation, a significant t-test, and a significant regression that demonstrated the association. Figure 13. illustrates the change in the ship turnaround time indication from 2017 to 2020, which was clearly noticeable and apparently coincided with the pattern of the change in rail turnaround time. At the start of 2016, the typical ship turnaround time was approximately 11 days. It gradually decreased until 2021, when it reached 7.5 days.
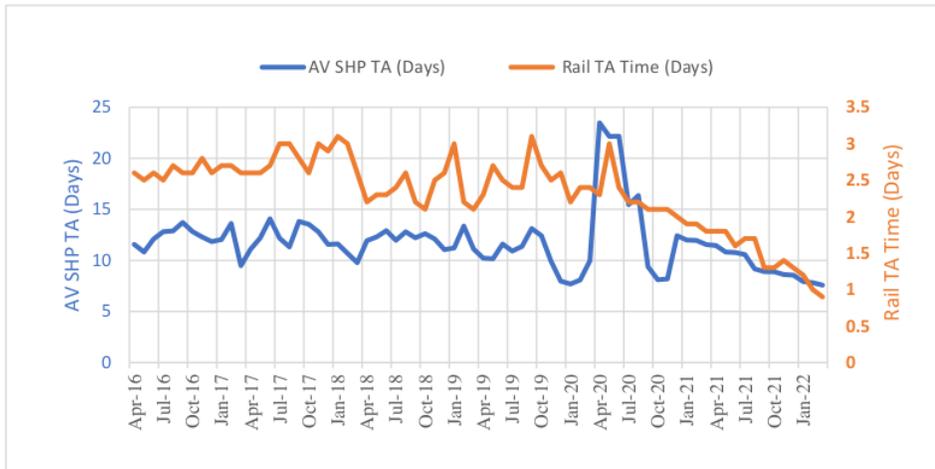
Figure 13: Average Ship Turnaround Time & Rail Turnaround Time

Rail turnaround time, on the other hand, was significant in 2017, coming in at about 3 days. Then it gradually decreased to 0.9 days by 2021. The regression results show that the ship turnaround time decreases by 2.2 days for every unit that the rail turnaround time decreases.

Additionally, in the short term, the decrease in rail turnaround time reacts with the decrease in ship turnaround time. Although this doesn't take as long, in the long run, it affects ship turnaround time since ships tend to wait for less outside the berth, which causes less congestion and, as a result, a shorter turnaround time.

There is no doubt that the trend in rail turnaround time affected the trend in ship turnaround time, but this impact cannot be fully explained by the reduction in rail turnaround because the ship turnaround time is also significantly influenced by other factors. Figure 13 shows that there were numerous spikes in the observed ship turnaround times, which might be attributed to the presence of additional factors that affect ship turnaround, berth time, and

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berth productivity, such as seasonal variations in ship and cargo sizes and supply and demand dynamics.

In other words, when the cargo quantity is large, the ship turnaround may occasionally prolong as a result of the time needed to load or unload the ship at the berth. In this instance, rail turnaround time may have a small but significant impact on ship turnaround time. In general, the turnaround time for ships increased and decreased along with the turnaround time for rails.

4.5.2 Hypotheses Two

Due to the moderate association between the two variables, the second hypothesis—that rail turnaround time affects gross berth productivity—was also accepted. Additionally, the independent variable was significant in the simple regression that was performed, indicating that it has an effect on gross berth productivity because rail arrives at the terminal in less time than in the past, which has gradually increased the average gross berth productivity of the terminal (see Figure 14).
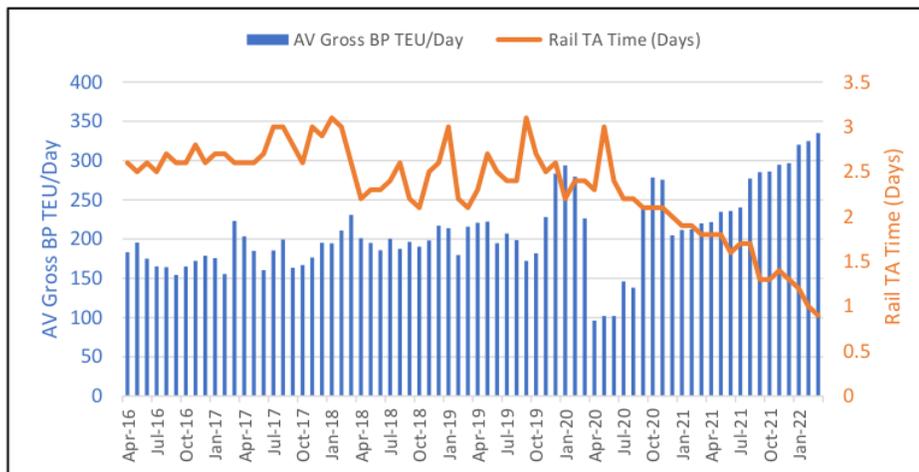
Figure 14: Average Gross Berth Productivity & Rail Turnaround Time

