

A STUDY ON DETERMINING THE FACTORS AFFECTING VESSEL TURN AROUND TIME

Submitted to the School of Maritime Management,
Indian Maritime University, in partial fulfillment of the requirements
for the award of degree of "Master of Business Administration" in
International Transportation and Logistics Management

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CERTIFICATE

This is to certify that the dissertation titled – **“A STUDY ON DETERMINING THE FACTORS AFFECTING VESSEL TURN AROUND TIME”** is a bonafide record of project done by RICKY PIOUS. It is also certified that the above work has not previously formed the basis for the award of any degree, diploma, fellowship or other similar titles, and it is an independent work done by the student.

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I, RICKY PIOUS (Reg.no: 1905305030) student of School of Maritime Management, Indian Maritime University- Kochi Campus hereby declare that this project report titled “A STUDY ON DETERMINING THE FACTORS AFFECTING VESSEL TURN AROUND TIME” submitted in partial fulfillment of the requirement for the degree of **Master of Business Administration in International Transportation and Logistics Management** is my original work carried under the guidance of my project guide. It has not formed the basis for the award of any degree/diploma or associate ship of any University/Institution. The information submitted is true and original to the best of my knowledge.

Date: 29/06/2021

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Place: Ernakulam

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EXECUTIVE SUMMARY

The dynamic and competitive nature of maritime industry has urged container terminal operators to improve their performances day-by-day; not just to attract new customers, but to survive in the business. With the understanding that the Vessel Turnaround Time (VTT) is one of the key performance measures that the international shipping lines consider in selecting their transshipment hub ports; this study analyses the factors that affect the turnaround time of container vessels.

During the study, it was identified that there are a number of factors that affect vessel turnaround time; hence key factors under the control of the terminal operator were considered for in-depth analysis using the regression model. The study was carried out as a scenario analysis in order to identify how VTT and influential factors behave in different situations. As per the results; number of container moves, crane intensity, gross crane productivity, berth productivity and number of quay cranes were identified as the key affecting factors while recognizing the importance of the time related variables such as berthing delay, sailing delay, idle time, productive time and vessel detention times in determining VTT. With the results of the study, along with the discussion and recommendations; it was expected to highlight the areas that terminal managers need to focus on in order to reduce the turnaround time of container vessels to enhance the competitiveness of ports.

This study was carried out under a limited scope within a limited time frame, thus only the quantitative factors were considered for the analysis. It was assumed that the effects of other non-considered factors are negligible, yet in reality, situation is more complex where there are lots of factors affecting the measures of these identified variables and VTT.

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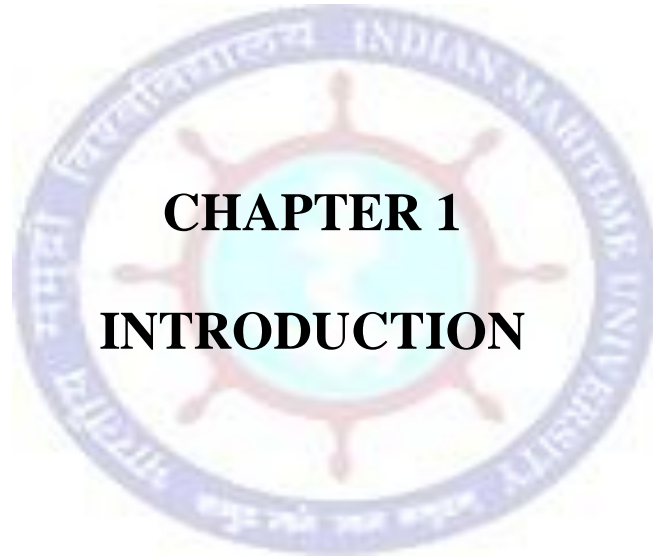
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LIST OF ABBREVIATIONS

ATA	- Actual Time of Arrival
ATB	- Actual Time of Berthing
ATC	- Actual Time of Completion
ATS	- Actual Time of Sailing
BAP	- Berth Allocation Problem
DCT	- Dual Cycling Technique
DC	- Dangerous Cargo
DT	- Detention Times
GCP	- Gross Crane Productivity
GDP	- Gross Domestic Product
ICS	- International Chamber of Shipping
ITT	- Inter Terminal Trucking
IMO	- International Maritime Organization
OBT	- Out Bound Carrier
OOCL	- Orient Overseas Container Line
OOG	- Out Of Gauge
POD	- Port of Discharge
PUI	- Port Utilization Indicators
QCAP	- Quay Crane Assignment Problem
QGC	- Quay Gantry Crane
RTG	- Rubber Tyred Gantry Cranes
TEU	- Twenty-foot Equivalent Unit
TLSP	- Total Logistical Service Providers
TSA	- Terminal Service Agreement
UNCTAD	- United Nations Conference on Trade and Development
VTT	- Vessel Turnaround Time
WCT	- Work Commenced Time



CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Maritime transportation is considered as the primary mode of transportation in worldwide trading because of its ability in facilitating high volume goods with low transportation cost. According to International Maritime Organization (IMO), maritime transportation accounts for 90% of international trade by volume and 70% by value. This derived demand is catered by over 50,000 cargo vessels owned by shipping lines or individual ship owners which are registered in over 150 Flag States and manned by over one million sea farers from all over the world.

Few decades ago, ports were just operated as the intermediaries between land and sea where they were mainly involved in basic cargo handling activities and providing shelter for vessels. Yet, looking at the current scenario, their contemporary role has changed to a new role of Total Logistical Service Providers (TLSP) in vast supply chain networks, thus they are no longer seen in their traditional view. Today, ports' customers cannot be satisfied with mere handling of their precious cargo as they have many expectations mainly including consistent and reliable services, high performance in cargo handling operations, on-arrival berthing or dedicated berths for vessels, competitive rates and rebates on performance commitments.

Container vessel operation is mainly characterized by fixed schedules and fixed port of calls. Major international container carriers follow tight sailing schedules with minimum sailing times from port-to-port while expecting quicker cargo handling times at ports, thus the performances of terminals determine the overall effectiveness of shipping lines. Number of container moves handled per hour is used as a measure of calculating productivity at terminals as it leads to determine Turnaround Time (TT) for vessels. In general scenario, productivity is inversely proportional to vessel

turnaround time, which means as productivity increases vessel turnaround time reduces also vice versa.

Time means money; especially in shipping industry. Ship owners and international shipping lines expect faster operations at ports to achieve shorter Vessel Turnaround Times (VTT), thus leading to low costs while increasing higher number of load trips per year. An average size container vessel was assumed to be spent around 60% of its time at berths with a daily cost of \$65000 in year 2000. Looking at the contemporary scenario this figure is much higher for a present day mega carrier, thus shipping lines are not in a position to lose the time and the money in ports that their vessels saved at sea. As such, it is unavoidable that port operations are going to be seen as bottlenecks in complex supply chain networks while urging the shipping lines to move towards invest in terminal operations to secure better and quicker performances for their vessels.

From another view, terminals are mainly operated either as “Dedicated Terminals” or as “Multi User Terminals” based on their ownership, type of operation and key customer basis. The Multi User Container Terminals are commonly characterized by state ownership nature where berths are allocated “First Come First Served” basis subject to Terminal Service Agreements (TSAs) and berth restrictions. As such, berths, quay cranes and other machineries are allocated to a vessel considering its time of arrival and availability of terminal resources, unless specifically requested.

Container terminals are operating in a very competitive environment where they are continuously competing with each other to retain their existing customers despite of attracting new businesses to their terminals. The competition is so intense, such that, it is believed once a shipping line decides to divert its vessels from a terminal to another, it is almost gone

forever for that respective terminal (*port*). Looking at the history, European Ports were ranked as the busiest container ports few decades ago. However, considering the present scenario it can be seen that this concentration has shifted towards Asian region with its fast developing economies, including China, India, Malaysia and Singapore etc.

As such there cannot be see any European Ports within busiest top 10 container ports in the world at the moment, where the ports of Shanghai, Singapore, Shenzhen and Ningbo lead at the top, followed by other Asian ports, with annual container throughputs of 37,133 million TEUs, 30,904 million TEUs, 23,979 million TEUs and 21,560 million TEUs respectively in 2016.

Considering the above discussed aspects, this project is inspired with the expectation of identifying key determinant factors affecting the turnaround time of container vessels and how VTT affect the competitiveness of a container terminal.

1.2 CASE DEFINITION

Vessel Turnaround Time is defined as the total time that a vessel spends at a port from its arrival to departure. Although it is conveyed as a specific time measure, VTT is a summation of several sub activities including waiting time for a berth, maneuvering time, mooring/ unmooring time, idle time, container handling time and other time components until the vessel leaves port limits (Moon, 2018). At the same time, it is needed to highlight that these time measures are influenced by many other affecting factors, including the availability of berths, number of quay cranes available, congestion at yard, speed of crane operators and many more. Moreover, delays caused due

to bad weather including heavy wind, poor visibility and tidal conditions cannot be neglected, since those influences are beyond the control of terminal operators. So in a nutshell Vessel Turnaround Time (VTT) is defined as a summation of all waiting times, idle times and container handling times at ports.

1.3 OBJECTIVE OF THE STUDY

The dissertation aims to look at a theoretical approach of identifying factors that affect turnaround time of container vessels in the light of determining key influencers that can be controlled by terminal operators. Considering the practicality of the basic research scenario, container vessel operations are analysed in detail with the expectation of identifying solutions for its contemporary issues at hand. It needs to be highlighted that all the operational and non-operational delays incur costs to both to ports and its customer shipping lines in terms of time and money; thus underlying factors are to be analysed with the expectation of reducing overall costs and minimizing avoidable and controllable delays, finally resulting to achieve quicker Turnaround Time for vessels. Following objectives are expected to be achieved at the end of the research study:

- i. To identify factors that influence Vessel Turnaround Time directly or indirectly
- ii. To identify controllable factors from the uncontrollable factors that affect VTT
- iii. To identify the nature of relationships those controllable factors are having with turnaround time
- iv. To identify most critical factors that need to be given priority to achieve fast VTT.

