Assessing the factors impacting the shipping container dwell time : A multiport research study

Mohan Saini, Ph.D.

Doctoral Thesis Summary

Tomas Bata University in Zlín

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Faculty of Management and Economics

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Posouzení různých faktorů ovlivňujících dobu zdržení přepravního kontejneru: Studie napříč několika námořními přístavy

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ABSTRACT

Ocean transportation is the most preferred mode of transportation that represents a significant role in global trade. Ocean transportation comprises around 80% of the aggregate worldwide cargo volume. This doctoral thesis focused on investigating the factors that influence the dwell time of shipping containers in ocean transportation. This research study focused on the significance of implementing a continuous track and trace system in the management of shipping containers. The stakeholders in a typical container supply chain involves port operators, shipping lines, transporters, shippers, consignee who operates in silo conditions. These stakeholders must synergize and collaborate by standardizing the information transaction mechanism.

This research thesis is divided into three phases. For the Phase I, the World Bank's secondary dataset for the key economies is extracted, and fuzzy qualitative comparison analysis is carried out. This is accomplished through comprehending the impact of the indicators such as logistics cost (LC) and Logistics performance index (LPI) on economic growth (GDP per capita). The phase I result indicates in determining LPI is the core causal configuration along with track and trace for the positive impact on economic development. For the phase II of the research, terminal operating data of the fourteen ports is analysed utilizing ordinary least squares (OLS) with Python as a tool for big data science. The container data amounting to 2.8 million rows was analysed utilizing ordinary least square method and subsequently discussed with port operators through structured interviews. The results shows that continuous track and trace results in the reduced dwell time of the container. The top three ports (A, G and L) were selected based on the lowest RMSE (Root mean square error) 15.6, 15.7, 15.86 % in the phase III of research study for qualitative reasoning.

The prime reasons of free period and gate cut off for cycle (The cut off time before which container must gate in to the port), equipment demand (the demand of equipment 20 feet or 40 feet which is basis the industry in the proximity of ports) and heavy cargo manufacturing for size (the odd dimensional of bulk cargo which can fit in to a specific container size), higher rail frequency, connectivity, sustainability goals and efficient truck docking strategies for mode were identified. Tran shipment ports, along with better pre-inspection clearance steps were few of the major reasons for empty/laden efficient movement. Trade support schemes along with free days due to high competition at CFS (Container Freight Station) were reasons cited by trade for DPD/DPE(Direct Port Delivery/Direct Port Export). The majority of the container which are imported or exported via container freight station have lesser dwell time. A qualitative framework is presented while collating the results from the structured interviews. The research contributed to academia and practice on novel insights of tracking technology impact on the efficiency of container movement and will be of interest to researchers and industry practitioner on evaluating the container movement and op-

erations handling. By continuous monitoring and tracking containers, port operators can manage the shift efficiently leading to the controlled shift timings of operators along with their safety and direct benefits to environment. The varying reasons of dwell time at different ports are presented in the concluding results.

ABSTRAKT

Námořní doprava je nejpreferovanějším způsobem dopravy, který hraje významnou roli v celosvětovém trhu. Námořní přeprava představuje přibližně 80 % celkového celosvětového objemu nákladu. Tato disertační práce je zaměřená na zkoumání faktorů, které ovlivňují dobu zdržení přepravních kontejnerů v námořní dopravě. Tato rešerše se venuje významu implementace systému průběžného sledování a sledování v řízení přepravních kontejnerů. Zúčastněné strany v typickém dodavatelském řetězci kontejnerů zahrnují provozovatele přístavů, lodní linky, přepravce, zasilatele, příjemce, kteří operují v podmínkách sila. Tyto zúčastněné strany se musí spolupracovat prostřednictvím standardizace mechanismu informačních transakcí.

Tato výzkumná práce je rozdělena do tří fází. Pro fázi I je extrahován sekundární soubor dat Světové banky pro klíčové ekonomiky a je provedena fuzzy kvalitativní srovnávací analýza. Toho je dosaženo pochopením dopadu ukazatelů, jako jsou logistické náklady (LC) an index logistického výkonu (LPI) na ekonomický růst (GDP na hlavu). Výsledek fáze I ukazuje, že při určování LPI je hlavní kauzální konfigurace spolu se sledováním pozitivního dopadu na ekonomický rozvoj. Pro fázi II výzkumu jsou roční data provozu terminálu čtrnácti portů analyzována pomocí běžných nejmenších čtverců (OLS) pomoci Pythonu jako nástroje pro vědu o velkých datech. Údaje o kontejnerech ve výši 2,8 milionu řádků byly analyzovány pomocí běžné metody nejmenších čtverců a následně prodiskutovány s provozovateli přístavů prostřednictvím strukturovaných rozhovorů. Výsledky ukazují, že kontinuální sledování vede ke zkrácení doby prodlevy nádoby. Tři nejlepší porty (A, G a L) byly vybrány na základě nejnižší RMSE (Root mean square error) 15,6; 15,7; 15,86 % ve fázi III výzkumné studie pro kvalitativní zdůvodnění.

Hlavní důvody prostoje pro cyklus (čas, před kterým musí kontejner vjet do přístavu), poptávka po zařízení (požadavek na zařízení 20 stop nebo 40 stop, což je základem průmyslu v blízkosti přístavů) a výroba těžkého nákladu pro velikost (lichý rozměr hromadného nákladu, který se vejde do konkrétní velikosti kontejneru), vyšší frekvenci železnic, konektivitu, cíle udržitelnosti a efektivní strategie dokování kamionů pro režim. Přepravní přístavy spolu s lepšími kroky odbavení před inspekcí byly jen málo z hlavních důvodů pro efektivní pohyb prázdný/naložený. Schémata podpory obchodu spolu s volnými dny kvůli vysoké konkurenci na CFS (Container Freight Station) byly důvody uváděné obchodem pro DPD/DPE (Direct Port Delivery/Direct Port Export). Většina kontejnerů, které jsou dováženy nebo vyváženy přes kontejnerovou nákladní stanici, má

kratší dobu zdržení. Při porovnávání výsledků ze strukturovaných rozhovorů je prezentován kvalitativní rámec. Výzkum přispěl akademické obci a praxi k novým poznatkům o dopadu technologie sledování na efektivitu pohybu kontejnerů a bude zajímat výzkumné pracovníky a odborníky v oboru při hodnocení pohybu kontejnerů a manipulace s nimi. Díky nepřetržitému sledování a sledování kontejnerů mohou provozovatelé přístavů efektivně řídit směny, což vede k řízenému načasování směn operátorů spolu s jejich bezpečností a přímými přínosy pro životní prostředí. Různé důvody prodlevy na různých portech jsou uvedeny v závěrečných výsledcích.

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1. INTRODUCTION

Ocean shipping containers are the primary storage equipment of choice for ocean transit and movement. A variety of container types are transported in the marine transportation such as general-purpose, reefer, dry, oil, and tank containers. According to research, a significant proportion of global trade, specifically 80% by volume and 30% by value, is facilitated through the utilization of these containers (Muñuzuri et al., 2020); (UNCTAD, 2018). These numbers are expected to further rise due to the expansion of economies and the process of globalization(Fruth & Teuteberg, 2017). The cross-border cargo transportation sector, currently valued at USD 10.9 billion in terms of industry capitalization, is seeing a steady growth rate of 8.5%, as depicted in Figure 1. This phenomenon will lead to an increase in the quantity of containers being transported, thus resulting in a significant surge in both the volume and traffic of containers at seaports for handling purposes. According to a research, India, as an emerging country, has experienced a significant increase of 30% in container volume during the period of April to October 2021 (Sam & Whelan, 2021). This rise has consequently led to an escalation in freight rates.

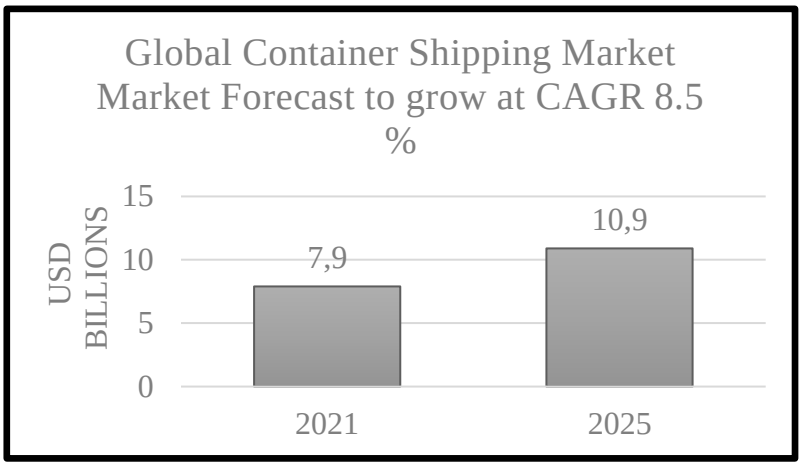


Figure 1 : Container shipping market global (Research and Markets, 2021)

The operational processes involved in container management at different ports worldwide is distinct and unique. The handling of containers involves a range of activities, which are inherently complex due to the large volume of containers involved. The primary containers utilized for global trade are the twenty-foot and forty-foot containers. These containers have the capacity to accommodate cargo volumes ranging from a few kilograms to 15,000 kilograms. Efficient handling of such substantial container and freight necessitates the utilization of specialized material handling equipment and information technology systems. Therefore, it is imperative to thoroughly research and analyse the intricacies and nuances of container handling operations. The series of activities encompassing vessel berthing to gate out includes a range of activities that contribute to the calculation of

dwell time. This doctoral thesis researches within the broader scope of the research community and practical application for reasons behind different dwell time at the ocean container ports.