The ratio of cargo handled in the container terminal to the ship's entire time at berth, calculated from the first line to the last line (TEUS/hour), is known as gross berth productivity. Figure 14. shows that, following the introduction of the DFC, berth productivity gradually rose over a 4-year period from 2018 to 2021. As previously stated, berth productivity is a function of the length of the berth and the volume of cargo handled. However, if utilized properly or improved by additional equipment or more labour,

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handling equipment and labour are some of the factors that increase berth productivity, i.e., they speed up the ship berthing time by introducing less idle time; consequently, less berth time and more gross berth productivity.

Due to the covid crisis, which had an impact on the volume of freight transit, the issue of fair cargo traffic during this time was mostly caused by fluctuations or disruptions in the supply and demand of the cargo.

Despite this, the rail system was organized, causing reduced congestion and a shorter turnaround time at the port, which improved ship waiting times. It might be argued that the port needs to address this issue by increasing the berth productivity factors, such as lowering idle time and maximising the use of both labour and equipment. The bottom line on the gross berth productivity issue is that the port must buy cranes, restore the berth infrastructure, widen the gates, and enhance the inland transit connectors in order to increase productivity. Simply said, terminal operators are fast unloading the ship by using more cranes throughout more shifts. Therefore, rail turnaround affects berth productivity although not significantly, as the other elements stated are more potent and dominant.

4.5.3 Hypotheses Three

According to the third theory, the rail turnaround time affects the berth occupancy rate. The tests were significant, and since the simple regression had already shown that the two variables in this hypothesis are up to 42% correlated and that the association is significant, the hypothesis was not rejected. Figure 15 shows that the berth occupancy rate trend decreased with time in a manner similar to the rail turnaround time.
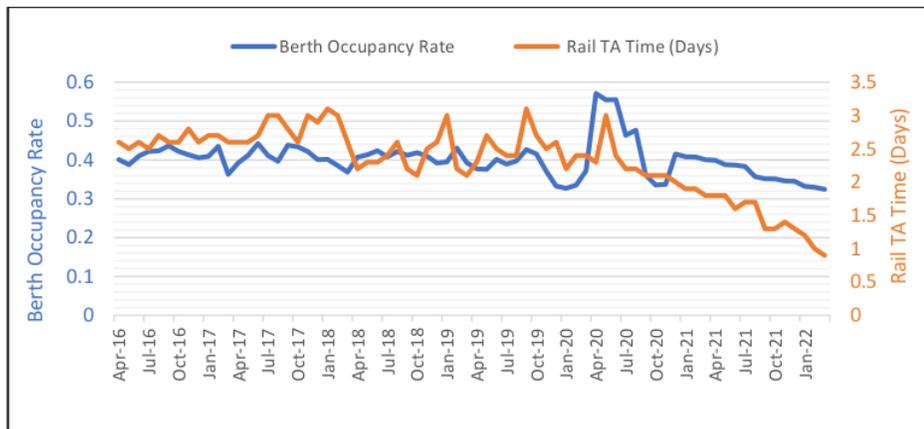
Figure 15: Berth Occupancy Rate & Rail Turnaround Time

Because rail turnaround time is an independent variable with a coefficient of 0.039, a reduction of one unit in rail turnaround time would result in a 0.039% reduction in berth occupancy. The rate decreases with time, much as the previous idea, meaning that it does not react right away. Due to the reduction in truck turnaround time, it can be inferred that there is a long-term effect on the berth occupancy rate.