1.4 METHODOLOGY

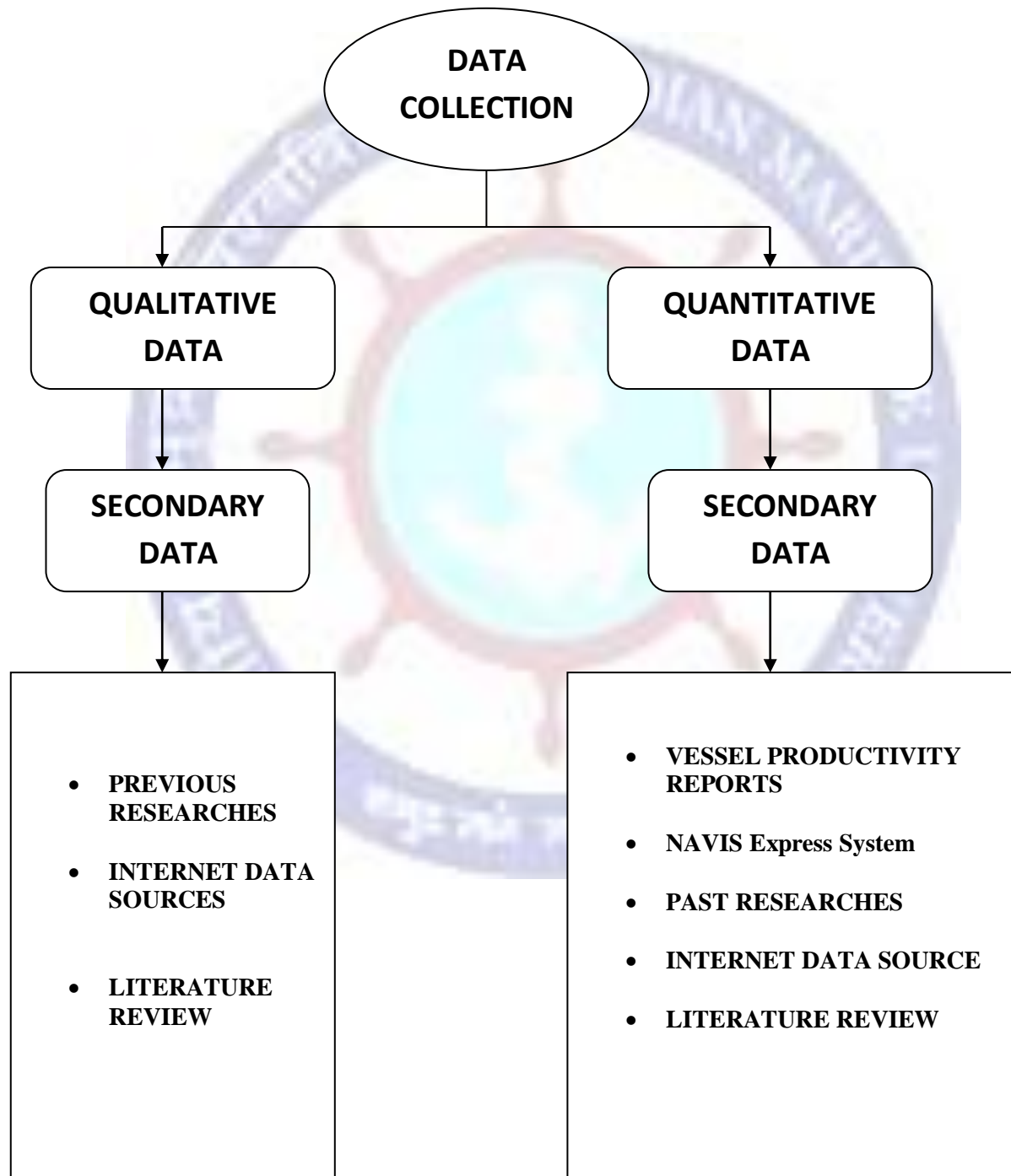


Figure – 1.1 Data collection

1.5 Research Design

The research analysis is designed in a way to statistically analyze the influential factors for Vessel Turnaround Time (VTT) where key determinant factors are analyzed in detail to identify their nature and intensity of relationships. Thus, Vessel Turnaround Time (VTT) is defined as Dependent Variable (Y) while the influential factors are identified as Independent Variables (X_i).

The dissertation contains a comprehensive Literature Review in Chapter 2 to highlight what previous scholars have discussed in relations to vessel turnaround time and similar scenarios in port operations. Chapter 3 discusses the problem formulation where a Conceptual Framework has been used to illustrate the concept of the research problem, while the Operationalization Process highlights how numerical values are derived for individual variables for calculations. Statistical analysis is carried out in Chapter 4 where the derived Regression Models (*Solution Algorithms*) are illustrated after identification of relationships, along with the discussion and recommendations for further improvements. Finally, Chapter 5 concludes the dissertation summarizing the analysis carried out while providing suggestions for future studies.



CHAPTER – 2
LITERATURE REVIEW

The visionary concept of containerization revolutionized international trade by facilitating intermodal cargo transportation; thus, goods can be moved from one mode to another inside a “*box*” without being loaded and unloaded at each time (Jin et al., 2017). At the beginning of the previous decade, it was assumed that the “containerization ratio would be over 70% of all general cargo” by end of 2010 with the growing rate at that period (Güler, 2002); where the “world’s container fleet reached to 37.6 million TEUs at the end of 2015” (Drewry, 2016).

Vessels are made to sail, thus, the more they sail – the more they earn. As such, ship owners and shipping lines expect quicker operations at ports to achieve shorter VTTs; increasing the number of load trips per year. As highlighted by Ghotb, Kia, & Shayan, (2000) an average size container vessel was assumed to be spent around 60% of its time at berths with a daily cost of \$65000 in year 2000. At the same time, considering the effect of economies of scale, larger the vessel - lower the unit cost, thus shipping lines prefer to deploy mega vessels into operations compared to smaller vessels (Cullinane & Khanna, 2000). However, this creates constant pressures on container terminals as their infrastructure and superstructure facilities cannot be developed at the pace of the increasing vessel sizes. As discussed by Meng, L, & Weng (2017), present day port facilities may not be sufficient to accommodate mega carriers in near future. In their study, the researchers have used the Queuing Network Model (QNM) along with few simulation models where ARENA simulation software is used considering the computational complexity. Further, high utilization rates, longer port stay times and waiting times are also highlighted as key concerns for shipping lines in addition to the physical restrictions at ports.(Meng, L,

& Weng, 2017).

According to Branch (1986), as illustrated by Esmer (2008), key roles of a seaport can be defined as handling of cargo and passengers, providing shelter and services for vessels, supporting industrial development by being part of larger transport networks. Later, Ting (2018), highlights container terminals as designated operational entities specialized for handling and storage of containerized cargo operations where containers can be discharged, loaded, received, delivered, stored and facilitated transferring movements among different transportation modes (*vessels, barges, trucks and railways etc.*). Considering the container port operations, large number of studies has been carried out to understand what factors influence container terminal performances and how terminal operators can enhance their productivity in container handling operations. In a study by Kim & Lee, (2015), authors simplified the container terminal operation under two basic categories such as; Vessel Operations and; Delivery and Receiving Operations. In another study, the terminal operation has been recognized under three planning stages, namely as Vessel Planning, Berth Planning and, Yard Planning and Equipment Scheduling (Cao, Lee, & Shi, 2010).

In a study by Niavis & Tsekeris (2012), the researchers used results from a Tobit Regression and a Truncated Regression along with Parametric Bootstrapping Models (PBM) to identify the key determinants of technical efficiency of container ports. Highlighting some previous scholars, the study illustrates that port performances get better when their sizes increase, meaning that larger ports perform better compared to smaller ports. Similarly, Cullinane, Song, & Gray, (2002) highlight that efficiency of a port/ terminal is closely correlated with its size while

mentioning that there are supports for the claim that the transformation of ownership from public sector to private sector improves economic efficiency of container ports. It is further mentioned that private sector terminal operators improve efficiency levels, especially when joined with the involvements of international terminal operators (Heng & Tongzon, 2005). In addition, distance from the main shipping route, GDP of the territory and per capita GDP of population are also identified as influencing factors to improve efficiency (Niavis & Tsekeris, 2012).

According to an Efficiency Analysis (EA) study carried out by Alemán et al. (2016), there was an upwards trend in port efficiencies in developing regions where their time series results illustrated an increase of 10% from 51% in 2000 to 61% in 2010. The study further discuss that improvements in liner connectivity, participation of private sector, reduction of corruptions in government sector and developments of multi- modal links have influenced to increase efficiency levels of ports in developing regions (Alemán et al., 2016).

Cariou & Oliveira (2015) used a Truncated Regression (TR) with a Parametric Bootstrapping Model (PBM) to examine how efficiency of container ports is influenced by the degree of competition measured at different levels of impacts. As per their study, competitiveness among ports can create positive and negative impacts in altering the performance levels of individual ports. From one side, inter-port competition may lead to higher efficiency of ports/terminals due to the pressure coming from competitive environment. However, at the same time, it may affect negatively, where a port subject to a high competition may be forced to over-invest on infrastructure and superstructure without much focus on long term results, thus lowering the efficiency levels

(Cariou & Oliveira, 2015).