The container handling procedures encompass a range of intricate activities, such as dock crane operations, customs examination, mobile and fixed container scanners, and yard operations. These procedures involve the utilization of diverse handling equipment's. The temporal limitation associated with each of these operational processes causes the dwell time to be different at different ports. It is also a contributing factor to the duration that a container remains at a given port. Based on the previous researches, it has been established that examination, scanning, and optimal timing are significant factors that contribute to dwell time during the import journey. The objective of this thesis was to investigate the variability in dwell time and time duration by examining the diverse aspects associated with container specifications. Figure 2, illustrates the duration of container stays at the prominent ports in India during import journey. It is evident that there exists variation in dwell time across ports, even when considering standardized container sizes and handling equipment. The research on significant variation in dwell time, spanning from 24 to 72 hours, is of utmost importance.

Port	Average Import Dwell time (In hours)
1	39
2	27
3	28
4	26
5	73
6	56
7	23
8	64
9	84
10	58
11	44
12	90
13	32

Figure 2 : Dwell time at major port of India, (Sagar Mala, 2016)

Figure. 2, illustrates the significant variability in the duration of container dwell time at the major ports in India for the import journey for the time period 2019-2020. The similar variation is also evident at the prominent international ocean ports, as depicted in Figure 3. The primary objective of this doctoral thesis was to evaluate the import and export procedures implemented at the major ports in India, with a specific emphasis on the time taken from the arrival of vessels to the completion of gate out processes.

This doctoral thesis made a unique and valuable contribution to the academic and practice by understanding the various factors and elements that influence

shipping container dwell time, with a particular focus on the role of tracking technologies. The qualitative examination of factors influencing stay duration was be conducted through structured interviews with port operators.

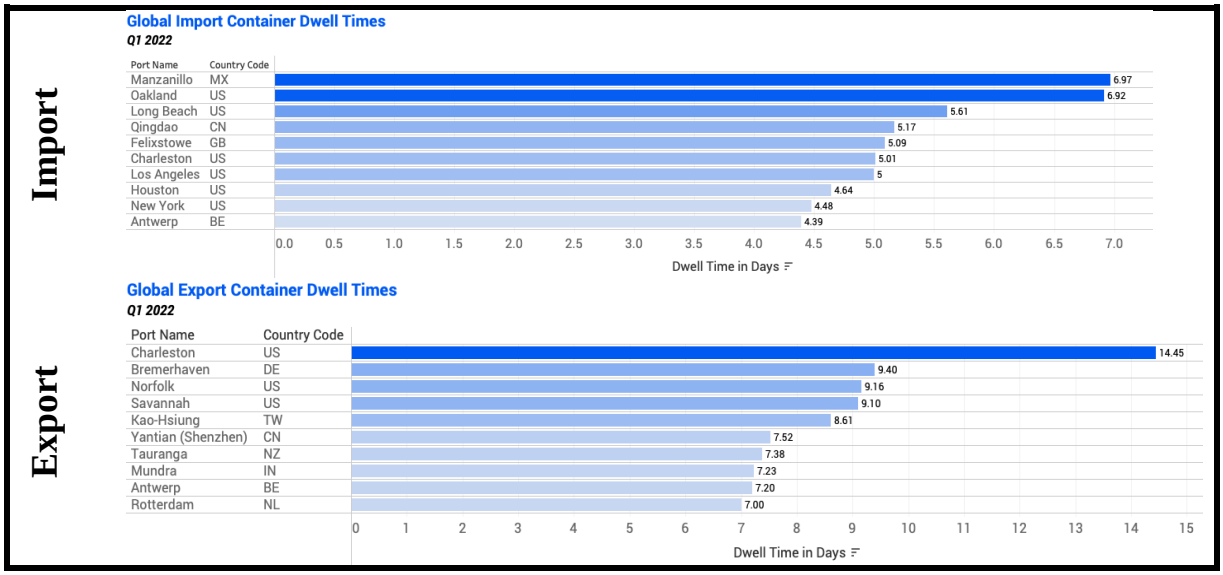


Figure 3: Dwell Time comparison at Global Ports (Cooke James, 2022)

The single window system, as defined by the United Nations Centre for Trade Facilitation and E-Business (UN/CEFACT), refers to a comprehensive service that enables all relevant stakeholders in the container trade and ocean transportation to exchange the data standardization and shipping documents in a prescribed sequence, thereby facilitating the completion of all necessary import and export procedures. The advancement of technology and security protocols in the context of data interchange within the shipping sector is predicated on the utilization of a model build, which aims to redefine the process of tracking and tracing between operators in the container supply chain (Transmetrics, 2021).

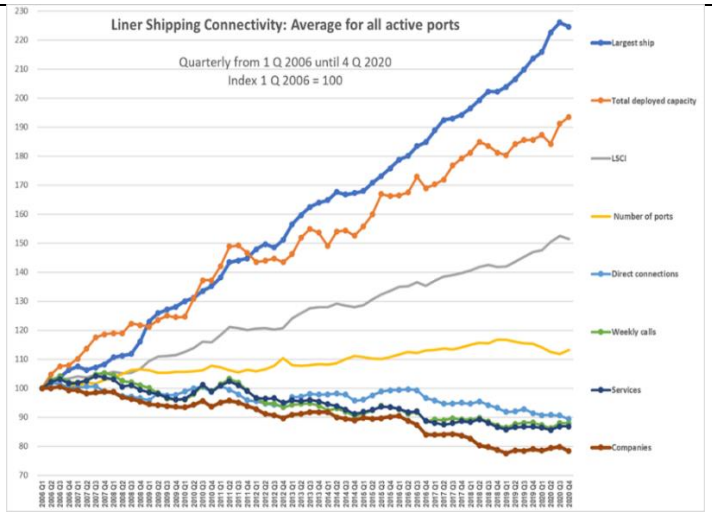
Various researchers have highlighted the importance of multitude criteria's that contribute to the definition of port performance. Performance indicators such as vessel operations time, port throughput, waiting times of truck at the port, dwell time of container, vessel berth in to berth out time, productivity of labour, vessel turnaround, vessel waiting time, and container dwell time have been utilized in previous studies to assess port productivity(UNCTAD, 1976) (MONIE, 1987);(Tongzon,1995);(Nicoll & Nicholson, 2007);(Brooks, 2006). Additionally, other indicators of a similar nature, such as the manpower skillsets, stevedoring, loading, and unloading of cargo, turnaround times, shipment timeliness of maritime services (Marlow & Casaca, 2003). This doctoral thesis outlined to assess significant logistical performance factors, including LPI (Logistics Performance Index) and TT (Tracking and Trace), as well as port performance criteria such as dwell time, these parameters were examined for research purposes, as depicted in Table 1.

Table 1: Important researched parameters (Source: Own Research)

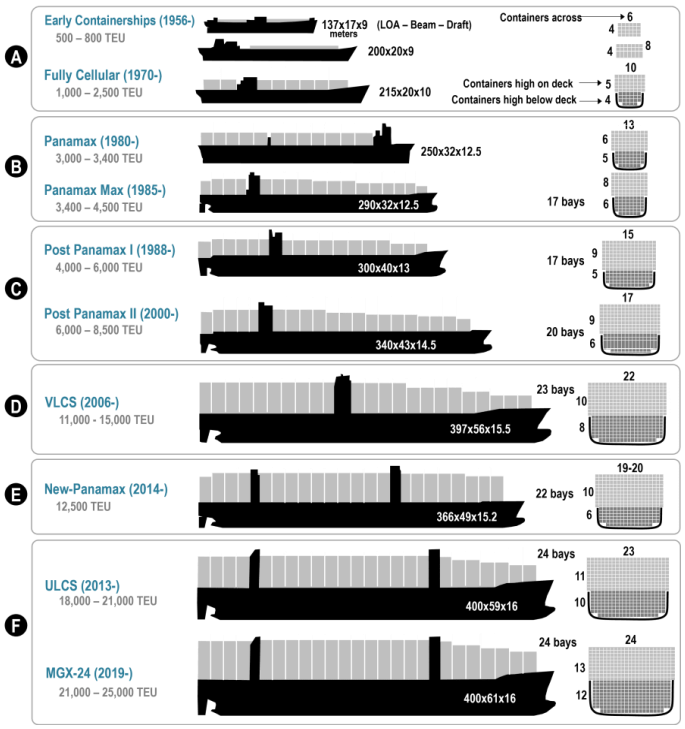
Logistics Performance Index (LPI)	**Tracking and Trace**	**Dwell Time**
The Logistics Performance Index (LPI) is an interactive benchmarking tool created by the World Bank to help countries identify the challenges and opportunities they face in their performance on trade logistics and what they can do to improve their performance (World Bank, 2023)	The ability to track and trace consignments.(World Bank, 2023).	Container dwell time is defined as the period containers stay at the terminal(Mwasenga, 2012).

1.1 Motivation and need for the research study

The size of vessels transporting containers is progressively growing, while the availability of land and space for operations remains constrained or same in size/area. Therefore, it is crucial to implement measures that enhance the efficiency of container handling and streamline operational processes. Figure 4 illustrates the relationship between the average ship size berthing at the port and the time period/duration in years. This observation demonstrates that the dimensions of vessels are expanding while the available area for port operations remains constant. Therefore, it is imperative for a container port terminal to use optimization strategies in order to ensure the provision and effective management of efficient processes.



Source : (Hoffmann & Hoffmann, 2021)
X – Axis Trimester in years, Y-Axis : Average Size of ship per port



(JEAN-PAUL RODRIGUE, 2022)

Figure 4 Average Vessel Size per port at a given trimester and vessel size over a time period

Based on the aforementioned information, and Figure. 4 the optimization of container handling must be achieved through the effective utilization of operating space and the implementation of processes that consider the factors such as, *(i)* Port infrastructure, such as berth areas, cranes, technology, *(ii)* Lean efficient processes and space optimization, *(iii)*High Investment for expanding the space/land area, *(iv)* Environmental Impact (Saini et al., 2021).