The number of hours available divided by the total number of berths occupied by vessels is known as the berth occupancy rate. Since the container terminal is open around-the-clock, there is no concern with ship congestion and the berth occupancy rate decreases. Furthermore, it may be claimed that because berth occupancy rate depends on berth time and berth availability time, even if the rail turnaround time improved and decreased at that time, it might not have an impact on it. The response is that with those major characteristics, Once the ships are there on time, not late, and unblocked, it helps to minimise the berthing time by a certain amount., resulting in quay congestions, as it was seen in this case as it moved down. It occasionally varied, though, and this was brought on by the influences of other prevailing forces, as was hinted at above.

4.5.4 Hypotheses Four

Regarding the fourth hypothesis, ship call size is influenced by rail turnaround time. There is a relationship between the independent variable, the rail turnaround time, and the dependent variable, the average ship call size, as determined by the simple regression that examined the relationship. However, the correlation was moderate at 67%, and the R-squared was only a fair 45%.
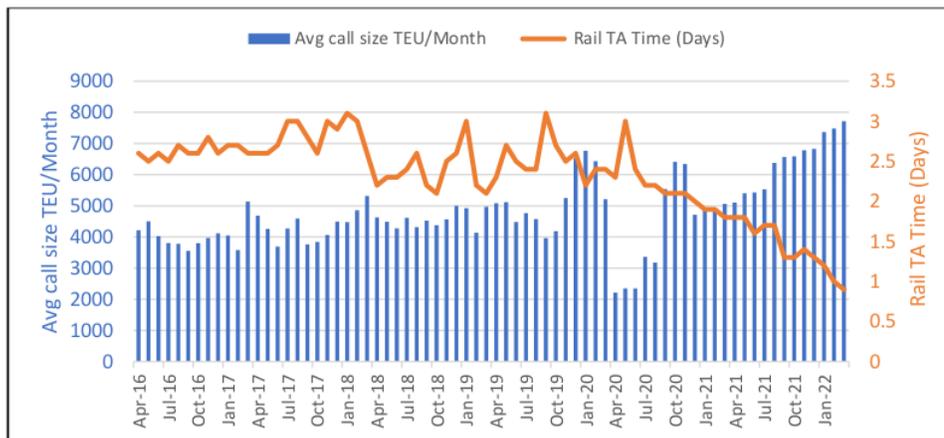

Figure 16: Avg Call Size TEU/Month & Rail TA Time

The TEU was low at the start of 2018, averaging approximately 5000 TEU, and then gradually increased through 2021, reaching an average of 8000 TEU. Contrarily, the Rail turnaround time for the same 4-year period declined from 2.8 days to 0.9 days, from its peak in 2017–18 to its lowest point by the end of 2022, as shown in Figure 16. According to the regression results, the link is explained by the independent variable's coefficient, which is -1524.03; it is an inverse association, meaning that as the truck turnaround time decreases by one unit, the average ship size (in TEUs per month) increases by roughly 1524 TEUs.

Of course, rather than a recent trend, this association explains a longer-term one. For instance, even if the rail turnaround time starts to increase, the ships' TEU will not alter immediately as predicted by the coefficient; instead, it will take some time before TEU starts to decrease once more.

The growth in TEU is the result of a number of reasons, including an increase in cargo import and export as well as an overall increase in ship size. Significantly, the port's rail services have improved with quicker turnaround times, which may draw larger ships because of the shorter wait times. Additionally, if inland transportation is the problem, ships may be content, especially due to poor inland transportation vessels having to wait around the port for very long, owing to lack of transportation service and congestion.

In conclusion, improvements in and slow declines in hinterland transit, particularly in rail turnaround, between 2017 and 2021 had an effect on the container terminal's port operating performance. The rail turnaround time has a substantial association with the four metrics that were used to explain the port performance.