In a study by Sanchez, Tovar, & Wilmsmeier (2013), the researchers have used the non-parametric Data Envelopment Analysis (DEA) to identify the effects of dynamic economic environments on efficiency and productivity of container terminals. The study has considered 20 container terminals in 10 countries in Latin America, the Caribbean and Spain considering the period 2005–2011. Similarly, Ding, Jo, Wang, & Yeo (2015) have carried out an analysis to evaluate operational and productivity efficiency of container terminals in China using Data Envelopment Analysis (DEA) and Malmquist Productivity Index (MPI). Further, the researchers have used Tobit Regression to estimate the factors affecting productivity efficiency change.

Terminals have limited yard spaces, thus containers with similar attributes (*size, POD, OBC etc*) are stacked at adjacent slots while following a number of yard planning policies of terminals to optimally utilize available spaces. In the study of Kim & Woo (2011), they analyze impacts of different yard allocation strategies on the productivity of the container vessel loading operations, thereby proposed a method for allocating stacking space and space requirements for container yards.

Looking at the container shipping industry, container vessels are generally classified based on their dimensions and carrying capacities (Meng, L, & Weng, 2017). At the same time, vessels are generally identified as Main Line vessels and Feeder Line vessels based on their number of port calls and also considering their Vessel Call Services (VCS), sizes and owner shipping lines. However, most studies look at the cost aspect of main line operators, yet it is also necessary to analyze that aspect from feeder operators' point of view as well; as feeder vessels

feeds hub ports by facilitating container movements between individual feeder ports and mega ports. Further, as highlighted by Schøyen & Bråthen (2015) it is commonly observed that information sharing and understanding between main line operators and feeder operators, and also shipping agents and terminal operators are not in adequate levels to achieve optimal operational speed per leg.

According to Jin & Lee (2013) feeder vessel management has to be addressed by considering frequent calling nature of feeders; where suitable berths and yard storage spaces are to be allocated in a way to facilitate smooth flows of transshipment containers between main line and feeder vessels. In their study, an integrated problem is formulated using a mixed integer programming model considering those key issues; and then the problem has been solved by a memetic heuristic approach. Further, when it comes to vessel turnaround times, Schøyen & Bråthen (2015) highlight that 24/7 cargo operations along with feasible tariff structures of ports are necessary to stimulate shorter turnaround times for feeder lines while providing them more opportunities for slow steaming and fuel savings.

The performance of container terminals is mainly assessed based on waiting time, container handling time and total ship turnaround time of vessels (Budipriyanto, et al., 2017). There, the availability and the allocation of a suitable berth for an arriving vessel can significantly influence the above performance measure. In their study, Budipriyanto et al., (2017) have carried out a simulation study of Collaborative Approach (CA) between terminals to find optimal solutions for Berth Allocation Problem (BAP) under uncertainty. As per the results, the researchers highlight that collaborative strategy helps to reduce overall waiting time, container-

handling time and total ship turnaround time giving benefits to both the shipping line and the terminals. In another study, He (2016) used a Mixed Integer Programming model (MIP) for berth allocation and QGC assignment which provides optimal solutions for time and energy savings in total berthing costs.

In the paper of Li et al.(2012), the authors have tried to find an effective approach to address Berth Allocation Problem (BAP) and Quay Crane Assignment Problem (QCAP) in a multi-user container terminal. Their study has considered BAP and QCAP as one single problem, namely Berth and Quay Crane Allocation Problem (B&CAP), where an integrated approach has been considered. Using several computational experiments authors have suggested a Nested Loop-based Evolutionary Algorithm (NLEA) which they conclude that their proposed approach has been able to achieve tiny improvement in performances.

Similarly, a number of studies have been carried out on BAP due to its complexity and ability in creating significant impact on VTT. Yet, it is important to understand that VTT is not solely dependent on berth allocation, where there are number of other factors such as the number of moves, number of QGCs, the distance between the yard and the berth and many more (Hendriks, Lefeber, & Udding, 2013). Hence, it can be said that the production of a terminal depends on efficient use of three key resources such as land, labour and machinery (Cullinane & Wang, 2010). Therefore, the effect of human factor on container terminal productivity should not be neglected although it is sensitive, comparatively difficult to quantify, collect data and analyze.

Considering the influence of berth occupancy on VTT, Guo, et al., (2016) conducted an analysis to study how berth occupancy is affected

by the dimensions of entrance channel of a container terminal to eliminate possible bottlenecks in terminal performances. The researchers used Process Interaction Based Simulation (PIBS) model along with other series of simulation experiments to simulate terminal operation in entrance channel. Their results illustrated that the berth occupancy depends on the dimensions on entrance channel where higher berth occupancy is resulted when there are more berths, two-way traffic channel and less travel time in channel.

The overall efficiency of quayside operations is influenced by many factors; among those the productivity of the terminal's container handling equipment (QGCs, PMs, SCs etc.) and the available capacity of quay area can be identified as paramount (Dinu et al., 2018). The authors used simulation model developed with ARENA simulation software along with some analytical models to identify ways to optimize transfer function by altering handling productivity. In a study by Bazzazi et al. (2009), researchers introduced a model for Quay Crane Scheduling and Assignment Problem (QCSAP) using Mixed-Integer Programming (MIP). With the study, researchers highlight that it is practically difficult to obtain optimal solutions for complex issues using traditional approaches; thus they suggest a Generic Algorithm (GA) to solve QCSAP in real-world scenarios.

According to Kim & Zhang (2009), minimizing the turnaround time of vessels is identified as one of the key objectives of scheduling in terminal. The performance levels of quay cranes place an important role in container terminal operations where it can make a significant effect on turnaround time of vessels. The researchers have proposed a Mixed Integer Linear Programming (MILP) for QC scheduling model and a Hybrid Heuristic Approach (HHA) has used to solve the model. Their

study on Dual Cycling Technique (DCT) proves that proper implementation of DCT helps to minimize the number of empty movements of QCs, thus maximizing the dual cycle movements leading to reduce VTT. Moving forward, Li, et al. (2018) suggest that terminal performance can be improved by proper prediction of ship arrivals by estimating delays or advances of vessels arrivals. Their study has been carried out using Back-Propagation network (BP), Classification and Regression Tree (CART) and Random Forest (RF) along with series of simulation experiments.



CHAPTER – 3
THEORETICAL FRAMEWORK

3.1 CONCEPTUAL FRAMEWORK

The container terminal operation is a complex and highly competitive business operation; thus terminals are continuously implementing a number of performance improvement methods to enhance their productivities. Looking at the global scenario, Vessel Turnaround Time (VTT) and Number of Container Moves Per Hour (MPH) can be identified as commonly used parameters with respect to container vessel operations, as identified through the literature review.

There are lots of factors affecting the VTT and MPH, most of those are interrelated with each other, even the VTT and MPH, where higher the MPH lower the VTT, in normal operating conditions.

Thus, the dependent variable (Y) - Vessel Turnaround Time can be illustrated as a function of influential factors (P) plus constant figure (α) of other uncontrollable influences as follow:

$$VTT(Y) = f(\text{Influential Factors (P}_j)) + \alpha \quad (1)$$

Although the VTT is defined as a single time component, it is basically a summation of several sub-activities such as waiting time for berth, maneuvering time, mooring/unmooring time, idles times, cargo handling time and other time components between arrival and departure (Moon, 2018).

As such:

$$VTT = \sum (WT + MaT1 + MT + IT1 + CHT + IT2 + UT + MaT2)$$

If; Y_j : VTT of “j”th vessel | X_{ij} : Independent variable “i” of “j”th vessel

3.2 PROCESS OF VESSEL TURNAROUND TIME

- **ONLINE BERTH MEETING**

This meeting is conducted online by port daily for planning the berthing of various vessels during that day. Meeting will be hosted by the Harbor Master and Traffic Department senior officers. All the shipping agents who have vessel arrival on that day will be presented and based on shipping agents needs and availability of berths a fixed arrival time will be given to each vessels and according to this timing shipping agent can chart their vessel.

- **VESSEL TRAFFIC SYSTEM**

When a vessel reaches closer to the outer of channel, they will communicate with the ports VESSEL TRAFFIC SYSTEM for the permission to entering the channel. Vessel Traffic System will forward arrival notice to pilotage boat and tugs. After receiving this information pilotage boat and a pair of tug will moves to outer of channel from port. Pilotage boat is a small boat which consist of two or three stevedores with a pilot, who is appointed by port trust. He or she is normally an ex ship captain and a highly experienced ship handler who possesses detailed knowledge of the particular channel, eg Actual depth, direction and strength of the wind, current and tide at any time of the day.

- **ACTUAL TIME OF ARRIVAL**

When the vessel reaches the outer Pilot will be entered to the respective vessel through Pilot Ladder and from there he will navigate the vessel through channel. When a pilot enters to a vessel is its ACTUAL TIME OF ARRIVAL.

- **CHANNEL**

The approach channel to the cochin gut is about 1000-meters long with a designed width of 200 meters and maintained dredged depth of 13.8 meters. When a vessel enters to the channel its engine will be off and vessel will be pulled and pushed normally by a pair of tugs. Number of tugs will be based on characteristics of vessel.

- **BERTHING**

A berth is a designed location in a port or harbor used for mooring vessels when they are not at sea. Berths provides a vertical front which allows safe and secure mooring that can then facilitate the unloading or loading of cargo or people from vessels. Vessel will be pulled and pushed by the tugs and berthing process will be done by dockworkers of respective ports and when the first mooring rope is placed on a bollard id known as First Line Assure and Berthing time starts from here. Berthing process will be controlled by the berthing superintendent.

- **OPERATIONS AT PORT**

The main operations are Loading and Unloading of cargo. It will depend on the type and amount of cargo the vessel is handling. Normally bulk carriers and liquid carriers are berthed for unloading their shipments. All operations of vessel at the port should be done within the time allocted by port, if not a fine will be putted for delay.