The research focuses on illustrating the major reasons of variation in dwell time at different locations of port operations in India. The research focused on identifying the importance of logistics sector by performing a pilot study utilizing fsQCA (Fuzzy qualitative comparative analysis). The pilot study on Phase. I, set the foundation for research by understanding the importance of logistics sector for economic development. The logistics performance index (LPI), developed by the World Bank, is to assess and rank the economies based on their logistical capabilities. This index serves as a valuable tool for comprehending the significance of logistics. Subsequently, the track and trace, which is one of the parameters of logistics performance index (LPI) is evaluated to understand its importance and relevance. The subsequent phases of the research study focused on evaluating the impact of various factors such as: (*i*)Size (20 feet or 40 feet), (*ii*)Mode (Train or Truck), (*iii*)Cycle (Import or Export), (*iv*)Status (Empty or Laden), (*v*)Delivery (Direct Port Delivery or Direct Port Export), (*vi*)Tracking , on the container dwell

time. The statistical method of ordinary least squares utilizing the code in Python for the large data sets and SPSS were adopted for data analysis. In the Phase. II, the data is analysed for the multiple ports of India and top three ports were selected for qualitative reasoning based on the least root mean square error. In the Phase. III of research study, the key representatives from the top three ports were interviewed on the data analysis results to understand the reasons for varying dwell time of shipping containers across different ports. This research study is of prime importance for the academia and practice to illustrate the reasons of varying container dwell time. This will enable port operators and academia to research strategies for container operational planning and container performance parameters.

Table 2: Summary of research analysis process and steps (Source: Own Research)

Research Objective	Method	Model	Tools
To establish the importance of logistics and track and trace technology	Qualitative	Causal configurations	fsQCA 3.0 fuzzy qualitative comparative analysis
To understand the impact of various variables of port operations such as, (*i*)Cycle, (*ii*)Size, (*iii*)Mode, (*iv*)Status,(*v*) DPD/DPE (*vi*) Tracking Technology	Quantitative	Ordinary Least Squares	Python for Data Science and SPSS
To understand the various reasons of the variation in container dwell time and qualitative reasoning	Qualitative	Qualitative framework	Qualitative coding technique

This doctoral thesis aimed to assess the factors that influence port operations, with a specific focus on continuous tracking and tracing, and their impact on the dwell time of shipping containers. The problem definition highlights the significance of investigating the collective influence of LPI (Logistics Performance Index) and LC (Logistics Costs) on economic development, as well as the presence or absence of tracking technology on shipping containers. This research is crucial for comprehending the various aspects that contribute to the port performance. This research thesis made a unique contribution to the existing literature by examining the effects of economic and technological factors on container dwell

time. This research employed a mixed methodology, encompassing both quantitative and qualitative elements, to examine the impact of Logistics Performance Index (LPI) and Track & Trace systems on economic development. The research community faces a challenge in accessing datasets due to their limited availability, (De Armas Jacomino et al., 2021).

2. THEORETICAL FRAMEWORK

The logistical sector plays a crucial role in facilitating economic growth and exerting substantial effect on several economic sectors, such as ports, infrastructure for transportation, storage facilities, and systems for information and communication, within the subject matter of supply chain management. The establishment of this sector towards becoming a significant component in the development of industry, trade and economy is widely acknowledged. The advancement of the logistics industry plays a pivotal role in facilitating significant transitions in the functioning of businesses and economies, particularly with regards to investments in logistics. Investments of this nature are undertaken within many subsectors of the logistics industry, including ports, warehouses, infrastructure, technology, and standardization. This chapter will provide an overview of the theoretical study conducted on the topics of Logistics Performance Index (LPI), economic development, and Port performance factors, specifically focusing on Dwell time.

2.1 Logistics performance index in research studies

Given the significance of the logistics sector, the World Bank has periodically released a comprehensive Logistics Performance Index (LPI), which assesses economies based on six characteristics, with updates occurring every two years. Numerous economies have achieved economic growth through the strategic expansion of their export-oriented industry activities. The significance of export success is particularly notable in developing economies, which is important for the development of logistics sector, (Ruzekova et al., 2020). In their research of specific Asian countries, the authors highlighted a positive correlation between trade liberalization and growth in the economy, (Sriyana & Afandi, 2020). In this research it was concluded that, it is imperative that favourable logistics conditions and robust infrastructure are in place to facilitate and sustain the level of trade openness.

The Logistics Performance Index (LPI) acknowledges the strong association and significant impact that exists between the transportation and logistics industry and the development of the economy. The Logistics Performance Index (LPI) was first created by the World Bank in 2007 with the purpose of evaluating and classifying economies according to their performance in the field of logistics. This index and technique are utilized to analyse and measure global economies in relation to one another based on six distinct factors. In a study, the authors

examined the significance of logistics from the perspective of importers and exporters in 26 European Union (EU) nations, (Puertas et al., 2014). The findings of the research indicated that logistics competence and tracking have emerged as significant determinants within the confines of the Logistics Performance Index (LPI). The LPI (Logistics Performance Index), is a standardized measurement tool used to evaluate and compare countries according to six separate factors, as specified in Table 3.

Table 3 Components of Logistics Performance Index (World Bank, 2023)

Customs	Efficiency of customs and border management clearing.
Infrastructure	Quality of trade and transport infrastructure.
Logistics competency	Competence and quality of logistics services.
Timeliness	Shipments delivering to within expected delivery times.
Tracking and Tracing	Ability to track and trace consignments
International shipments	Ease of arranging competitively priced shipments

The LPI database is released biennially and has been published for a total of six cycles to date, specifically in the years 2007, 2010, 2012, 2014, 2016, and 2018, 2023. The LPI index is derived from a survey that utilizes a questionnaire to assess respondents' evaluations of eight international markets based on the six fundamental components of logistic performance outlined in Table 3. The respondents provide ratings using a five-point Likert Scale. In this scale, 1 represents low degree and 5 indicates a very high degree. Subsequently, Logistics performance index is formulated by the application of Principal Component Analysis (PCA), a widely employed statistical methodology. The result obtained by Principal Component Analysis (PCA) is a calculated value that represents a weighted average of scores, similar to the LPI indicator. The reference provides a comprehensive explanation of the approach employed in the LPI, offering a thorough examination and comprehension of the subject matter (World Bank, 2023)

According to research, the improvement of logistics performance requires the adoption of many measures, such as the development of infrastructure, regulatory enhancements facilitated by the government, the usage of technological innovations, and the development of competent manpower (Jhawar et al., 2017). In order to address this issue, it is imperative for governments to effectively oversee and comprehend the prevailing logistics landscape inside their respective countries. This necessitates the establishment of comprehensive frameworks aimed at optimizing and advancing logistical operations through the implementation of policy reforms.

In a research study, the authors aimed to investigate moderating effect of the GCI (Global Competitiveness index) on the LPI. The results of the research indicated, enhancing the components of logistics performance index such as international shipments, Tracking and Timeliness can lead to the developments in global competitiveness (GCI) (Çemberci et al., 2015). Another research in this dimension explored the integration of the Logistics Performance Index scoring and EPI (Environment Performance Index) scoring while establishing carbon efficient system of green logistics index (Kim & Min, 2011). This novel index yielded a rating that diverged significantly from both the LPI and the EPI rankings. In their study, the authors conducted an evaluation of the logistics performance of countries of the Organization for Economic Cooperation and Development (OECD) by adopting the tool Fuzzy (Yildirim & Adiguzel Mercangoz, 2020).

A research study investigating the relationship between variables infrastructure of the GCI (Global Competitive Index and the LPI (Logistics Performance Index) (Erkan, 2014).The infrastructure components employed GCI encompass the road quality, supply chain value, research and development budget, infrastructure of the ports, air transport. The method of regression analysis was adopted in determining the statistical significance of the Logistics Performance Index score and its respective indicators. The results demonstrated that out of the six characteristics examined, namely Port Infrastructure quality and road development infrastructure infrastructure and quality of road infrastructure, had a statistically association with the overall LPI score. Research conducted further study on the correlation between doing business rating, GDP, and other variables that were not previously considered in the analysis. The authors recommended replicating the study to find any emerging trends (Estevão et al., 2020). Hence, it was crucial to conduct comprehensive research to determine to assess the significance of the LPI and the logistics cost in order to determine their respective roles.

According to a survey, an investigation was carried out to examine the many metrics that are considered when assessing logistics expenses (Supply Chain Digest, 2006). The findings of a study including 247 participants demonstrate that logistics costs may be classified into three distinct categories: *(i)* Logistics cost as a proportion of net sales, *(ii)* Logistics costs as a proportion of absolute cost, and *(iii)* Logistics costs as a proportion of gross domestic product. The research also demonstrated; the measurements of a firm cannot be directly related to the macro level. Therefore, assessing the cost of logistics presents difficulties and challenges owing to the intricate and multifaceted nature of logistics activities (Farahani et al., 2009);(Havenga, 2010).

2.2 Dwell time in research studies

The duration of time that cargo or vessels spend at a terminal, commonly referred to as dwell time, is a crucial factor in assessing the effectiveness of operations and the overall capacity of the port. The growing magnitude of global trade

and container volume necessitates effective yard management by yard managers in order to optimize terminal efficiency (Chu & Huang, 2005). Given the substantial growth in the cargo volume, the available options are constrained to either expanding operational processing area, or requires a significant investment in acquiring additional land acquisition, or enhancing operational efficiency to minimize dwell time and thus lessen the need for rehandling and reshuffling movements.

Container terminal operators are actively working towards minimizing the dwell time of containers by identifying the variables that contribute to its increase, hence reducing dwell time of shipping. In a research study , a framework was developed with the aim of providing guidance to the operators of the ocean container terminals about price structure and tariff for the quanta of time a container stayed in the terminal (Merckx, 2005). Various stakeholders in the container supply chain including forwarding enterprises, shipper and consignee's often store their cargo within a container yard of freight depot until the need for their utilization arises in the production process, (Rodrigue & Notteboom, 2008).