4.6 Discussion of the dedicated freight corridor case study.

4.6.1. Genesis of Dedicated Freight Corridor

The Indian Railways designed a quadrilateral, popularly known as the "Golden Quadrilateral," connecting the four major cities of Delhi, Mumbai, Chennai, and Howrah. Its two diagonals, Delhi-Chennai and Mumbai-Howrah, added up to a total route length of 10,122 km, with 16% of the route carrying more than 52% of IR's passenger traffic and 58% of its revenue-generating freight traffic. With line capacity usage ranging from 115% to 150%, the current trunk routes of Howrah-Delhi on the Eastern Corridor and Mumbai-Delhi on the Western Corridor were extremely congested. From 83% in 1950–51 to 35% in 2011–12, railroads saw a decline in

their proportion of freight traffic. Additionally, while only making up 0.5% of the total road network, the National Highways along these sectors carried nearly 40% of the road freight.

The development of the Dedicated Freight Corridors along the Eastern and Western was initially prompted by the soaring power needs that required the movement of heavy coal, flourishing infrastructure construction, and expanding international trade. In India, the demand for rail is anticipated to be 1.2 times more elastic than GDP growth. Due to capacity issues, it has, in the past, been restricted to 0.8 to 1. The design of DFC on the western and eastern high-density pathways was inspired by this requirement for capacity. (D. F. C. C. O. I. (n.d.). *DFCCI) L.*

Figure 17: Proposed Dedicated Freight Corridors in India.

The project was mentioned in the 2005–2006 Railway Budget. In order to conduct a "Feasibility study" and a "Preliminary Engineering Cum Traffic Survey (PETS)" for both corridors, the Ministry of Railways (MoR) engaged Rail India Technical and Economic Services Ltd. (RITES) in July 2005. The government of Japan was asked to offer technical assistance in the project's feasibility evaluation. Three new corridors, the East-West, the East Coast, and the North-South sub corridor, have just been approved for DPR preparation. (Limited, D. F. C. C. O. I. (n.d.). *DFCCIL).*

4.6.2. Scope of Dedicated Freight Corridor System

The DFCs were established in order to:

- Reduce unit cost of transportation by accelerating freight train operations and increasing productivity.
- Increase rail share in the freight market by offering tailored logistic services.
- Create additional rail infrastructure to handle high levels of transportation demand.
- Introduce high-end technology & IT packing of Freight Services. Introduce timetabled freight services & guaranteed transit time.
- Segregate freight infrastructure for a focused approach on both passenger and freight business of Railways. (Limited, D. F. C. C. O. I. (n.d.). *DFCCIL).*

4.6.3. Traffic and Freight Projection of Hinterland Transport (DFC) and JNPT Port

The Dedicated Freight Corridor (DFC) concept, which was used by Indian Railways, has come to pass and made it easier to carry and do business from Indian ports to India's hinterland regions. Ports, customs, shipping companies, logistical firms, clearing brokers, and financial companies are just a few of the significant parties it has included. DFC illustrates how administration, management, and new technology have improved logistic transport, synchronized it under one roof, and connected all stakeholders in an improved seamless system.

This decreases the complexity of multi-port access, eliminates all quasi-activities, eliminates mediators and facilitators with no added value, and provides twin moves for carrying cargo, where a rail has two functions when it arrives at the port: unloading and loading. The system uses an electronic exchange of information and a variety of delivery and communication methods via the Internet of things (IoT) for improved supply chain visibility upstream.

Thus, an organizational approach to inland transportation undoubtedly brings about a number of advantages and important implications, including those for ports, logistical firms, and governmental organizations. The following advantages and benefits are in line with studies conducted by the World Bank, analytical information from the Indian ports system, and the DFC System.

Hinterland Performance: The traffic projection for the Western dedicated freight corridor (WDFC) is from 125.3 metric tons in 2018 to 167 metric tons in 2022 at a CAGR of 10.7(%). For, Eastern Dedicated Freight Corridor (EDFC) from 184.6 metric tons in 2018 to 219.6

metric tons. The average rail turnaround time from 3 days in 2016-17 came down to 0.9 days after the introduction of the system. (DFCCIL Corporate Plan)

 In comparison to the pre-DFC condition in the city and port of JNPT, the controlled rail flow through inter-state border transit saved time and money while minimizing the lines and waiting times. It gives Indian Railways early notification of anticipated ship offloading time and fully eliminates waiting time for passenger train passage. However, by doing so, the strain on the current railway fleet was lessened rail turnaround time, train travel time, waiting and idle time, and rail turnover time were all greatly cut. In the past, rail turnover time was calculated in days; today, it is assessed in hours, which has improved the overall efficiency of Indian railways.