- **UNBREATHING**

After finishing the operations, the vessel will communicate with VESSEL TRAFFIC SYSEM at port that they are ready for sailing. If the channel is free this information will be forwarded to pilotage and tugs. Pilotage boat will

arrive to the respective berth and board the pilot to the vessel.

- **ACTUAL TIME OF DISPATCHER**

When the tug reaches all the mooring ropes from the bollard will be released by the dockworkers from the port and when the last rope is released it is known as **LAST LINE CAST OFF** which is normally referred as **UNBREATHING**. Tugs will be connected to the vessel and they will pull and push it to the outer. The vessel will be navigated by the pilot through the channel and when vessel reaches outer, the pilot will be disembarked to pilotage boat through pilot ladder and this time is measured as **ACTUAL TIME OF DISPATCHER**.

CALCULATION OF VESSEL TURNAROUND TIME

VESSEL TURN AROUND TIME = ACTUAL TIME OF DISPATCHER –ACTUAL TIME OF ARRIVAL

The main factors that have lead to inefficiencies in the Indian ports

- Most major ports were originally designed to handle specific categories of goods.
- Equipment utilization is very poor both because equipment is obsolete and poorly maintained.
- Over staffing
- Time consuming lengthy documentary procedures
- Port access facilities and arrangements for moving inbound and outbound cargo are inadequate and unsatisfactory

- A land use plan was developed in most ports. However, a clear vision on port planning and phased development is lacking for some ports

3.3 Factors that affect Vessel Turnaround Time

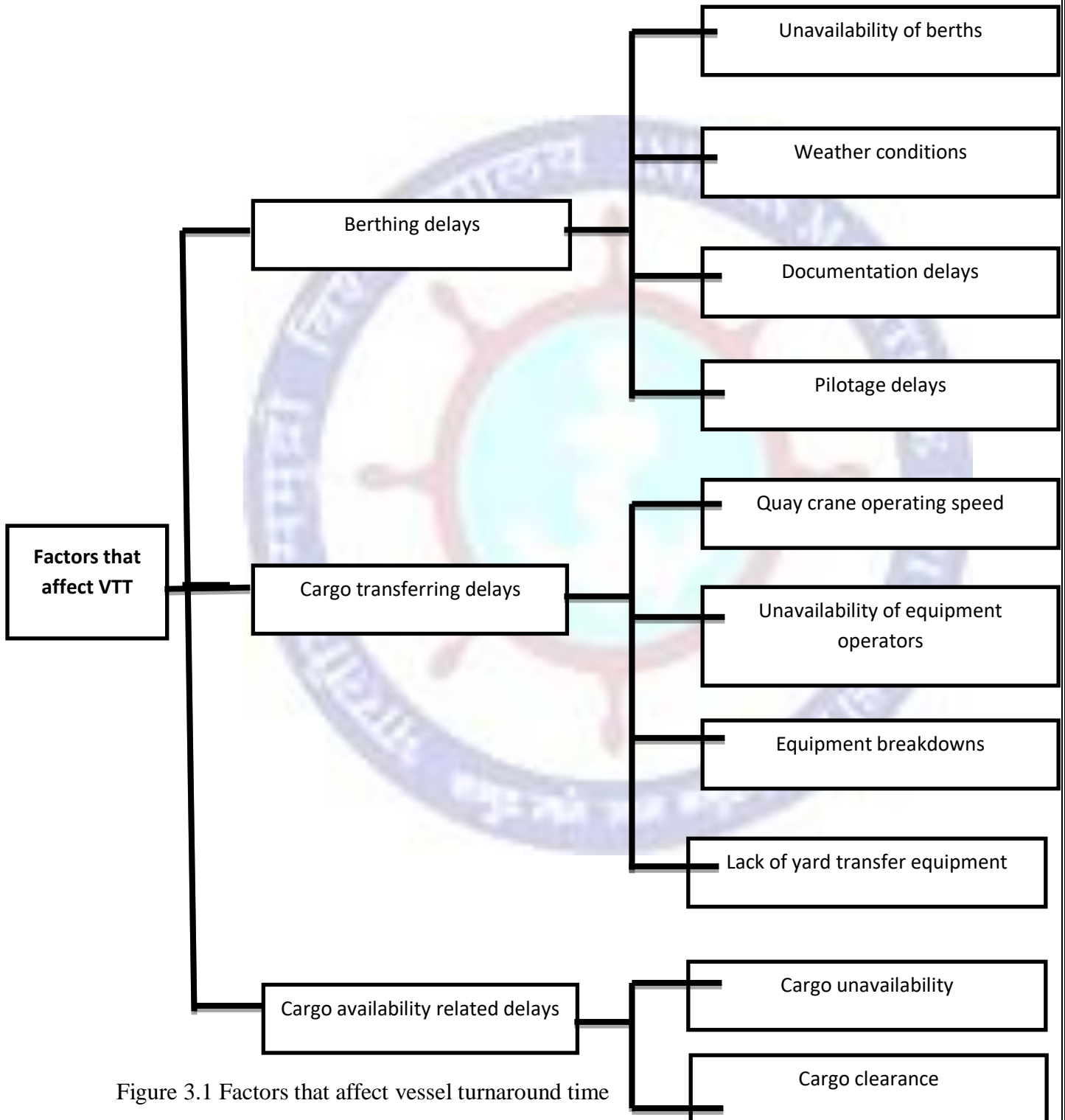


Figure 3.1 Factors that affect vessel turnaround time

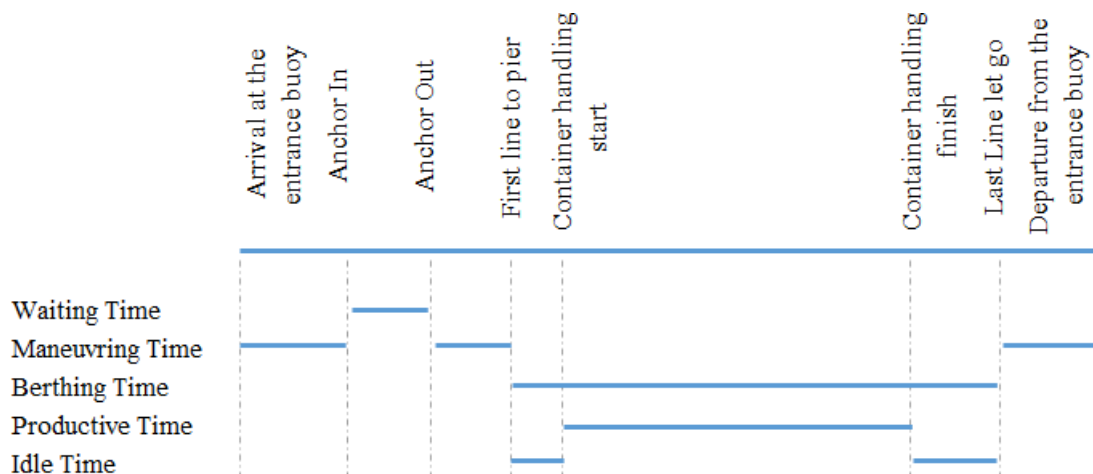


Figure 3:2 - Basic Illustration of Sub-time Components

As illustrated in the above Figure (3:2), minimization of each time components leads to shorten the total time span that a vessel stays at a port limits, thereby quicker the TT for vessels.

Waiting Time defines the time gap between anchor in and anchor out, meaning that the vessel has to wait until it receives a berth from the terminal. Availability of a suitable berth on-arrival allows the vessel to directly maneuver towards the berth, as such waiting time can be avoided. Maneuvering time is basically dependent on the size of vessel, number of tug boats available and weather conditions, thus it is normally beyond the control of container terminal.

Berthing time includes productive time that the container handling operations are actually carried out along with idle times, break times for meals, shift changeovers, crane breakdowns and many other operational and non-operational delays that need to be minimized or avoided where

possible.

Considering a typical container terminal, it has a limited quay length, thus, berths for vessels are allocated on FIFO basis, although the priority is given to main line vessels considering their tight schedules in calling several number of ports during the round trips. Nevertheless, feeder vessels are not taken for granted as they are carrying connecting cargo for mother vessels and vice versa. Similarly, berth allocation is dependent on availability of berths, Terminal Service Agreements (TSAs), location of loading containers stacked at yard and many other factors. However, Berth Allocation Problem (BAP) is another critical area in terminal operations in determining terminal performance and VTT.

In this light, considering the total quay length of Ports, it is necessary to highlight that each berth has its unique restrictions such as varying depths and quay cranes with different specifications. As such, few assumptions are made for analyzing terminal data as follow in order to discuss under the limited scope of this paper:

- ✓ Any vessel can be accommodated at any berth
- ✓ Container handling speeds are the same for all the quay cranes
- ✓ Laden and empty containers can be handled at the same speed
- ✓ Containers on decks and hatches can be handled at the same speed
- ✓ Crane operators maintain the same handling speed from the beginning to end
- ✓ Influences caused by poor weather conditions can be negligible

At the same time, looking at the characteristics of vessels, in practice, discharging and loading operations of larger vessels of main lines are much easier to handle compared to smaller vessels of feeder lines due to stability issues. Gearless vessels create less delay compared to vessels

with ship gears as quay crane operators do not need to worry about spreader or containers being accidentally touching the gear beams. Newer vessels are generally easier to operate compared to older vessels due to less troubles from damaged or poor cell-guide issues. Considering the complexity of all these practical issues, for the simplicity of basic research scenario, it is assumed that the influences of above mentioned restrictions are negligible.