In another parallel research study, a correlation was demonstrated between extended container stay periods and an increase in unproductive motions(Huang et al., 2008). These factors have a detrimental impact on the efficiency of a terminal, hence demonstrating its cost inefficiency. According to research, the study identifies several key factors that have an impact on dwell time. The determinants include the geographical location of the terminal, the effectiveness of its operation, the regulatory frameworks governing port operations, the protocols followed by customs authorities, the involvement of freight forwarders or shipping firms, the accessibility of inland transportation links, the chosen mode of transport, the nature of the cargo being transported, and the established commercial affiliations among the stakeholders (Moini et al., 2012).The research employed genetic algorithms as a methodology to assess the primary variables influencing container dwell time and quantified their influence on terminal productivity.

One area that has been identified as a potential focus for future research is the collection of data pertaining to landside activities and the nature of the items or commodities being transported. The inclusion of this supplementary information is anticipated to improve the capacity to forecast outcomes using the suggested models. An additional significant result of this research investigation involved the establishment of a correlation between gate operations and berth operations at a maritime container terminal through the utilization of analytical and simulation methodologies.

In a research study, authors put forth a methodological framework aimed at integrating various models for the purpose of predicting the dwell duration of containers within a maritime terminal (Kourounioti et al., 2015). This framework incorporates a regression model that specifically examines the impact of the consignee of the shipping container and the content of container on the dwell time.

Another research conducted by (Zhao & Goodchild, 2010), emphasizes the significance of information pertaining to container discharge and tracking. The researchers employed a model simulating impact of advance information on the operational planning and efficiency for the container terminal. The study's findings demonstrated that having prior knowledge of truck arrival or departure information contributes to a decrease in unnecessary movements. The existing body of research and literature on the factors influencing dwell time, reshuffle, and rehandle is currently limited. However, conducting further research on these parameters, particularly in conjunction with tracking information on container pick up or discharge, will greatly enhance the effectiveness of operational level terminal planning. In their study, (Nooramin et al., 2011), examined the impact of truck congestion time and the reduction of waiting time at terminals on overall efficiency. They focused on a specific aspect of the process in order to assess its effectiveness. Figure. 5, depicts the process-wise complexity model, which establishes a relationship between process efficiency and the perspectives of time and complexity.

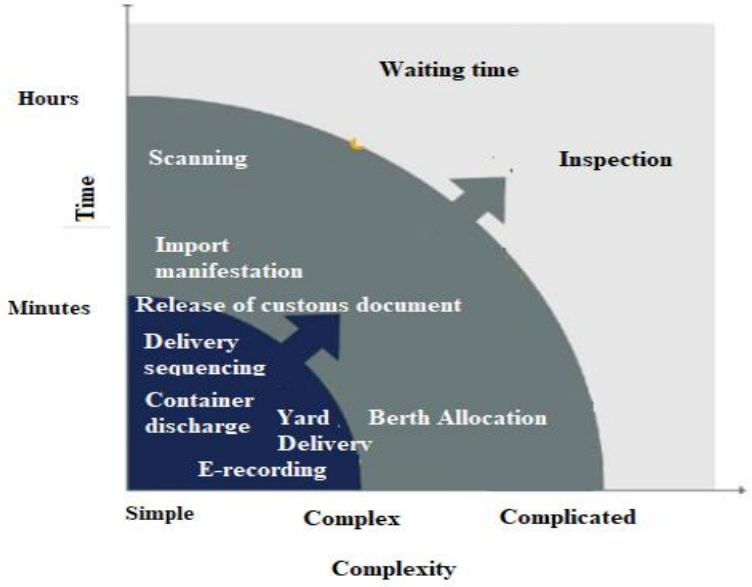


Figure 5 Time Complexity Model, (Saini et al., 2021)

The port management highlighted the challenges for the quay cranes operations for the throughput and moves per hour for container processing. The cranes are performing thirty to thirty-two moves per hour for the container operations. These operations are significantly impacted due to the congestion of truck at the gate and the yard side. According to a study, the port operator in a range of advanced planning techniques for the bay planning and the stowage plan of the berthing vessel (Saini et al., 2021). These strategies consider factors such as the cumulative weight of the stacks, the sequence of loading, and the weight of the container. The presence of several stakeholders leads to various complex challenges, resulting in further inefficiencies in the operations.

Table 4 Summary of dwell time literature review (Source: Own Research)

Variables	Literature reference	Research parameters
Logistics Performance Index	Erkan (2014), Civelek et al. (2015), Milenkovic et al. (2020), Marti et al. (2014)	LPI, International trade, GCI (Global competitive index), GDP (Gross domestic product)
Logistics Cost	Karri Rantasila and Lauri Ojala (2015), Hayaloglu (2015), Devlin and Yee (2005,	Logistics cost as % of GDP, Sales or turnover and absolute cost.
Dwell Time	Jacomino et. al (2021), Aminatou Met. al (2018), Kourounioti I get. al (2016), Sagar et. al (2022), Moini et. al (2012), Goodchild et. al (2005), Merckx (2005), (Rodrique, 2008), Huang (2008), Zhao and Goodchild (2010) Nooramin et. al (2011)	Crane and terminal operations, Container size, commodity, factors determining dwell time, Tracking, Port performance parameters

Based on the findings of the literature review (Table 4) and a thematic analysis of key words, it is evident that there is a lack of research studies that specifically investigate the analysis of container dwell time, both with and without the use of tracking devices. The doctoral thesis examined the correlation between economic factors and the field of logistics, specifically focusing on industrial engineering in connection to shipping and container dwell time.

This section of the theoretical review provides an overview of prior studies conducted on the research subject of dwell time at various ports worldwide. The research was conducted either at a single port with a limited dataset or in conjunction with an additional scenario that affects the performance parameter of the port. A number of studies have emphasized the significance of a real-time accessible dataset in assessing the efficacy of initiatives aimed at lowering dwell time. This doctoral thesis focuses on the influencing factors of dwell time at numerous ports, taking into account the presence of tracking tools on containers. This study aims to make a significant addition to the field by examining and establishing relationships among different characteristics in container specifications.

2.3 Keyword search and Analysis of the originality of the topic

The selected keywords for evaluating the novelty of the topic were carefully designed to encompass all potential combinations that precisely depict the subject matter of the study. The searches were conducted on October 18, 2022, using the scientific databases "Scopus" and "Web of Science". The search parameters were set to include the title, abstract, and keywords within the search fields. The examination of originality involves the identification of keywords, which have been carefully selected through a meticulous and rigorous process, Table 5. The following keywords have been selected to be significant in this research:

1. Marine OR Sea OR Ocean AND Ports AND, 2. Port Performance AND, 3. Shipping container AND, 4. Dwell Time AND, 5. Tracking AND, 6. Yard.

Table 5 Keyword Search Analysis Results (Source: Own Research)

Keyword Combination Topic, Title, Abstract, Keyword	**Databases**	
	Scopus	**Web of Science**
1	23479	12780
2	30167	23008
3	6175	6325
4	19443	30485
5	586862	740631
6	21284	11492
1 + 2	1753	1062
1 + 3	543	535
1 + 5	339	354
1 + 2 + 3	70	84
1 + 2 + 5	55	46
1 + 2 + 3 + 5	1	2
1 + 2 + 5 + 6	1	0
1 + 3 + 4 + 5	1	0
1 + 3 + 4	0	3
2 + 4	33	29
1 + 4 + 5	0	0
1 + 2 + 3 + 4 + 5 + 6	0	0

The data presented in Table 5 indicates that there are very few research studies that integrate the mentioned factors, (*i*)Marine OR Sea OR Ocean AND Ports, (*ii*)Port Performance, (*iii*)Shipping container, (*iv*)Time, (*v*)Tracking, (*vi*)Yard.

3. RESEARCH OBJECTIVES, QUESTIONS AND HYPOTHESIS

3.1 Research Objectives

The primary aim of this study, as indicated by the literature review, was to examine the influence of track and trace technology, a significant component of the logistics performance index, on the port performance metric known as container dwell time. The purpose of this study was to investigate the significance of LPI (Logistics Performance Index) and TT (Track and Trace) systems in relation to economic development and port performance indicators, specifically focusing on dwell time. This evaluation is conducted with a specific focus on the following sub-objectives:

RO1: To identify the role of logistics performance index and logistics cost on the economic development.
RO2: To assess the role of track and trace and logistics cost on the economic development.
RO3: To identify the impact of track and track technology of container on the port performance measure such as container dwell time.
RO4: To evaluate the role of container size and port operations location on the container dwell time considering availability and non-availability of track and trace technology.

3.2 Research Questions and Hypothesis

The primary aim of this thesis was to investigate the influence of track and trace systems on the dwell time of shipping container. In order to address the current gaps in the literature, the following research questions were formulated.

Research question 1: How do logistics performance index and logistics cost influence economic development?
Justification: The currently available literature has examined the impact of the logistics performance index on economic development. Nevertheless, it is crucial to examine the influence of LPI (Logistics Performance Index) in conjunction with logistics costs on economic development, as these factors constitute the fundamental pillars of any economy. Therefore, it is crucial to examine the collective influence of logistics cost and logistics performance index on economic development.
Research Question 2: Does track and trace and logistics cost impact economic development?
Justification: Based on the current state of studies, there is a lack of research studies that have examined the influence of specific factors of the logistics performance index on both economic development and logistical cost. This study

aims to assess the significance of different factors within the logistics performance index, with a specific focus on track and trace. It is crucial to examine the effects and implications of these characteristics.

Research Question 3: What is the impact of cycle, mode, size of the container on the container dwell time?

Justification: The multiport data set from fourteen ports was analysed to understand the impact of, *(i)*Cycle : Import of Export, *(ii)*Mode : Truck or Rail, *(iii)* Size : 20 feet or 40 feet, *(iv)*Delivery (DPD- Direct Port Delivery/DPE- Direct Port Export) Yes/No , *(v)*Status (Empty/Laden), *(vi)*Tracking on the shipping container dwell time. For any container performance parameter, it was important to research on the factors associated with container and the reasoning. The qualitative research for the top three ports out of fourteen ports provided insights on the variation of dwell time due to container performance parameter.