WDFC

Commodity	2018	2019	2020	2021	2022
Container	45.6	49.8	54.3	59.2	64.6
Coal	21.5	22.4	23.3	24.2	25.2
Food grains	8.1	8.4	8.6	8.8	9.1
Fertilizer	11.5	11.9	12.4	12.9	13.4
Cement	6.3	6.8	7.3	7.9	8.5
Steel	1.6	1.7	1.9	2.0	2.2
POL	6.7	6.9	7.0	7.2	7.3
MISC	6.6	6.8	7.0	7.2	7.4
Total	**108.0**	**114.6**	**121.8**	**129.4**	**137.7**
Modal shift from Road	12.7	13.3	14.0	14.7	15.4
DMIC Traffic	4.6	6.1	8.0	10.6	14.0
Grand Total	**125.3**	**134.1**	**143.8**	**154.8**	**167.1**
CAGR (%)	**11.2**	**11.4**	**11.7**	**12.0**	**7.5**

Figure18: Traffic Projection for Western Dedicated Freight Corridor.

EDFC

Commodity	2018	2019	2020	2021	2022
Container	6.2	6.7	7.2	7.8	8.5
Coal	102.2	106.2	110.5	114.9	119.5
Food grains	13.8	14.2	14.6	15.0	15.4
Fertilizer	5.2	5.4	5.6	5.9	6.1
Cement	9.3	10.0	10.8	11.7	12.6
Steel	11.8	12.7	13.7	14.8	15.9
POL	4.1	4.1	4.2	4.3	4.4
MISC	21.3	21.9	22.6	23.3	24.0
Total	**173.8**	**181.3**	**189.3**	**197.6**	**206.3**
Modal shift from Road	10.9	11.4	12.0	12.6	13.2
AKIC Traffic	0.0	0.0	0.0	0.0	0.0
Grand Total	**184.6**	**192.8**	**201.3**	**210.2**	**219.6**
CAGR (%)	**6.5**	**6.3**	**6.2**	**6.1**	**4.4**

Figure19: Traffic Projection for Eastern Dedicated Freight Corridor.

Resource: DFCCIL Corporate Plan 2017-22(metric tonnes)

DFCs provide India's freight logistics a substantial opportunity. What matters is how the increasingly upbeat traffic estimates will really pan out. That is dependent on the expansion of India's trade and industry, as well as the growth of its feeder network and industrial corridors.

Port Performance: Since its inception, the port traffic has expanded significantly and can be noticed in the following figures. From 5.6 million tonnes in 2018 to 7.8 million tonnes in 2022 or a cumulative annual growth of 10.7%. (2022). Www.Indiastat.Com.
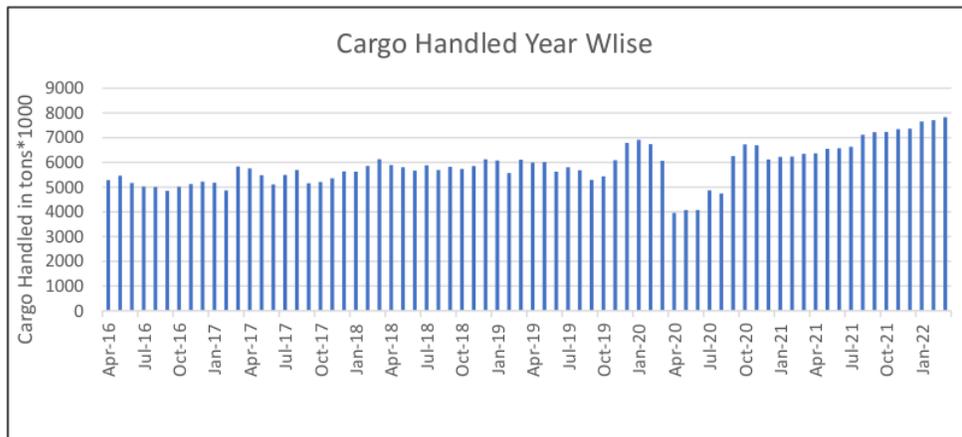
Figure 20: Cargo Handled Year Wise