Waiting time is mainly affected by whether the allocated berth is available when the vessel is arrived at port. Berthing program indicates when the allocated berths become available upon completion of each vessel, as such following vessels need to maintain their schedules not to wait at anchorage for the berth or speedup vessels to retain the given berth, where slow steaming has become the industry norm.

According to the main concern of the project, influential factors are to be identified for VTT, thereby regression models to be developed by recognizing relationships to understand ways to minimize VTT for better terminal performance. As such, in addition to the quay side issues it is necessary to look at how performance at the container yard influence the VTT. In general operating conditions, it is commonly observed that yard cranes are not operating at the same speed as quay gantry cranes. Thus, nearly 3-4 RTGs are required for each gantry crane for a smooth operation as containers are fetched from several yard locations at a time. Therefore, smooth yard operation is required for continuous operation on quay side which ultimately result in quicker operation for a vessel, leading to reduce VTT. In that sense it is necessary to ensure that yard

operations do not become a bottleneck for achieving productive performance in berth operations.

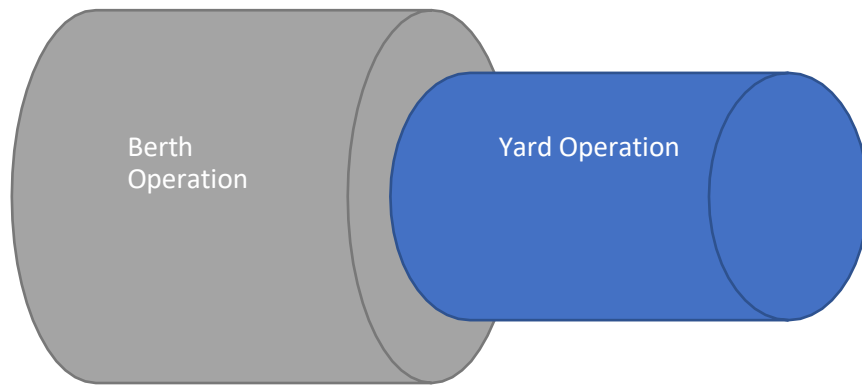


Figure 3:3 - Bottleneck Situation at Yar

3.4 Conceptual Framework

Considering all the scenarios discussed above, it can be understood that VTT is subject to numerous influences that are within and beyond the control of terminal operators. As such, it is necessary to understand that the same vessel with the same amount of container moves does not get the same VTT each time it calls at the port. Thus, below conceptual framework highlights different categories of influences, while clearly segregating controllable influences from the rest, which are to be analyzed under the scope of this research paper.

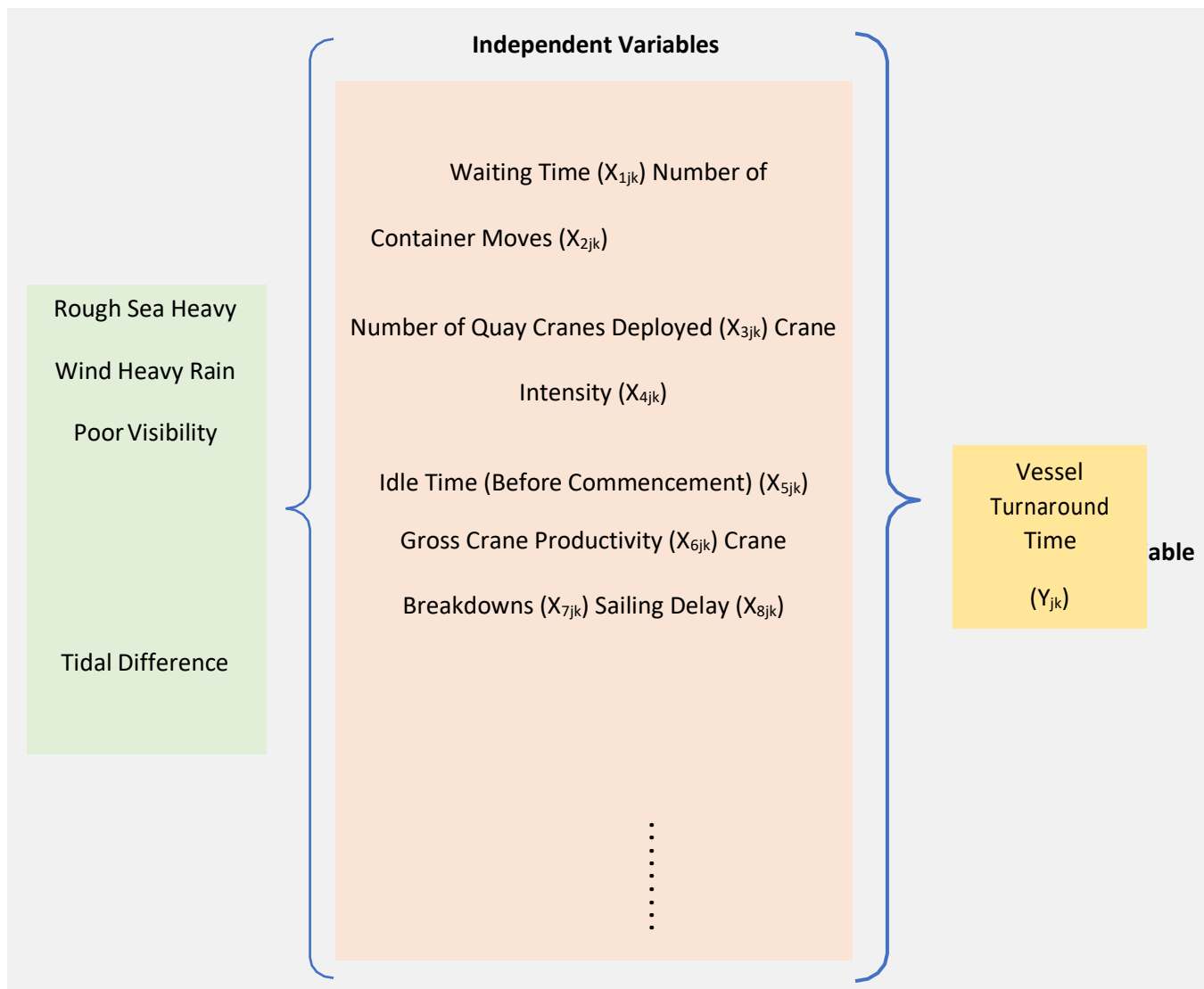


Figure 3:4 - Variables for the Analysis

3.4 Operationalization

Each independent variable indicates a unique measure for each vessel berthed at the terminal. However, considering all the individual variables some are straight forward direct figures such as number of container moves and number of cranes; while time measures have to be derived using simple calculations for waiting time, berthed time, productive time etc. Thus, the operationalization process simplifies the Dependent and Independent variables as follows:

Table 3:1 - Operationalization

Main Concept	Variables	Explanation	Calculation Method
Dependent Variable (Y)	Vessel Turnaround Time (Y)	Total duration of time between arrival of the vessel to its departure from the port	ATS - ATA
Independent Variables (X _i)	Number of container moves	Total number of Discharging + Loading + Restow containers	Total Moves
	Number of Quay Cranes deployed	Number of cranes assigned for the vessel operation	No. of Quay Cranes
	Crane Intensity	How much larger the Total Move count is compared to the heavy crane	$\frac{\text{Total No. of Moves}}{\text{Move count of Heavy Crane}}$
	Gross Crane Productivity	Average number of containers handled per hour	$\frac{\text{Total No. of Moves}}{\text{ATC - WCT}}$
	Berthed Time	Total time gap between berthing time to sailing time	ATS - ATB
	Service Time	Total time gap between commencement to completion	ATC - WTC
	Productive Time	Total productive time after reducing detention times	ATC - WTC - DT
	*Berthing Delay	Time gap between arrival time and berthing time of vessel	ATB - ATA
	Sailing Delay	Time gap between completion time and sailing time of vessel	ATS - ATC
	Vessel Detention Time	Total Time durations that the vessel operations were detained	Summation of detention times
Idle Time	Time gap between berthed time to commencement time	WCT - ATB	

* Based on the availability of data from the terminal; Waiting Time and Berthing Delay are defined in a similar manner including Manoeuvring time to the berth