Research Question 4: What are the major reasons behind variance in the container dwell time?

Justification: Different ports with same set of technology have high variance in dwell time and port performance parameters despite same set of operations. The research question 4 and 5, evaluated the reasons cited by port operators during the multi-port comparative analysis.

Hypothesis 1: Continuous track and trace of containers results in reduced container dwell time.

Justification: In the previous research, there have been study which evaluated the several factors such as container size, commodity, status for the impact on dwell time, however, there have been rarely any study performed which evaluates for the impact along with the availability and non-availability of tracking. Also, this research was performed for the multi-port scenario, which makes it more comprehensive in terms of results to be researched.

4. METHODOLOGY

This doctoral research study employed a mixed method technique for the analysis of data. The research started with a comprehensive examination of the existing literature and theoretical framework pertaining to the logistics performance index, track and trace, and container dwell time. The research purpose and questions outlined in the preceding sections were examined using a three-phase analysis for the study.

During Phase I, a mixed methods approach was employed to assess the significance of LPI (Logistics Performance Index), LC (Logistics Costs), and T & T (Track and Trace). The research was undertaken utilizing analytical techniques, specifically employing fuzzy qualitative comparative analysis. During the second part of the research project, the regression method was utilized to discover and analyse the elements that have an impact on port performance characteristics. The

phase III of the research project involved the identification of the factors influencing dwell time through the conduction of multiple discussion interviews with port practitioners.

4.1 Data Collection, and data analysis

This study examined the prominent economies situated in Asia (China, India, Japan, and Singapore), Europe (Czech Republic, France, Germany, and Slovenia), as well as the United Kingdom and the United States of America. The data utilized in this study was obtained from secondary sources, specifically the data repository of the World Bank (World Bank, 2023); (World Bank,)(Hofman Bert, 2017). The variables of interest included economic development, logistics cost, and the Logistics Performance Index (LPI).

During the second phase of the research study, the regression method (OLS – Ordinary Least Squares) was utilized to ascertain the components that have an impact on dwell time. The data was obtained from primary sources located in ports, specifically designated for research purposes. During the third part of the research project, the significance of dwell time was determined by the conduction of several discussion interviews with port practitioners. The data analysis steps employed is outlined in Table 6.

Table 6: Data analysis steps Phase I, II and III (Source: Own Research)

Phase	**Research phase variables**	**Methodology/method**	**Tool**
I	LPI, LC, EODB and ED	Fuzzy Qualitative Comparative Analysis	fsQCA 3.0
	Impact of tracking on container dwell time	Regression (OLS)	Python data science
II	Impact of *(i)* Cycle : Import of Export, *(ii)* Mode : Truck or Rail, *(iii)* Size : 20 feet or 40 feet, *(iv)* Delivery (DPD- Direct Port Delivery/ DPE- Direct Port Export),*(v)*Status (Empty/Laden), *(vi)* Tracking	Independent Sample T-Test	SPSS

III	Qualitative study of ports having least 3 RMSE (Root mean square error) for impact on dwell time.	Qualitative study through snowball research questions based on results of regression and independent sample t test	Qualitative

4.2 Methods for data analysis

4.2.1 Phase I

In the context of data analysis methodology for the Phase I, the utilization of fsQCA (fuzzy qualitative comparative analysis) was employed to ascertain the influence of LPI (Logistics Performance Index), LC (Logistics Cost), and T&T (Tracking and Tracing) on the economic development. The fuzzy set qualitative comparative analysis (fsQCA) is a widely employed method across various research domains, primarily utilized in situations characterized by limited sample sizes. The utilization of this analytical approach has been increasingly adopted in several study domains, (Kraus et al., 2018). The fsQCA methodology, as proposed by (Ragin, 2000), is specifically designed to find causal recipes rather than focusing on individual independent variables. Causal recipes are formal statements explaining how causally relevant elements combine into configurations associated with outcomes of interest (Park et al., 2020) This results in the establishment of a series of pathways that culminate in the desired outcome, (Park et al., 2017). It is important to note that there is no singular causal configuration that can be deemed as perfect in determining outcomes. Instead, this method elucidates how various attributes come together and converge into diverse paths that ultimately result in the same outcome. This is achieved by examining the presence or absence of certain attributes (Misangyi et al., 2017).

4.2.2 Phase II and III

The Phase II. focused on identifying the impact of (*i*) Cycle : Import or Export, (*ii*) Size : 20 feet or 40 feet, (*iii*) Mode: Truck or Rail, (*iv*) Status : Empty or Laden, (*v*) Delivery : DPD/DPE (Direct Port Delivery or Direct Port Export), (*vi*) Tracking Technology availability : Yes or No on the container dwell time. The research study was conducted based on the combination of the quantitative and qualitative analysis of the data collected from the port terminal systems. Qualitative research involves collecting and analysing non-numerical data from port terminal operating system and quantitative research is the process of collecting and analysing numerical data. The research was conducted following both qualitative

and quantitative methodology. The data collected for analysis was coded and analysed with regression statistical analysis tools using Python for data science.

For calculating the impact of track and trace technology on the dwell time on the container dwell time, the well-known technique to identify the dependent variables as weighted sum of the covariates along with coefficients obtained using ordinary least squares will be adopted (Maldonado et al., 2019). Based on the collection of port operations data collected from key sources research for research purpose only. The data was studied for seasonal variations and cyclical fluctuations.

5. PORTS DATA ANALYSIS AND MODELLING

5.1 Phase I

5.1.1 Phase I: Logistics Performance Index, Logistics Cost and Ease of Doing Business

The Phase I of this doctoral thesis examined research questions 1 and 2, with a specific focus on the variables of LPI, EODB (ease of doing business) and LC. FsQCA, also known as Fuzzy Set Qualitative Comparative Analysis, is a research methodology that aims to discover and combine independent variables in order to understand their collective impact on a dependent variable. This approach utilizes causal recipes to analyse and interpret the relationships between variables. The scholars in the field of management science widely employ the fuzzy fsQCA data analysis method, (Kraus et al., 2018).

Table 7 Intermediate solution results of LPI, EODB, LC and ED (Saini & Hrušecká, 2021a)

Causal Configuration	**1**	**2**
fz LC (Fuzzy Logistics Cost)	ø	x
fz EODB (Fuzzy ease of doing business)	x	ø
fz LPI (Fuzzy Logistics Performance Index)	●	●
Raw Coverage	0.818882	0.445087
Unique Coverage	0.421965	0.0481696
Consistency	0.889121	0.878327
Overall Solution coverage	0.867052	
Overall Solution consistency	0.862069	

Notes: ● indicates the presence of a condition; Ø indicates the absence of a condition; ●/Ø indicates core conditions; ●/ Ø indicates peripheral conditions; x indicates no contribution to configuration.

Table 7, presents causal configuration 1, which demonstrates that a higher degree of participation in the absence of LC and the presence of LPI is associated with increased values of GDP per capita. Causal configuration 2 reveals that the lack of ease of doing business (EODB) and the presence of logistics performance index (LPI) are factors that contribute to higher levels of gross domestic product (GDP) per capita. The variable LPI is included in the parsimonious models as a key predictor of the outcome variable, with larger values indicating a stronger impact.

It is important to note that the EODB, LPI, and LC parameters taken together are not the primary factors influencing the higher values of GDP per capita. The inclusion of LC in one of the configurations has a detrimental impact on economic development, but LPI is a crucial variable. LPI is included in the parsimonious solution and its presence in both configurations leads to greater values of GDP per capita. The presence of a negative relationship in the logistics cost variable indicates its significance within the study and its inclusion in the Logistics Performance Index (LPI) when evaluating and comparing economies based on their logistics performance.

5.1.2 Phase I: Logistics Performance Index parameters, Logistics Cost and economic development

This section describes research on the variables of logistics performance index along with logistics cost to illustrate on research question II. The data in this section comprises of the individual parameters of the Logistics Performance Index (LPI) such as *(i)*Customs, *(ii)*Logistics Competence, *(iii)*International shipments, *(iv)*Timeliness, *(v)*Track and Trace, *(vi)*Infrastructure and Logistics cost on economic development of ten major economies of Asia, Europe, UK and USA.

Table 8 : Intermediate solution results of LPI parameters, LC and ED (Saini & Hrušecká, 2021b)

Causal Configuration	**1**	**2**
fz LC (Fuzzy Logistics Cost)	ø	•
fz Cust (Fuzzy Customs)	•	ø
fz Infra (Fuzzy Infrastructure)	●	●
fz Tm (Fuzzy Timeliness)	•	•
fz TT (Fuzzy Track and Trace)	●	●
fz Log comp (Fuzzy Logistics competence)	●	●
fz Intl (Fuzzy International Shipments)	x	•

Raw Coverage	0.782274	0.292871
Unique Coverage	0.535645	0.046243
Consistency	0.906250	0.938272
Overall Solution Coverage	0.828516	
Overall Solution consistency	0.892116	

Notes: ● indicates the presence of a condition; Ø indicates the absence of a condition. ●/Ø indicates core conditions; ●/ Ø indicates peripheral conditions; x indicates no contribution to configuration.

It is significant to highlight that not all aspects of LPI are the primary factors influencing greater values of GDP per capita, Table 8. The inclusion of LC in the set of indicators for evaluating logistics performance can be attributed to its significant impact on the overall economic development of a country. In conclusion, it is imperative for economies to prioritize the enhancement of infrastructure, as well as the implementation of robust tracking and tracing systems, in order to effectively address the logistical aspects of economic development. The condition of labour conditions (LC) for the inverse relations indicates that LC has a significant impact on the economic development of a nation. In order to achieve higher levels of GDP, it is imperative to maintain improved processes, including but not limited to customs, timeliness, and international shipping, while also ensuring that these systems are adequately supported. Table. 9, summarized the results of section 5.1.1 and 5.1.2.