While after the implementation of the DFC the Container traffic at Jawaharlal Nehru Port Trust (JNPT) increased by 40.40% in the first half of the fiscal year 2021–2022. (FY2021-22). In comparison to 1,925,284 TEUs for the same period last year, JNPT handled approximately 2,703,051 TEUs throughout the period. The total volume of containers handled in September 2021 was 452,108 TEU, up 18.86% from September 2020. In the first half of FY2021–22, the rail coefficient was 18.04 percent. The highest TEU handled since the terminal's inauguration was 100,814 at DP World's Nhava Sheva (India) Gateway Terminal (NSIGT) in September 2021. Donnelly, J. (2021, October 14).

In terms of overall dwell time, JNPT has made great progress, particularly with respect to import dwell time, which has dropped from 55.55 hours in 2018-19 to 37.33 hours in 2019-20 as of January. In addition, the dwell time on the road has decreased by 33% and the dwell time on the rail by 45%. These outcomes have been attained as a result of the port's consistent efforts using a three-pronged strategy of infrastructure enhancement, process simplification, and operation digitization.

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India has been given credit for moving up two places in the World Bank's Ease of Doing Business Index's segment on "Trading Across Borders," from 146 to 68, thanks to JNPT. Additionally, the adoption of an RFID-based Gate Automation System has made it possible to cut the time it takes to operate a gate from ten minutes to only one. Additionally, JNPT debuted the Navis N4 Terminal Operating System, E-Delivery orders, mobile apps, and container tracking—all firsts for India.

Additionally, during the five-year time frame that was looked at, the effect on port operational efficiency, which was in-depth explained previously in this chapter, was evident, i.e., the systematic observation of capacity planning and involvement with users sped up vessel port operations, decreased ship turnaround time, and increased berth occupancy rate. Additionally, it cut the number of rails inside the ports and the turnaround time for those trains, which ultimately reduced congestion on both the land and the waterside. Such a service's dependability eliminates the need for big stocks and enables just-in-time operations.

4.6.4. Collateral benefits and challenges:

- The main benefit would be less traffic on the roads, which will relieve pressure on the infrastructure. DFCCIL will support the migration of freight transportation to more effective rail transit and relieve the existing congested road network.

- Environmental benefits will also be observed as a result of the deployment of electric locomotives, which will reduce fuel use and the emissions from idle trucks, unregulated truck flow, and truck movements. This change is anticipated to significantly lower Green House Gas (GHG) emissions in India's transportation industry. In the first 30 years of operation, it is anticipated that DFC will reduce CO_2 emissions by more than 450 million tonnes (Assessment based on Ernst & Young study).

- The system also established a foundation platform, making it possible for the Ministries of Railways and Shipping to update their database, which records all rail movements and provides information to logistics firms via an internet-based application so they may coordinate appropriately. As a result, it generates accurate statistics on the efficiency of the transportation sector. Customers and system users benefit from the increased cost savings in cargo transport.

- DFCCIL has designed its wagon to carry trucks into it and multimodal hubs along its route where easy loading and unloading of the trucks can take place. This will help to optimize the logistic transport and last-mile delivery to the customer.

- The Government of India in collaboration with the Government of Japan has planned an ambitious project for Delhi-Mumbai Industrial Corridor. The DFC will support as the backbone of this project in the coming years.

- The low volume of containers evacuated through the rail at JNPT, which is currently 20% of the volume and below the national average of 22%, is another problem. Due to the use of mixed-rail handling between terminals rather than individual trains, which increases container waiting times, this ratio is lowered in JNPT. After the DFC is constructed, transit time may be dramatically reduced. Over long distances, rail transport of cargo is significantly more affordable than road transit. The two distinct rail yards might be combined into one 1500-meter-long rail yard with a sizable container storage facility adjacent to boost the port's rail coefficient.

- Coal forms the major bulk of quantity of total cargo transported towards the northbound region through the rail system. It supplies to the major power plants in the region, as the country is moving towards the use of more renewable and sustainable forms of energy. This may affect the overall efficiency of the transport system and had to be addressed in the coming years.