3.6 Process Flow for a Container Vessel

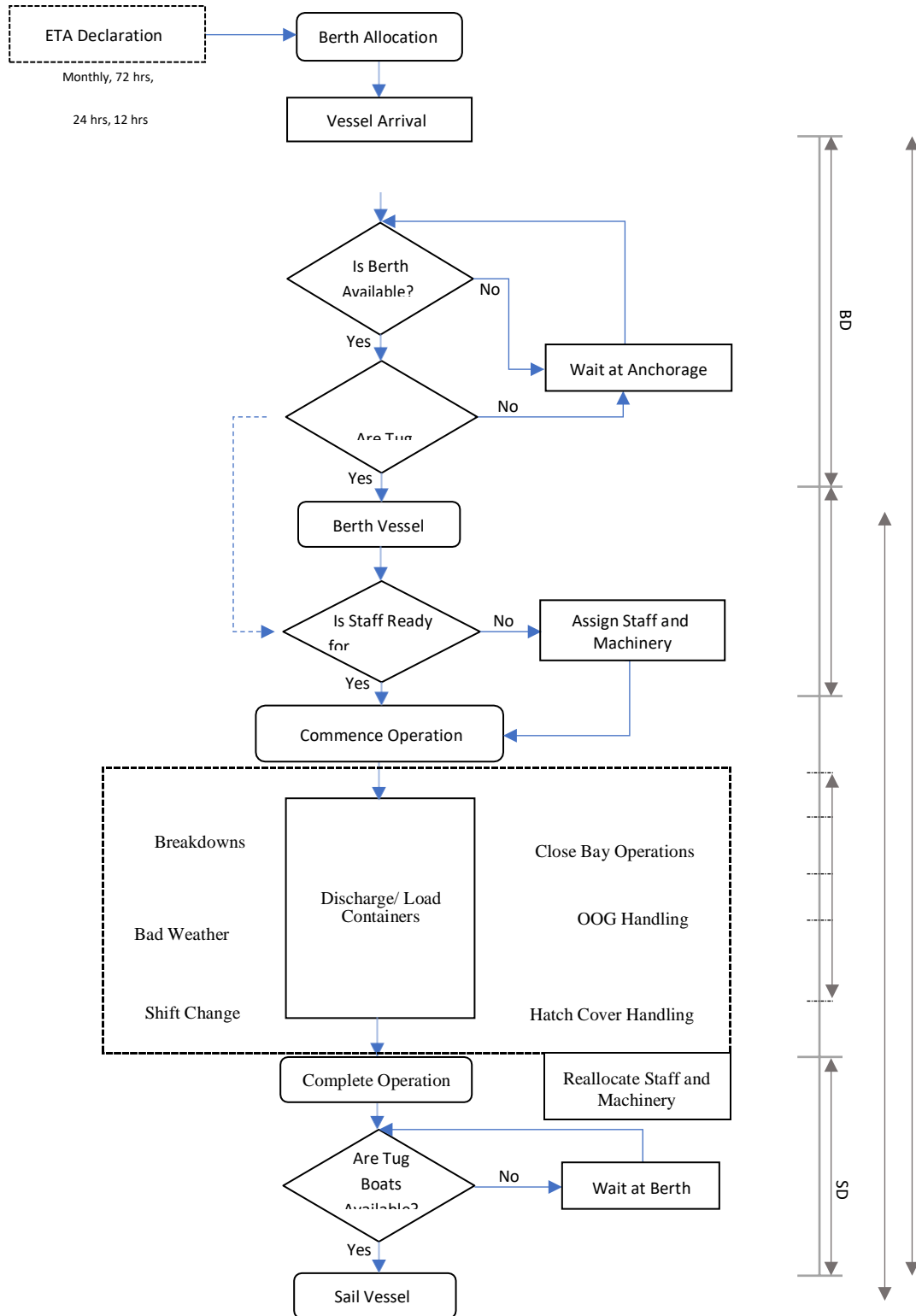


Figure 3:5 - Process Flow for a Container Vessel



**CHAPTER FOUR
STATISTICAL ANALYSIS &
DISCUSSIONS**

Reliability of the empirical model depends on the quality of data; as such latest vessel operations details at the terminal were taken for the statistical analysis. However, considering the practical operations at ports, not all vessels call the terminal with the same level of priority where some vessels request to wait at anchorage although a suitable berth is available at the terminal, while some others stay at berths (*under the permission of terminal operator*) without sailing after completion of the container operations. Some of the reasons can be highlighted as:

- i. Request delayed berth
 - a. Waiting for permission to enter the port (due to DC cargo/ weapons, etc.)
 - b. Waiting for containers to be delivered to the terminal
 - (export containers from outside, ITT containers from other terminals, special cargo operations, etc.)
- ii. Stay at berth
 - a. No immediate following vessel for the respective berth at the terminal
 - b. Urgent maintenance before sailing

These vessels indicate higher turnaround times, although the terminal operations do not have any influence on them. Similarly, some smaller feeder vessels are operated at non-priority feeder berths under the requests of respective feeder shipping lines, thus resulting very low operational productivity and higher turnaround times. Details of these vessel operations have the capability in deteriorating the actual performance details of the terminals; as such those vessel data were not considered for statistical analysis.

The following analysis is carried out in a few steps, where first step being

the Bivariate Correlation analysis for all the identified variables. Appendix II (a) illustrates the results of the analysis where it highlights the correlations between dependent variable and the independent variables. Multicollinearity test was carried out to check whether there were strong inter-correlations between identified independent variables, thereby highly correlated variables were removed from the model. Identified variables were taken for further analysis where each variable was regressed against the dependent variable to understand the relationship between the two performance elements. After that, all the variables were considered together and tested against the dependent variable. This analysis step was carried out considering several different scenarios to understand behavior of performance elements in different situations.

VTT Against Independent Variables Individually

4.1 Container Moves vs VTT

The number of container moves (M) is a key factor that basically determines how long a vessel has to stay at a berth, thus, influence the VTT at the end. In normal operating conditions, if move count is less - the time required for discharging and loading the containers takes shorter time, while if it is a larger amount it takes a longer time. However, this time duration is affected by many other factors such as Gross Crane Productivity (GCP), type of vessel, location of containers (*hatch / deck*), type of containers (*empty, laden, reefer, etc.*), the weather condition and many more. The relationship between VTT and the number of container moves is highlighted by Figure (4:1) where there is a positive relationship between the two variables

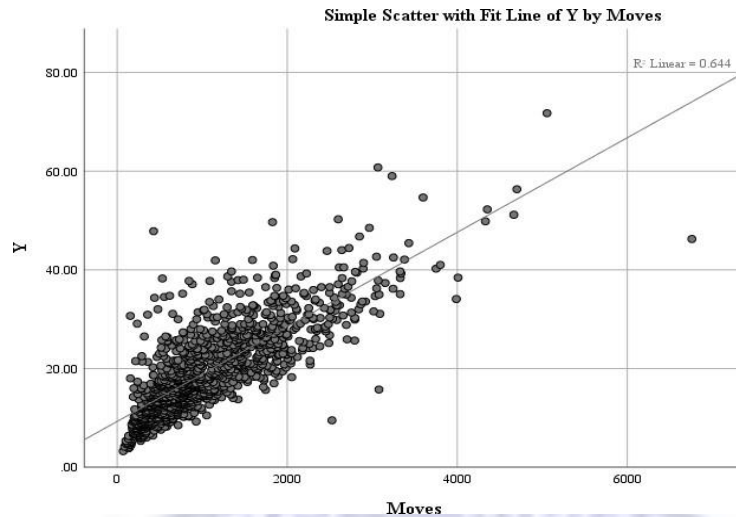


Figure 4:1 – VTT vs Container Moves

4.2 Crane Intensity vs VTT

Crane Intensity provides an indication of discharging and loading container spread inside a container vessel where it helps container terminals in determining the number of quay cranes to be assigned. Greater Crane Intensity (CI) provides many opportunities for assigning several cranes to the vessel (*based on availability*) due to the greater distribution of the move count along the vessel, while a lower CI reduces possibilities

$$\text{Crane intensity} = \frac{\text{Total Number of Moves}}{\text{Number of Moves on Heavy Cranes}}$$

The relationship between VTT and crane intensity is highlighted in Figure (4:2) where there is a positive relationship between the two variables. However, considering the practical difficulties in achieving equal crane splits, even the same vessel calling with the same number of container moves may not be able to obtain the same CI at each vessel call. Thus, this is proven by the scatter plots in Figure (4:2) where the distribution is higher compared to Figure (4:1).

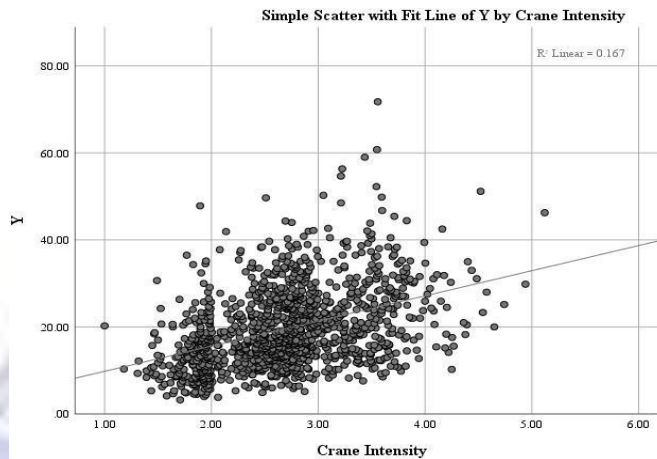


Figure 4:2 – VTT vs Crane Intensity

4.3 Productive Time vs VTT

Productive time indicates the total productive time that a vessel is operated at a berth after reducing all the idle times and other gantry

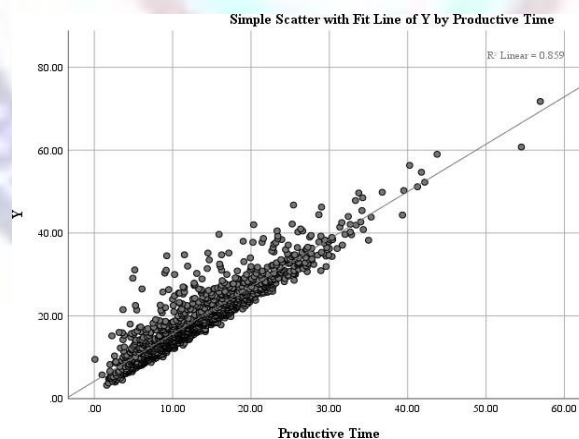


Figure 4:3 – VTT vs Productive Time

detention times. Referring to the Equation (2) and Table (3:1), productive time is considered as a key element that determines vessel turnaround time where the Figure (4:3) illustrates its strong relationship with VTT.

4.4 Other Independent Variables vs VTT

Gross Crane Productivity (GCP) indicates the average number of container moves handled by a quay crane assigned for a container vessel. Higher GCP conveys higher number of container discharging / loading moves leading to reduce VTT while lower GCP conveys vice-versa, thus illustrating a negative relationship between the two variables (Figure (4:4)).