Table 9 : Comparison of fsQCA results (Source: Own Research)

Outcome Variable	**Variables (Test)**	**Correlation**	**fsQCA**	
			fsQCA Config I	**fsQCA config II**
GDP	LC	Negative	Absent peripheral solution	No relation
	LPI	Positive	Present core solution	Present core solution
	EODB	Positive	No relation	Absent peripheral solution
LPI	Tracking	NA	Present core solution	Present core solution
	Infrastructure	NA	Present core solution	Present core solution
	Logistics Competency	NA	Present core solution	Present core solution

5.2 Phase II and Phase III

In the phase II of data analysis, data from fourteen ocean ports was collected for determining the factors impacting shipping container dwell time. Variables such as, *(i)*Cycle (Import/Export), *(ii)*Size (20 feet/40 feet), *(iii)*Mode (Truck/Rail), *(iv)*Status (Empty/Laden), *(v)* Delivery: DPD/DPE (Direct Port Delivery or Direct Port Export) , (vi) Tracking Technology Availability Yes/No, was regressed against the container dwell time.

In order to ensure data security, the ports were assigned static values denoted by alphabetical characters from A through N. The trend analysis, correlation analysis, ordinary least squares, and independent sample t-test were conducted to explore and analyse all the ports in relation to their impact on tracking dwell time. Figure 6 depicts a visual representation of dwell time across the aforementioned six variables. The significance of considering the variability among ports and variables should be acknowledged for further study in this doctoral thesis.

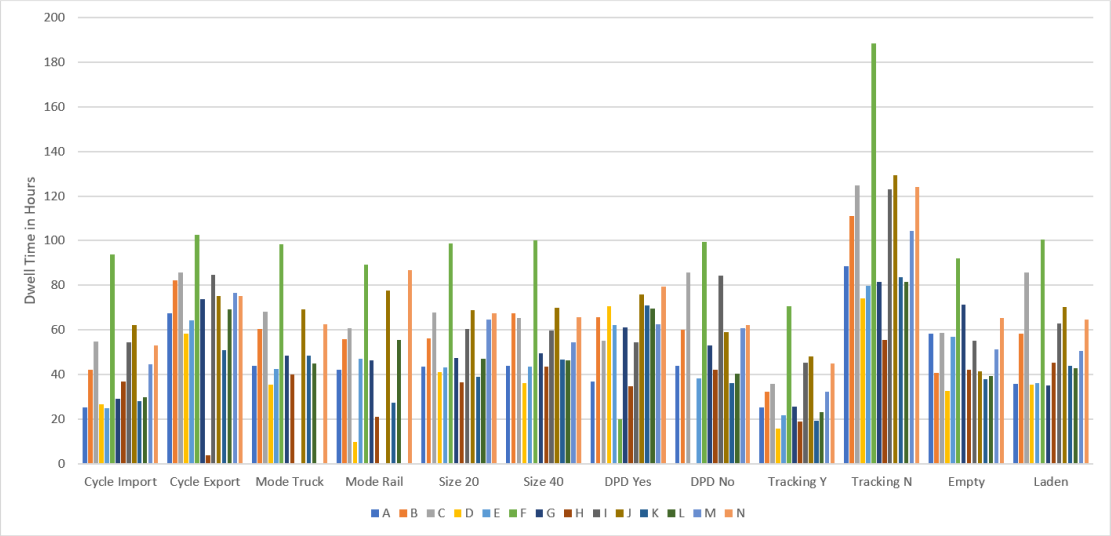


Figure 6 : Graphical summary of mean dwell time at fourteen ports (Source: Own Research)

Table 10 presents a comprehensive overview of the data analysis results for all fourteen ports, including the corresponding Root Mean Square Errors (RMSE). The purpose of this investigation was to examine the correlation and coefficient of determination (R^2) for the relationship between dwell time and port performance characteristics. The Ordinary Least Squares (OLS) test was conducted in order to ascertain whether tracking has a significant influence on dwell time. The independent samples t-test was conducted to assess the difference in the mean between subgroups based on the given parameters. Subsequently, the root mean square error was computed, and the three ports with lowest root mean square error were chosen for qualitative analysis in Phase III.

Table 10 : Summary of analysis of OLS and T-test at all fourteen ports (Source: Own Research)

Port	Container Volume	Correlation Tracking and Dwell Time	R^2	β Coefficient	T Value	Regression Sig. Tracking	Independent T Test Tracking	Cycle	Size	Mode	Status	Delivery	RMSE
A	232731	0.86	0.78	55.56	280.51	<0.001	Y	Import	20	Rail	N	Y	15.6
G	226441	0.85	0.761	45.82	511.18	<0.001	Y	Import	20	Rail	N	N	15.7
L	311269	0.86	0.77	49.2	683.3	<0.001	Y	Import	40	Truck	Y	N	15.86
K	213612	0.87	0.77	60.5	696.1	<0.001	Y	Import	20	Rail	Y	N	16.9
B	155986	0.86	0.74	74.4	562.7	<0.001	Y	Import	20	Rail	Y	N	19.2
I	76402	0.81	0.67	75.2	364.6	<0.001	Y	Import	40	NA	Y	Y	21.5
N	167374	0.83	0.7	76.4	585.1	<0.001	Y	Import	40	Truck	N	N	22.3
M	50044	0.84	0.71	68.08	309.4	<0.001	Y	Import	40	NA	N	N	23.15
J	106225	0.82	0.68	79.2	458.3	<0.001	Y	Import	20	Truck	N	Y	23.4
H	62705	0.82	0.667	37.3	325.7	<0.001	Y	Export	20	Rail	Y	Y	31.3
C	346857	0.75	0.74	56.3	44.9	<0.001	Y	Import	40	Rail	Y	Y	34.6
F	52443	0.82	0.67	118.3	324.2	<0.001	Y	Import	20	Rail	Y	Y	34.82
E	721232	0.86	0.77	49.8	1090.5	<0.001	Y	Import	20	Rail	N	N	36.9
D	97076	0.62	0.4	22.11	33.33	<0.001	Y	Import	40	Rail	Y	N	47.3

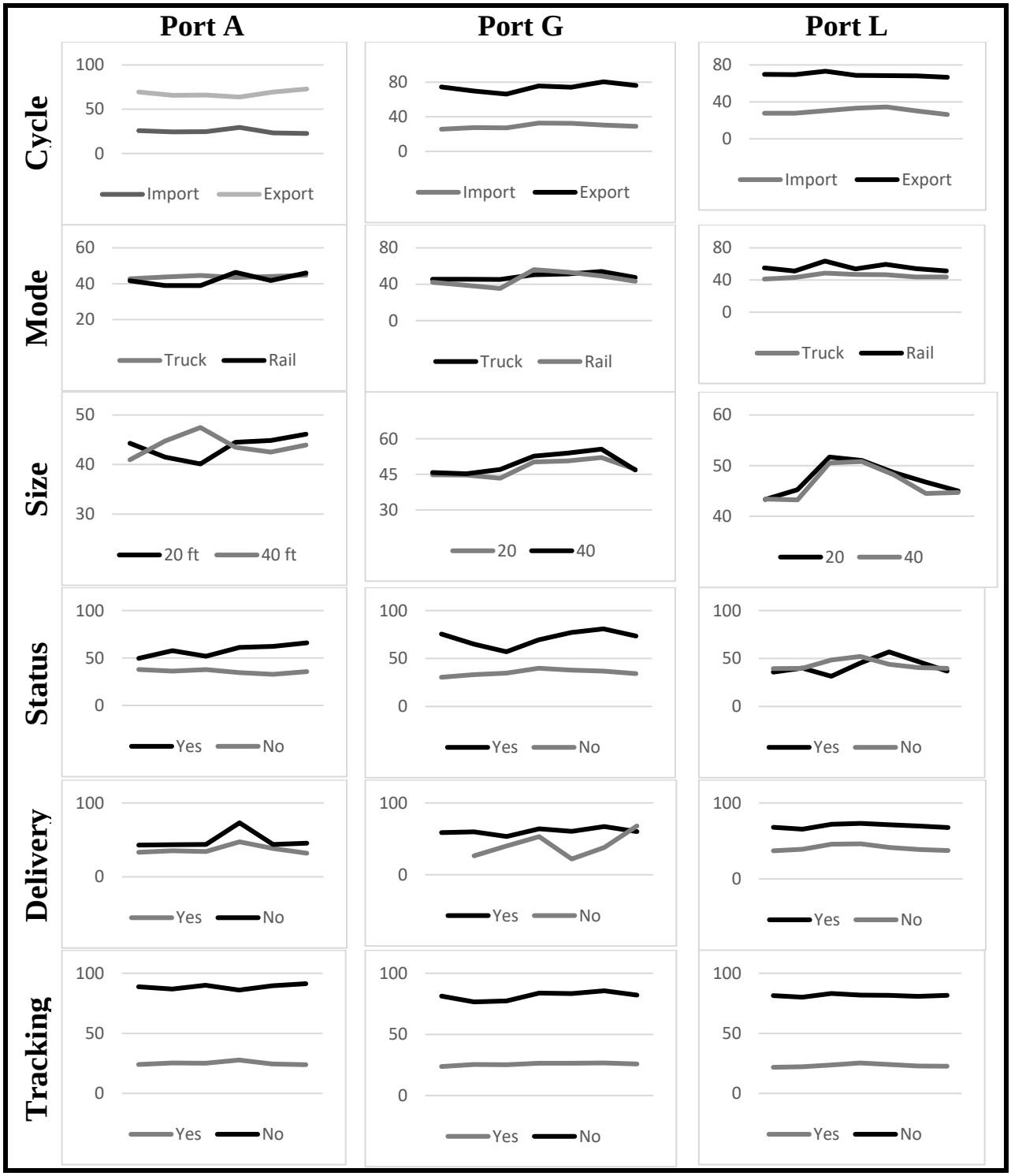


Figure 7 : Dwell time and port performance parameters of the top three ports (Source: Own Research)

The outcomes relating the study of data trends in the top three port performance metrics and dwell time are illustrated in Figure 7. In the majority of cases, it is apparent that there is a correlation between dwell time and other variables, such

as cycle, size, mode, and others. The utilization of graphical representation enables a thorough examination of the correlation, hence aiding the comprehension of patterns and fluctuations in dwell time.