4.6.5. Conclusion

The improvement in the ship turnaround time, reduction in berth occupancy and the growth in TEU of calling vessels and berth productivity, as well as the decrease in vessel waiting time, all happened after the rail turnaround decreased and in a longer duration of time, meaning they did not arise right away but took some time. The results obtained from the four hypotheses form part of the quantitative research while the improvement in the traffic projection, financial performance, and dwell time were answered through the qualitative research. However, there are still other significant and dominating aspects that have an impact on port performance, therefore it is not thought that rail performance is the only cause of this improvement in performance factors. However, the organized hinterland's overall contribution did have a good effect and would be taken into account when evaluating the port's success.

This leads us to the conclusion that DFC affects port operations and container terminal performance, which shows an improvement once the system is implemented. Generally speaking, this conclusion would show that, among other factors that affect port performance, efficient inland transit has an effect on the port's operating effectiveness.

Chapter 5. Conclusion

The goal of the study was to determine how hinterland transportation affected port operational efficiency. To evaluate that influence, the study created a framework for an analytical model, which was later statistically tested.

This study provided answers to the research's aim of **How an effective hinterland transport system will improve the port's operational performance** and was argued that the operation of ports is significantly impacted by and correlated with hinterland transit.

Evaluating the case that was used to achieve the **objectives** of the research was centered on the Dedicated Freight Corridor (Railway network), which was constructing new rail tracks specifically intended for the transportation of cargo trains to seaports in place of the existing rail tracks. The analysis began by studying the DFC project and attempting to ascertain the influence on the port performance, from 2016 to 2021, after reviewing the literature on port performance and hinterland transit in a broad and larger sense.

Regarding the significance of hinterland transit to ports and the entire supply chain, the literature in this situation was comprehensive and helpful. However, there were few studies that specifically looked at the connection between hinterland transport and port performance, i.e. the few that highlighted and statistically assessed the connection between hinterland transport and port operational efficiency. Additionally, measuring port performance is quite challenging and complex. In other words, seaports operate the terminals in a distinct setting in addition to providing a variety of solutions.

Some port performance metrics appeared to have improved over time, for example, the port performance changed as a result of the improved and less constrained hinterland transportation. Interestingly, it was clear that the organized and dedicated rail network had improved significantly in connection with a larger system and a single national window of transportation.

The researcher continued on the basis of the presumption that hinterland transport affects port performance. Because it interacts directly with the rail transit, the container terminal was advantageous in this situation. Consequently, utilizing time series data spanning five years, associated variables from the JNPT port's container terminal were selected.

The four hypotheses that made up the analytical model were evaluated and discussed in chapters three and four. The four performance indicators and the rail turnaround time were the hypotheses, and the analytical tools used to assess them. All four hypotheses were supported

by the results of the tests, and the gross berth productivity was determined to be less significant than the others. Because there are more significant factors that may have a significant impact on this variable, such as delays brought on by quay due to equipment failure, labour issues, ship machinery breakdown, and/or a lack of efficient equipment, gross berth productivity failed to recognize the enhancement and influence of hinterland transit.

During the five-year observation period, improvements were seen in each of the four-port performance measures stated. They responded gradually over time, showing that it takes time to react to coordinate accordingly. It is indisputable, however, that those results demonstrated an improvement in port performance overall, which was consistent with the coordinated and more effective hinterland transit at the time of observation. Furthermore, the absence of significant improvements to the port of JNPT, such as the construction of new berths or the purchase of new machinery, which could have boosted port performance, contributed to the result's clarity and dependability.

Although there are other factors that influence port performance, it cannot be assumed that changes or improvements are entirely attributable to efficient hinterland transport. Nevertheless, The larger number of port performance parameters can positively include and take into consideration the enhancement of hinterland transit.

The study's findings added to the understanding of the interactions between the two research components, port performance, and hinterland transport, and gave recommendations for measuring and identifying the relationship between and implications of hinterland transport on port performance. Additionally, the DFC provided numerous benefits to the port of JNPT through the rail network system, including less traffic at the port's entrances, more efficient rail travel, and faster rail turnaround times every time the rail called the port.