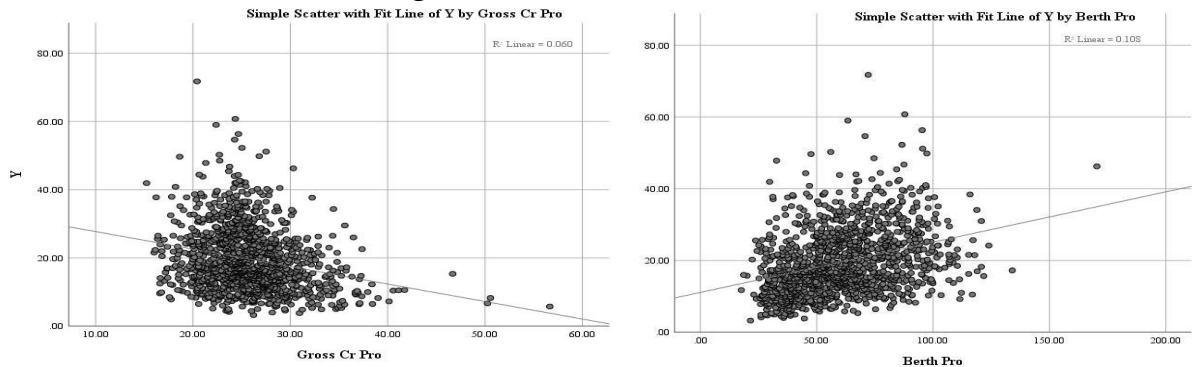


Figure 4:4 - VTT vs Gross Crane Productivity / Berth Productivity

Berth productivity indicates the average number of container moves done at a berth when several cranes are assigned for a vessel. Similar to GCP, higher value indicates higher performance while lower value indicates a lower performance. In that sense, there must be a negative relationship between the BP and VTT.

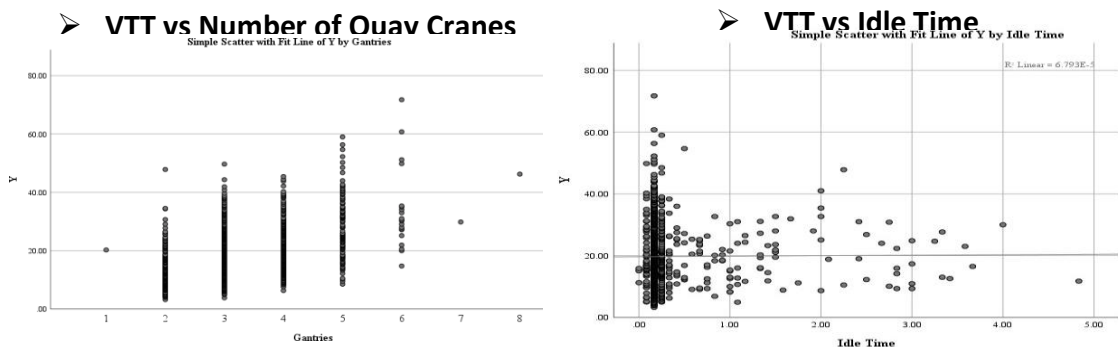


Figure 4:5 - VTT vs Number of Quay Cranes / Idle Time

The number of Quay Cranes assigned for a vessel depend on several factors such as number of container moves, LOA of vessel, crane split, availability of cranes and few others. In general operating conditions,

ICTT assigns minimum of 1 cranes up to a maximum of 7 cranes per vessel where scenarios of assigning 4 cranes are observed in very rare occasions.

Idle time is defined as in Figure (4:5) where the terminal performance data illustrate a mode of 0.17 hours and a mean of 0.29 hours. Considering a vessel's total time at a port (*VTT*), IT is an unproductive time where no container discharging, loading or any other productive operations are done, thus its value causes to increase *VTT* for vessels.

Similarly, Berthing Delay (*BD*), Sailing Delay (*SD*) and Vessel Detention Times (*VDT*) are also considered as unproductive time components where vessels are waiting to be berthed at anchorage, waiting to be sailed at berth and breakdowns /held-ups to operations while at berths respectively. As highlighted by Ghotb, Kia, & Shayan (2000) vessels incur huge costs when they are at ports, thus lower delay times reduce costs on shipping lines; while providing more opportunities for the terminals to utilize their available berthing spaces for other vessels.

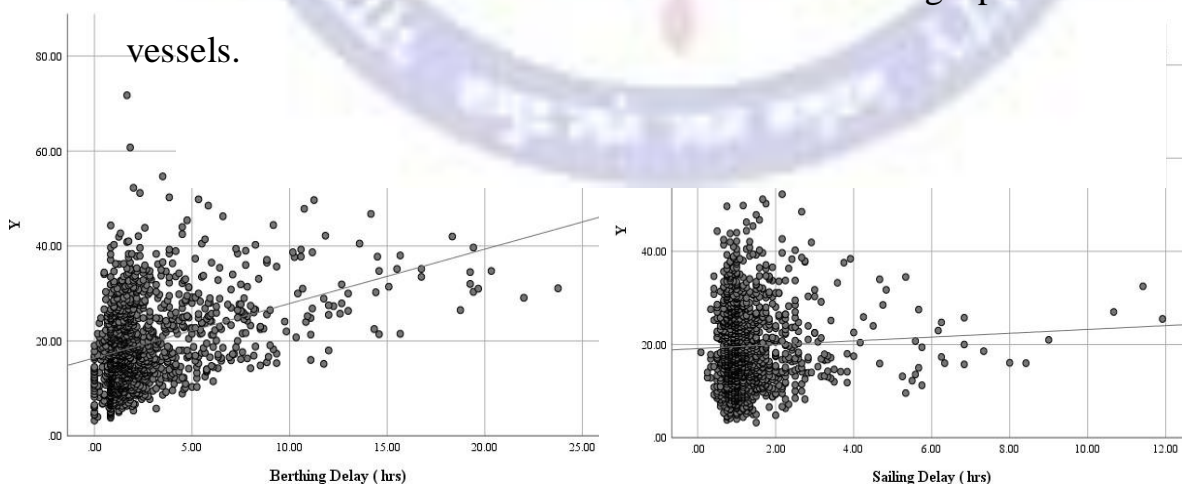


Figure 4:6 - VTT vs Berthing Delay / Sailing Delay

➤ VTT vs Vessel Detention Time

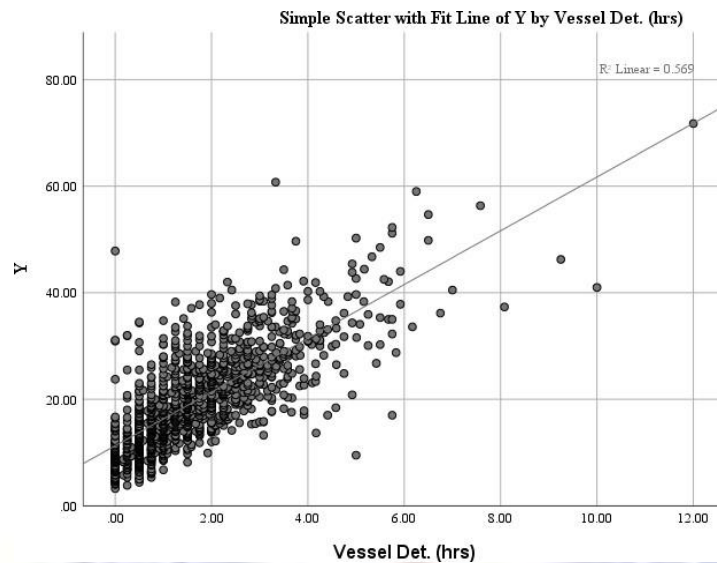


Figure 4:7 - VTT vs Vessel Detention Time

4.5 VTT Against Independent Variables All Together

After analyzing and identifying the nature of each individual variable against the dependent variable, all the variables were tested together to look at the combined effect. As per Appendix IV (a) the preliminary regression model can be highlighted as follows.

$$Y_{jk} = \alpha + \beta_1 X_{1jk} + \beta_2 X_{2jk} + \dots \beta_n X_{njc}$$

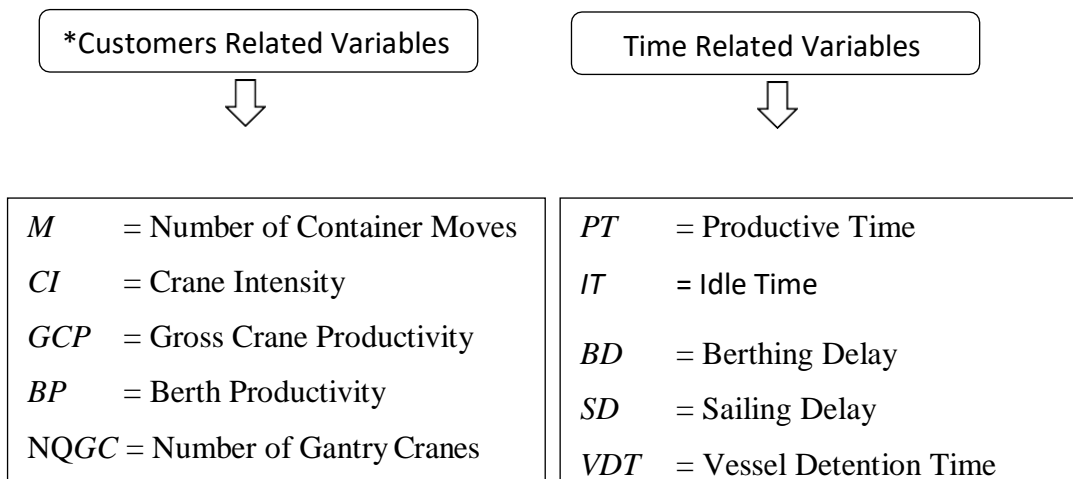
Where:

- VTT* = Vessel Turnaround Time
- M* = Number of Container Moves
- CI* = Crane Intensity
- GCP* = Gross Crane Productivity
- BP* = Berth Productivity
- NQGC* = Number of Quay Gantry Cranes
- PT* = Productive Time
- IT* = Idle Time

BD = Berthing Delay
SD = Sailing Delay
VDT = Vessel Detention Time

The Equation illustrates that the impact of number of container moves has an insignificant influence on VTT contradicting to the real world observation where higher move count require longer operating time while lower move count require shorter time. As mentioned previously it is necessary to understand that each of these individual variables are influenced by many other factors: even the same move count may be represented with different categories of container (*empty, laden, reefer, OOG etc*). As such it can be assumed that the effect of number of container moves is reduced due to the combined effect of other determinant factors.