The heat map presented in Figure 8, illustrates the correlation between container performance metrics and the dwell time for Ports A, G, and L. The ports listed below have the lowest Root Mean Square Error (RMSE) when considering qualitative analysis conducted on the variability of dwell time.

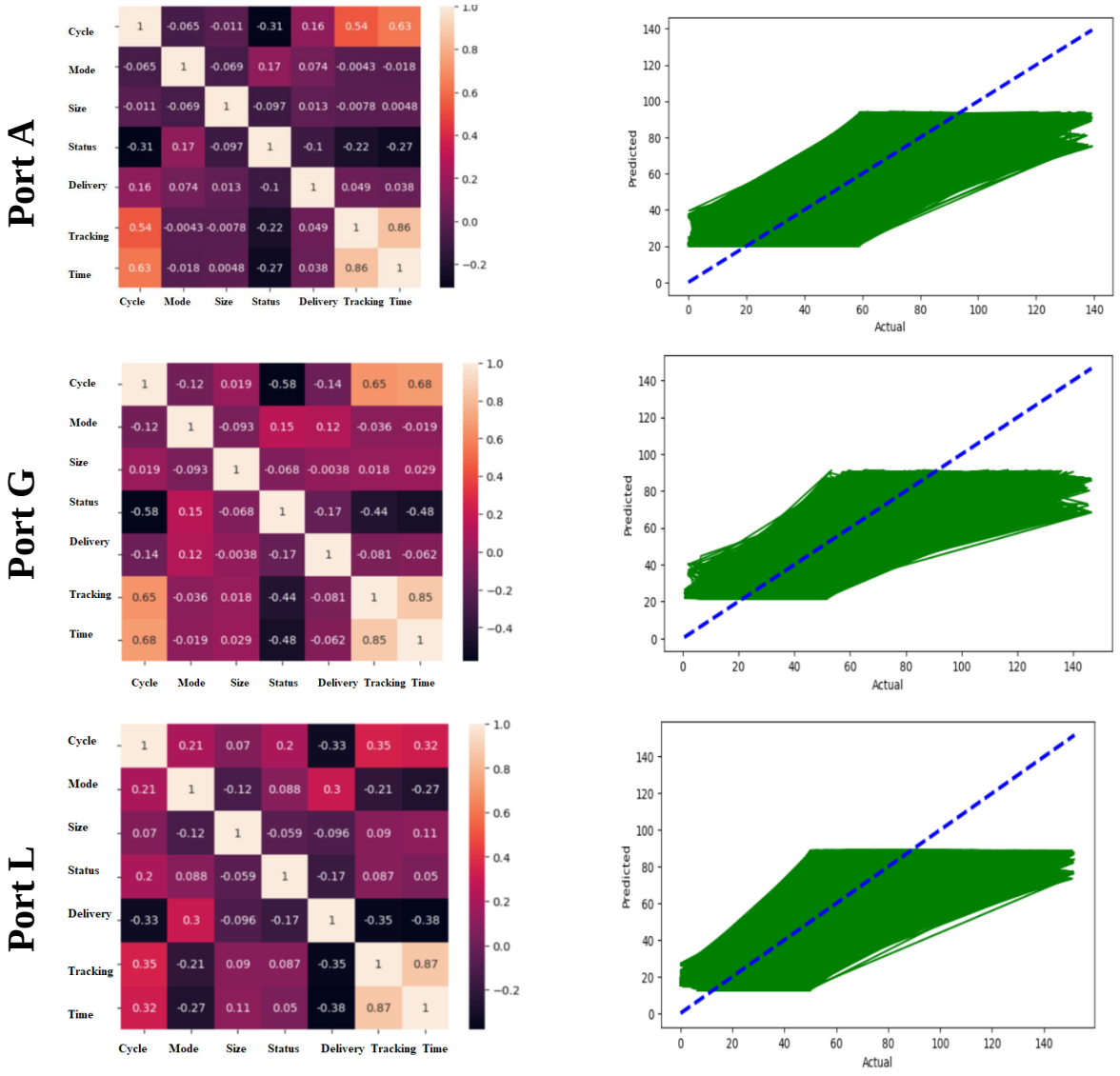


Figure 8 : Correlation heat map and actual versus predicted (Source: Own Research)

The data collected for the third phase of the qualitative research study included conducting structured interviews with the primary operating personnel of the port terminal. The questions were formulated in accordance with the quantitative analysis that was carried out in phase II. Eleven resources were chosen from the three ports with the lowest Root Mean Square Error (RMSE) in order to examine the various factors that contribute to the variation in dwell time for each independent

variable, such as*(i)*Cycle(Import/Export), *(ii)*Size(20 feet/40 feet), *(iii)*Mode(Truck /Rail), *(iv)*Status(Empty/Laden),*(v)*Delivery-DPD/DPE(Direct Port Delivery/Direct Port Export) ,*(vi)*Tracking Technology Availability (Yes or No). The snowball method was employed to conduct discussion interviews and obtain expert comments, simplifying the acquisition of crucial details for the purpose of information collecting. The criteria for selecting respondents for the debate were determined by their level of expertise and their involvement in the operations of the container transportation sector. The structured interviews underwent data processing through the systematic application of the selective coding technique (Strauss & Corbin, 1990); (Saldaña, 2021). The rationale behind choosing this strategy was mostly based on the objective of preserving qualitative consistency and organization. This approach also aimed to effectively address the concerns and challenges associated with the organization and analysis of interview discussion data.

The primary aim of this phase of research was to gain a comprehensive understanding of the diverse factors influencing dwell duration at key ports in container transportation. The classification of this data involved the presentation of Phase II data, a thorough evaluation of the discussion, and the identification of actions related to dwell duration variations. The analysis of open-ended responses involved the process of mapping, integrating, and filtering extracts into groups based on their conceptual similarity. Consequently, the process of reducing data into aggregate categories facilitated the derivation of insightful relationships throughout the analysis of the results.

Figure. 9, represents a graphical illustration of the initial, intermediate, and advanced levels of aggregation, as well as the potential benefits and opportunities associated with the outcomes derived from the collection of data inputs during the qualitative analysis of variance in dwell time. Based on the interviews conducted with port operators, it was found that several key aspects played a crucial role in understanding the variation in container dwell time. These factors included first-order affordances such as the provision of a free period, gate cut off, the demand of equipment, the rail connectivity, the pre inspection process and transhipment nature of ports, the prevalent trade schemes along with free days provided by CFS for container stay.

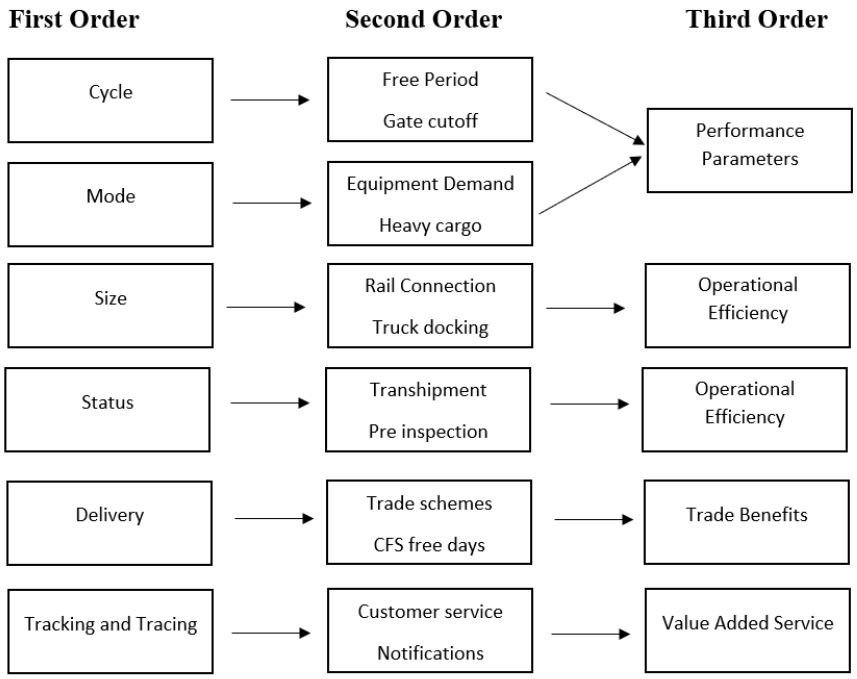


Figure 9 : Qualitative reasons of varying dwell time (Source: Own Research)

The discussion with the top three ports A, G and L (with lowest root mean square error), was held and the qualitative reasoning for one port optimizing and performing better than other on a specific parameter was gathered. Figure 9, illustrates the reasoning for the port optimization and port performance parameters. It was widely acknowledged that the ports exhibited enhanced performance during the import cycle as a result of the demurrage costs levied on importers or the handling of Container Freight Stations (CFS) by terminal operators. Hence, it can be observed that the dwell time for all ports improved during the import journey. Additionally, it is important to note that throughout the process of exporting, containers must be gated in four days prior to vessel departure in order to meet gate cut off timings. This requirement contributes to an increased dwell time at ports.