5.1 Implications

Finding the connection between and the effect of hinterland transit on port performance has significance from various angles. This research contributes to the body of knowledge by giving proof of the association between the aforementioned variables as well as by developing and testing an analytical model for determining the relationship between hinterland transport and port performance.

Regression analysis, correlations, the t-test, and statistical approaches are all effective tools for defining the link and effects of hinterland transport. They offer a chance to investigate the link

in more depth in several ports using various assumptions. Some of the hypotheses were true, supporting statistically and empirically the idea that the relevant variables are correlated.

Three potential variables are found to be affected by rail turnaround time in the hypotheses testing, which is a sign of the influence of effective hinterland transport on port operating performance. Ship turnaround time, berth occupancy ratio, and average call size of ships are those factors. Better port performance, particularly the aforementioned indicators of port performance, would also result from a more focus on rail turnaround.

Once the transport is organized and enhanced, this type of interaction clarifies and aids in valuing the correlation and effects of inland transport on the port's operational efficiency of a container terminal and rail transport. Furthermore, since the effects of effective inland transit on port efficiency take time to materialize, the relationship and subsequent effects become increasingly clear over time.

However, because they vary from port to port, ports must determine the performance parameters that are impacted by inland transit. Finding out what actually affects the performance metrics is necessary. In order to improve port performance, attention should be focused on optimizing and further organizing the hinterland transport.

5.2 Issues and Future Research Directions

The findings and results of this study have some limitations, just like any other research. As previously stated, port performance is extremely complicated. It has numerous interconnected subsystems that are difficult to reduce to a handful. They all come together in a specific order and at a specific moment. What matters is understanding that among the vital components of effective port operation is hinterland transport one that quickly unloads and reloads cargo from and into the port. The performance of ports would benefit from such a reliable transport system.

 It was difficult to integrate all of the performance metrics and confirm the correlation with hinterland transport, even though there are several that might be connected to it and tested. The only performance metric for hinterland transportation was rail turnaround time. Even in the context of this study, there are some other indications that can be used to describe hinterland movement, but they were either not available or may not have been generally observed.

The performance of the entire port with respect to hinterland transit is not accurately represented by the container terminal's overall picture. It's important to note that there are more terminals, including general cargo, liquid cargo, and dry bulk terminals. If other terminal

performances were included to take into consideration the overall port performance, it's feasible that this study's uneven weighting of the container terminal might change. Other prominent and more strong factors may have contributed to the significant variation in the influence on the indicators; furthermore, these dominant factors vary from port to port relying upon the way the ports are operating in general.

More crucially, because each port organizes and makes use of transportation in a different way, the research's conclusions about the connection between hinterland connectivity and port performance cannot be extrapolated to other ports. In other words, the knowledge of the link is advantageous since it can be applied in every port independently, and it also encourages many ports to continue observing and identifying the effects of hinterland transit on port performance.

The research into the effect of hinterland transit on port performance has increased our understanding of the link, notwithstanding the aforementioned restrictions. The study was conducted with few noteworthy restrictions. Most crucially, the research was conducted with the understanding that no research design is flawless. Therefore, if the research is wisely designed, flaws can be eliminated and the research can successfully accomplish its intended goals. Overall, every effort has been made to guarantee that the work is morally sound and pertinent to the goals of this research.

However, because this study is experimental in nature, more research is needed to identify and evaluate the correlation between inland transportation and port efficiency. In addition, there are just a few measurable variables employed in this study; increasing the number of variables and utilizing a variety of approaches would produce more diverse results.

Additional inputs to the model parameters would also improve its ability to explain the effects of hinterland transportation using a variety of quantitative and qualitative techniques, including the use of surveys and interviews. Due to its narrow scope and context, this analysis can only partially establish the questioned effects and links because it covers such a vast issue and involves so many complicated aspects.

Future studies should investigate this link at other terminals, including liquid cargo, general cargo, and different ports in various nations. Various situations will undoubtedly need unique parameters in order to differentiate between additional elements. However, the hypotheses of the statistical method given in this study can be used to assess the correlation between rail turnabout and performance parameters that were clarified here.

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