In that sense, the selected variables were subdivided into two categories as time related variables and customer related variables and then tested their influence against the dependent variable VTT at a confidence level of 95%.



* Customer Related Variable – container handling Information given by shipping lines or their expectations from container terminals

Figure 4:8 – Variables Categories

As illustrated in Equation (9), the regression analysis provides the relationship between the VTT and time related variables as follow; (*Appendix IV -4.2(b)*)

$$VTT = 0.009 + 1.001 * PT + 1.002 * IT + 0.999 * BD + 0.986 * SD + 1.000 * VDT$$

Regression analysis test result for VTT and the customers related variables illustrates in following Equation proves that number of container moves positively impact on increasing VTT while CI, GCP and BP negatively relate with VTT where increasing the values of those variables help to reduce VTT.

$$VTT = 21.280 + 0.013 * M - 0.335 * CI - 0.223 * GCP - 0.165 * BP + 0.393 * NQGC \quad (10)$$

4.9 Discussions

As per the above discussed factor analysis it was proved that the number of container moves, gross cranes productivity, berth productivity, crane intensity and number of gantry crane are having direct influence on determining vessel turnaround time and how they behave in different situations. In addition, regression analysis helped in deriving a linear model proving the viability of Equation which is generally used in calculating turnaround time of vessels. Once again it is necessary to highlight that all the identified variables are dependent on

many other influential factors due to the complexity of container terminal operations. The research study is carried out within a limited scope to identify key influential factors with the expectation of developing a regression model between them and VTT. With that understanding, following discussion is carried out to highlight how practical operations are done at port and which aspects can the terminal focus in improving its performance and obtaining lower turnaround times for its vessels.

1) Number of Container Moves, Berthing and Sailing Delay

As per data analysis it was found that higher the container movement volume, longer the time a vessel stays at a port where the proportion of BD and SD represent lower value out of VTT. In that sense, Ports have to focus on increasing its productivity in operations to reduce the impact of BD and SD on VTT as it does not have any control over container moves bring by the shipping lines.

2) Berthing Delay and Sailing Delay

Berthing, sailing, mooring and unmooring operations are done by the Port Pilots and their mooring crew from Pilot Station of Ports Authority according to their priority sequence which is prepared based on the information given by the terminals. Hence, port needs to maintain proper two-way communicate with Pilot station regarding ETA, ETC, ETD and other delays of their vessels in order to avoid delays.

➤ **Area to consider:**

Mooring Systems, Stability of Vessels (Cavotec, 2011), (Goedhart, 2002)

Most ports still practice the conventional way of mooring vessels with ropes as it is done in most of container terminals in the world. However, there are some modern container terminals that use vacuum-based mooring and unmooring technologies that reduce time consumptions significantly for those operations while increasing steadiness of the vessels.



Figure 4.8 - Vacuum based mooring

Idle Times, Breakdowns and Other Delays

Although port tries to practice 24/7 operations with “Hot Seat” change over in its vessel operations, in reality there are delays during shift changes in the mornings and evenings, during meal hours and during tea breaks and so on. As an international container terminal which is in a competitive business the management must take strict actions to reduce these delays irrespective of the fact that these type of labour related issues are subject to interventions of politically backed employee unions. In addition to these, some delays occur due to crane breakdowns and unavailability of enough cranes when two vessels are at berths. These situations become worse when the yard cranes and prime movers are also busy accommodating quayside and yard side operations at the same time. It is suggested to enhance the efficiency of equipment controlling and scheduling functions by optimally utilizing the NAVIS Terminal Operating System and encouraging more corporation between the Operations and Engineering Divisions as solutions.

Crane Scheduling and Optimal use of Sophisticated Technology

Technological advances help to smoothen tedious, repetitive and complex tasks such as vessel and yard planning, equipment controlling and monitoring and many more. These reduce time-consuming manual works while enhancing efficiency of overall operations. Although port uses a Terminal Operating System (TOS) such as NAVIS SPARCS, it can be found that the terminal is not fully utilizing the available features of the purchased systems. Considering the huge costs of these investments, it is suggested to optimally utilize all the available features of TOS while considering the replacement of current quay cranes with twin lift capable cranes for better performance which will help to reduce VTT at the end.

Yard Allocation and Traffic Flow

Yard Operations has a direct impact on the productivity of quayside operations. The container yard layout, container stacking policy and prime mover traffic plan should be in a way that they minimize unnecessary container marshaling movements and avoid the mix of terminal trucks and the trucks from outside. In addition, it is necessary to understand that RTGs do not operate at the same speed of QGCs and nearly 3-4 RTGs per QGC is required for a smooth quayside operation which ultimately results in shorter VTT. In addition a proper yard maintenance is required to be carried out to get the proper contribution for a smooth quayside operation.

Non-Operational Delays and the Human Factor

Container terminal operations are a capital intensive complex business operation which requires high technological equipment and systems. Although there can be seen some automated and semi-automated container terminals in European regions, still most of the container operations are human labour intensive in most parts of the world. Unlike machineries, human labour cannot maintain the same level of efficiency from the beginning to the end of each container vessel operations, 24/7 throughout the year. Hence, there can be seen many non-operational delays, errors, mistakes and dropping of productivity. In addition, most of the ports in world are highly unionized and same situation can be observed at the terminals in Ports. These employees related issues are highly sensitive and even a smaller issue may lead up to huge losses. As such, terminal management need to handle its labour force in a way that it balances the human factor and the organizational performance requirements.



CHAPTER FIVE
CONCLUSION

The research study addresses a main concern in the container terminal operations business through its effort to identify factors affecting turnaround time of container vessels and what sort of relationships they are having with Vessel Turnaround Time (VTT). Looking at practical operations, there can be seen that number of factors that affect VTT with different levels of influential capabilities where some of the factors are within the control of terminal operators while some others are beyond their control. From the view point of terminal operators, they can take actions to enhance performance of their terminal operations to reduce turnaround time of container vessels by increasing productivity in container handling operations while taking measures to eliminate or minimize unnecessary delays. Yet, terminal operators do not have any control over the influences that are beyond their control, which were recognized under two main categories as influences due to environmental related causes and constrains from customer shipping lines including move count, low crane intensity, old vessels or vessels with ship gears and many more. In that sense, the research study focused on the factors within the control of terminal operators where variables were identified based on the findings from literature review and also based on researcher's years of work experiences.

After achieving the first two objectives of the research study; different scenario analyses were carried out to understand behaviors of identified variables in different situations and what kinds of relationships that they exhibit with vessel turnaround time in each situation. With this, it was possible to achieve the third objective of the study while the in-depth analysis along with the facts identified in the literature review and the

researcher's previous experience in terminal operations helped in deriving solutions for the fourth objective.

Although it is practically observed that the number of container moves has a direct impact on determining turnaround time of container vessels where higher the volume longer the time that the vessel has to stay at port. However, this time period depends on many factors such as type of containers, nature and status, type of vessel, stacked location of containers in the vessel, container distribution along the vessel and many more. Thus, it was proved that even the same vessel with same amount of containers does not get the same turnaround time each time it calls at the terminal. In that sense, the derived regression models did not highlight much significance of the variable - the number of container moves in determining vessel turnaround time compared to Gross Crane Productivity (GCP) and Berth Productivity (BP) due to the combined effect of all the influential variables.

In addition, regardless of the number of container moves; berthing, sailing, mooring and unmooring operations generally take a similar (*specific*) amount of time, while slightly varying based on the DWT and the type of the container vessel. Thus container terminals prefer vessels with higher container volumes compared to lower volumes; as the above operations represent a smaller portion with respect to the total VTT. GCP and BP proved to have significant possibility in affecting VTT and it was even found that scheduling an optimum number of QGCs help in reducing VTT where too many QGCs negatively affect by increasing time for operations due to clashes of schedules.

Furthermore, it is necessary to highlight the optimal utilization of all the available features of NAVIS TOS at the terminal where it helps to increase the efficiency and productivity of terminal operations by eliminating repetitive, complex and time consuming manual works. The study focused about aspects such as crane intensity, gross crane productivity, crane scheduling and so on where TOS helps to plan these activities better than manually working on papers.

Finally, considering the limitations of this study and the suggestions for future studies; it is necessary to highlight once again that this study was carried out under a limited scope within a limited time frame, thus only the quantitative factors were considered for the analysis. It was assumed that the effects of other non-considered factors are negligible, yet in reality, situation is more complex where there are lots of factors affecting the measures of these identified variables and VTT. Moreover, the effects of qualitative factors were not taken for analysis, specially considering the effect of human element including the inability of maintaining the same operational efficiency from the commencement to the completion of a vessel's operation. Most importantly, terminal operation is a combination of three operational areas such as quay operation, yard operation and gatehouse operation; yet quayside operation was only considered under the limited scope of the study. As such, it can be suggested to consider about the above highlighted areas, using simulation or other analytical techniques to increase the accuracy of the results in future studies.