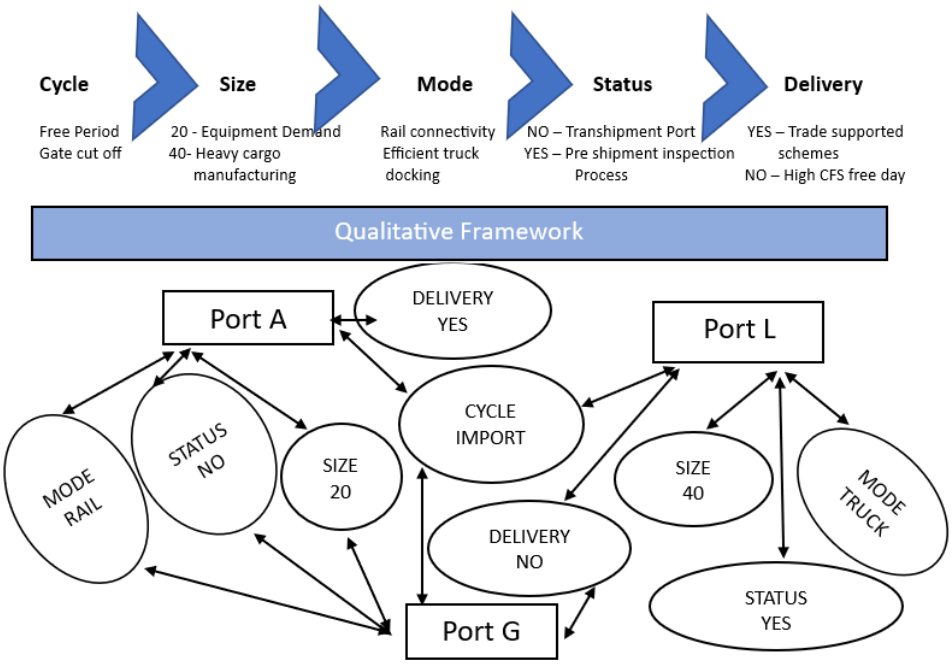


Figure 10 : Qualitative framework for dwell time variation (Source: Saini and Lerher, under review)

For the container size parameters, it was understood that due to the nature of operations and equipment demand, Port A and G were doing good in twenty-foot size and industries or manufacturing units in the vicinity of Port L were producing bulk/heavy cargo to be stuffed in forty feet container. For the mode category Port, A and Port G has good infrastructure for rail connectivity and had sustainability goals as part of their organizational objectives where Port L had faster turnaround times for truck due to efficiency docking strategies. Due to the transhipment nature of Port A and G, the containers which were laden with cargo efficiently planned for movement and further connection to port of destinations. Also, the pre-inspection process was quite efficient at these locations to enable faster clearance. In the case of Port L, majority of the empty containers were transacted for relocation and repositioning.

Figure 11, details the competency summarization of management perspective and discussion with the port terminals. Basis the qualitative discussion, it was observed that the common interpretation of results with the port managers focussed on supply chain planning and operational routing advance planning for their major success to outperform competition. High skilled manpower with focussed learning, training and development on logistics related concepts leads to the efficiency which is backed by rewards and recognition methods. The results of research questions and hypothesis are listed in Table. 11, along with the detailed reasoning and observation/outcome of discussion with port teams.

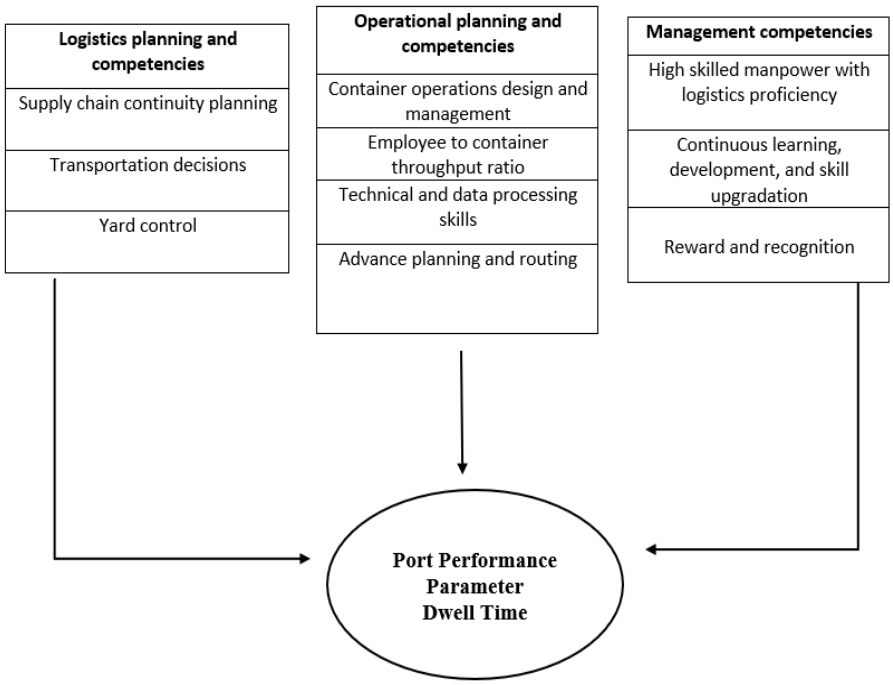


Figure 11 Competency summarization of top 3 ports (Source: Own Research)

The Table. 11, illustrates the results of the research conducted in this doctoral thesis. Research question and hypothesis wise results are tabulated in the Table. 11. Through the fuzzy QCA comparison in the phase I, it was resulted that both LPI and Tracking and Tracing are the core causal configurations that impact the economic development. This test was performed for the major economies across Asia, Europe, UK and UK. The results illustrated that for any economy to perform well, they must be logistically advanced with high infrastructure parameters including technology dimensions such as tracking and tracing. Various container specification parameter such as Cycle, Size, Mode, Status and Tracking impacts the dwell time of the container. Major reasons listed for the top three ports are illustrated in the Figure 11 and Table 11.

Table 11 Summary of results/observations of research questions and hypothesis (Source: Own Research)

Research Question	Associated Hypothesis	Result/Observation
How do logistics performance index and logistics cost influence economic development?		Logistics Performance index (LPI) has a significant positive impact on the economic development. Logistics costs has a significant negative impact on the economic development.

Does track and trace impact economic development?		Track and trace have a significant positive impact on the economic development along with other parameters of LPI, viz. Infrastructure and Logistics competency on the economy.
Is there any impact of location of port, size of container on dwell time?		The location of port, size of container significantly impacts the container dwell time. The reason commensurate various factors around trade facilitation schemes, free periods, and equipment balancing.
What are the major reasons behind the variance in container dwell time?		The variance in dwell time is due to region specific concerns commensurate to size, cycle, mode etc. The free periods, gate cut offs, trade related schemes, docking strategies are the prime reasons.
What is the impact of track and trace on container dwell time?	Continuous track and trace of container results in reduced dwell time	Continuous track and trace significantly result in reduced container dwell time. Various factors including operational efficiencies and planning augments in port performance parameters.

Continuous tracking is an important dimension on controlling the dwell time of the container and stay time at any port. This can be coupled with various employee centric activities on learning and development along with reward and recognition for ensuring performance on this aspect of parameter.

6. CONTRIBUTIONS

The thesis contributes to the academics and practice as per the sections 6.1 and 6.2.

6.1 Academic contribution to the theory and knowledge

This doctoral research contributed to the theory by examining and researching on the introduction of tracking technological factors to the container port operations. The research on port performance parameters with the presence or absence of tracking technology is rare, and most of the studies that are conducted focuses on single port dataset scenario(De Armas Jacomino et al., 2021). This research study evaluated the data on multi-port scenario while focusing on the core impact of the presence of tracking on the shipping container. As technology penetration in port sector is an emerging field, this research contributed by providing empirical study on the port performance parameters.

This research also contributed to the field of social science and management by illustrating on factors which can decrease the dwell time of the containers and thus assisting workforce on the better planning of shift times and thus reducing the overtime working hours leading, to unhealthy prolonged working hours.

6.2 Contribution to Practice

The port sector is on the cusp of the technological transformation and automation is necessary for competing with global ports. This research study contributed to the practice by providing results for improvising port performance parameters such as dwell time by incorporating various data analytics tool. Various factors across multiple ports emphasizes on customizing region-specific operations and advance planning port operations for ensuring efficiency in operations.

7. CONCLUSION

The main objective of this doctoral thesis was to understand the varying reasons of dwell time at container ports. The research was initiated by developing an understanding on the importance of logistics for the research and economy. To establish this relationship, a fuzzy QCA method was performed on the selected economics of Asia, Europe, USA and UK. The data from the secondary data base of World bank was selected. The analysis of LPI, LC, EODB and the parameters of LPI was performed to establish this relationship and the impact on economic development. The results showed that both LPI and Tracking and tracing are the core causal configuration with positive impact on the economic development.

The phase II performed analysis on the variation in dwell time due to the major port performance parameters. The data analysis was performed on the 2.8 million container entries utilizing python for data sciences and SPSS software for independent T test. Dwell time which is one of the major port performance parameters varies due to certain reasons which are important for the research and practice. The study was conducted at the fourteen major ports of India with an objective to qualitatively analyse the reasoning for variance along with objectifying the standardization tools for further research.

The result illustrated on the data analysis of fourteen ports shows that continuous tracking has an impact on reduced dwell time, where in port managers efficiently pre-plan the containers to be offloaded and onloaded on a vessel with accurate load planning. The major factors of cycle, size, mode, empty/laden showed that due to the geographical circumstances and port specific strategies there is a considerable variance in dwell time at the ports. The top three ports (A, G and L) were short listed based on lowest RMSE (Root mean square error) 15.6, 15.7, 15.86 % for qualitative reasoning. The prime reasons of free period and gate cut off for cycle, equipment demand and heavy cargo manufacturing for size, higher rail frequency, connectivity, sustainability goals and efficient truck docking strategies for mode were identified. Tran shipment ports, along with better pre-inspection clearance steps were few of the major reasons for empty/laden efficient movement. Trade support schemes along with free days due to high competition at CFS were reasons cited by trade for DPD/DPE.

The research contributed to science by providing research on a large multiport data set along with feature of tracking and tracing which is one of the important factors in logistics performance index. Further study will focus on sourcing data around commodity, port of loading and destination. The study will also focus on developing a product for practice to have a real time idea of which port is performing on which parameter for the shortlisting of moving container via that port for its onward journey. The practice will be highly benefited by such approach and will foster in bridging the gap between academia and practice. The practice can utilize the results to identify and ship cargo by observing which factor is best performing factor for one port.

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